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Assessment in scientific enquiry at age 14: A comparison between England and Korea

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ABSTRACT

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This study is an international comparative study exploring the research question '***What is the impact of assessment in scientific enquiry on the perception of the teaching of science at 14 in a comparison between England and Korea?***'. Implementing scientific enquiry in the classroom has been a common goal in both countries in order to foster pupils' scientific literacy and to improve the quality of science education.

Based on a conceptual framework of theory-practice triangulation, this study has been divided into two sub-questions; one which has asked what is taught and assessed in scientific enquiry in the national curricula in England and Korea, the other enquired how teachers perceive their teaching of scientific enquiry. Thus, this study has been twofold: a documentary analysis of the national curricula and assessment (the end of KS3 test papers and High school entrance examination papers) for the first question and for the second question, survey research of science teachers using 190 questionnaires and 7 focus group interviews.

Key findings were:
The assessment content directly affects teaching practice under assessment driven school curricula, which applies to both countries. Both groups of teachers do not teach in the way in which they perceive pupils' scientific enquiry ability can best be fostered, such as scientific investigations, group discussions and research projects. However, the national curriculum content and assessment in England more fully reflects the aims of its curriculum. Korean test papers are extremely narrow in scope and contain higher cognitive ability questions. Although teachers' views about the nature of science and their perceptions about teaching science may not affect teachers' teaching in practice directly, these factors can affect teachers' attitudes towards science, their confidence in teaching scientific enquiry and their resistance to taking up new teaching methods. As assessment content directly affects teachers' teaching, there is a need for good assessment items, which comprise a variety of content and context of scientific enquiry. These can be developed in order to implement more scientific enquiry. At the same time, there is scope for enabling teachers to gain a more refined understanding of the nature of science.

This study was to explore teachers' perceptions about their teaching of scientific enquiry. Based on this teachers' survey the area of the actual teaching of scientific enquiry may be worthy of further comparative study.

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Chapter 1 Introduction

The major research question is '***What is the impact of assessment in scientific enquiry on the perception of teaching science at age 14 in a comparison between England and Korea?***'This study is a comparative one exploring sub-questions concerning what is assessed in the national curricula of England and Korea and how scientific enquiry is taught in both countries. This research question leads to the investigation of commonalities and differences in science education in both countries and leads to implications for the improvement of science education.

1-1 Background

It is known that science provision for all students through their compulsory education is becoming the norm internationally. For the majority of students, science is part of their general education, aiming to improve scientific literacy for preparation as future citizens in a changing society (Fensham, 2000; Kim J C, 2004). Only a minority will use science for career purposes, such as engineers, scientists, medically related careers, researchers and technicians. Hence the science curriculum has to meet the needs of two groups, providing the first stages of training in science for a minority of students and giving access to basic scientific literacy for the majority (Driver, et al, 1996). Although these two purposes can often appear in tension in terms of the priority and depth of curriculum content, they share the common aim of helping students come to an understanding of the nature of science, which with scientific knowledge, comprises scientific literacy (Driver, et al, 1996).

Therefore, the importance of scientific enquiry seems closely related to the demands of a changing society and the quality of education. Although the curricula in England and Korea stem from different backgrounds in terms of different cultural and historical value systems, both national curricula in both countries are heading towards similar goals by fostering 21st century citizenship for young people and by putting the emphasis on the quality of education by incorporating more scientific enquiry in the science classroom (Ministry of Education, MOE, 2001a: Department for Education and Skills, DfES, 2001).

1-1-1 The perspective of a changing society

A Korean report refers to 21st century society as information centred and globalised (MOE, 2001a). In accordance with this, one of the aims of science education is to nurture future citizens to be able to understand advanced science and technology in a globalised society (MOE, 2001a). Consequently, scientific literacy has become a great concern for citizens of the 21st century.

According to the national science curriculum in Korea, the need for scientific literacy is described as follows:

... in order to foster scientific literacy for the citizens of the future, through scientific enquiry, pupils should be taught scientific concepts enabling them to make everyday applications and to foster enquiry with the ability to investigate natural phenomena and to understand the relationship between science, technology and society ' (MOE, 2001a).

According to the national science curriculum in England, scientific literacy also has a central place, being mentioned as follows.

... because it helps pupils to understand how scientific ideas are developed and because the skills and processes of scientific enquiry are useful in many everyday applications. Scientific enquiry provides opportunities for pupils to consider the benefits and developments in the environment, health care and quality of life" (DfES, Department for Education and Skills, 2001)

Therefore, scientific enquiry as '*the methods and activities that lead to the development of scientific knowledge'* has become the core of both curricula rather than scientific knowledge itself (NRC, 1996, p23, quoted in Schwartz, et al, 2004). In a broad sense, scientific enquiry refers to the characteristics of scientific enterprise and processes through which scientific knowledge is acquired including consensus and the ethics involved in the development, acceptance and utility of scientific knowledge (Shwartz, et al, 2004).

1-1-2 The perspective of the quality of education

Conventional science has placed much emphasis on scientific knowledge and neglected understanding about the nature of science and scientific enquiry (Osborne, et al, 2003; Han J H, 1995). The appropriateness of this emphasis on content knowledge has been doubted from the evidence that too many young people are leaving school with a confused sense of the significance of what they have learnt about science (Driver, et al, 1996; Osborne & Collins, 2000). TIMSS (Third International Mathematics Science Study) also supports the above argument that students' inability to recall science they have learnt in school is simply consistent with the evidence from surveys of public knowledge, which reveals the low state of passive residual knowledge of science by adult citizens (Fensham, 2000). Thus, as Osborne, et al, (2003) argue, science education has failed to communicate *'the grand ideas of science'* that have both personal and cultural significance and which should develop a deeper understanding of science. Another shortcoming is that students are not engaging critically with the socio-cultural and historical issues of science as well as having a negative attitude towards science and showing little interest in the subject (Osborne & Collins, 2000; Kim J H & Lee M K, 2003). In particular, despite having the highest achievement in science literacy through the international comparative studies, Korean young people show the least interest and motivation in science subjects and do not want to choose science related careers (Song J W, et al, 2003).

Recently, much research in this area has been carried out in order to improve the quality of science education (Fensham, 2000). With the growing concern about the relationship between science and society and the need to improve the quality of education about science, implementation of the nature of science and scientific enquiry as a core of scientific literacy has become an important research interest among science educators. This trend has led to curricula revisions strengthening the elements of the nature of science and being highlighted in the public understanding of science (Osborne, et al, 2003; Song J W, et al, 2003).

For the curricular revisions, TIMSS results have been used as an important reference for making new policies and for revising the curriculum in both England and Korea (Han, 1995; Fensham, 2000). As a universal subject, science is being taught with similar content and with more or less the same amount of time at Key Stage 3(KS3, students aged 12-14) level in both countries. The curriculum framework underlying TIMSS science test was developed by a group of science educators and the tests were developed through an international consensus involving inputs from experts in science and measurement specialists (Kim C J, 2004). Then, it ensured that these tests reflected current priorities within the content of science (Kim C J, 2004). The current emphasis on the area of scientific enquiry has also been reflected in the TIMSS-2003 science test which showed considerable increase in the proportions of analysis and reasoning domains compared with the TIMSS test of 1999 (NFER, 2004).

Both countries have participated in the TIMSS science tests in 1995, 1999 and 2003. On these three occasions, students in both countries have shown much higher than average achievements compared with the other countries. Also, according to the report, Korean students consistently have shown higher achievements than English students. In 2003, Korean students were in 3rd place with 558 marks compared with 544 achieved by English students, estimated at being in 6th place from among 46 countries (KICE, Korean Institute of Curriculum & Evaluation, 2004). Along with these science tests, other factors have been included in the TIMSS survey such as gender differences, pupils' attitudes, the current situations of teachers and schools and pupils at home (NFER, 2004). TIMSS-PA (performance assessment) also revealed that pupils in England were more likely to carry out investigations in their science lessons. English pupils received high scores for problem solving and investigative skills in science (NFER, 2004). All these elements seem to make the international comparative study more relevant in identifying advantages and disadvantages of each education system

However, neither the TIMSS science tests nor the background survey may be able to show the reasons why Korean students achieved consistently higher scores in science. The TIMSS results may also not be able to indicate the advantages and disadvantages in terms of the national curricula, examinations and teachers' teaching practices in depth.

In addition, implementing scientific enquiry as a learning goal and introducing it into the classroom seems to be a complex process interlocking various factors. As Osborne, et al, (2002) argue, the process involves changing the culture that forms and moulds a teacher and is, a much harder task than simply changing the curriculum. It also seems to require continued support and endeavour for such a course requires that teachers adapt and change their existing practice (Osborne, et al, 2002). Along with these various factors, assessment driven school curricula has been known as a great stumbling block to improving the quality of education (Black, 2000).

1-1-3 Assessment of curricular goals

Traditionally, assessment in Korea has been represented as norm referenced and done on a selective basis. It has long been recognised that what teachers teach and the ways in which they teach are heavily influenced by the assessment (Kim J H & Lee M K, 2003). In contrast, the national curriculum in England originally set four main criteria that the assessment in the system should meet: They should be criterion referenced, formative to serve learning needs, moderated to ensure comparability within and between schools and related to the learning progression of students (DfES, 1987, quoted in Millar, 1991). Later on, the target attainments and standard achievements have been imposed on each year and there is a great emphasis on examinations in order to maintain the standard of achievement (Brooks, 2002). Recently, schools have been required to set targets for getting a certain percentage of pupils achieving more than level 5 in science at the end of KS3 (Black, 2003). This approach entails setting performance norms and a composition of individual performances (Black, 2003). As a result of the emphasis on target setting and achievement, assessment has dominated teaching and learning as it becomes high stakes with the traditional content of assessment becoming a powerful determinant of learning goals (Black, 2000).

There are issues, then, in shifting the focus of assessment to the nature of science and scientific enquiry.

Firstly, the nature of science is related to the epistemology of science including creativity, tentativeness, an empirical base and subjectivity (Bartholomew, et al, 2003), Yet, conventional school science tends to represent absolute values in the knowledge content ignoring the nature of science (MacComas, 1998; Batholomew, et al, 2003; Kim J W, 2004). Teachers also tend to be concerned only with the transmission of the products of '*the context of epistemological justification*', what is been termed as '*final form' science* (Batholomew, et al, 2003, p4). Thus, under the assessment driven school curricula, deliberations about the nature of science, the tentativeness of scientific knowledge or its social dimensions are marginalised. (Osborne, et al, 2003).

Secondly, under a mass assessment system catering for all abilities of pupils in most schools, the performance assessment that assesses scientific investigations is affected by a number of factors including the subject matter, the setting and context and procedural complexity (Roberts & Gott, 2004). The content of the performance assessment tends to be skills and observations in order to minimise the tension between validity and reliability of the performance assessment (Roberts & Gott, 2004).

Lastly, the main purpose of scientific investigations is the performance assessment as other research has revealed (Roberts & Gott, 2004; Kim J H & Lee M K, 2003). Thus, difficulties in assessing students' performance in scientific investigations have led to 'cook-book type' investigations as the performance assessments are being incorporated with pupils getting higher marks; students more or less know the results of the investigation in advance and are expected to follow instructions to reach that end. As Roberts & Gott (2004) argue, students may see little point in carrying out the investigation when they already know the result and are just expected to follow instructions to reach that end from the view point of scientific investigation as a core of scientific enquiry (Roberts & Gott, 2004, p7). Often this 'cook-book' type scientific investigation and practical work has been blamed for the mismatch between the understanding of related scientific knowledge and the doing activities in the classrooms (Millar, 2003). As Woolnough (1991) argues, although practical activity in the science laboratory is known to contribute towards developing students' thinking and learning abilities, because the purpose of the exercise is not always clear, any sense of achievement remains uncertain.

For these reasons, contrasted with the emphasis in the national curriculum, scientific enquiry, as a process of science, has been given a relatively low emphasis in teachers' teaching practice (Russell & McGuigan, 2003; Roberts & Gott, 2004). As McComas (1998) argued, the assessment of the nature of science should be a vital part of the science curriculum in order to make the science curriculum meaningful as well as enabling learning coherence between content knowledge and the processes of science.

Along with the assessment driven school curricula, teachers' perceptions and intentions to implement scientific enquiry are regarded as important factors (Lederman, 1999; Kim H K & Song J W, 2004). As teachers teach science, they are not only imparting scientific knowledge but also demonstrating scientific ways of questioning, thinking, handling and facing particular problems (McComas, 1998). Likewise, teachers' demonstrations perform an important illustrative role of the nature of phenomena and the scientific worldview as well as teachers' laboratory activities convey much about science processes and the construction of knowledge (Osborne, et al, 2002)

There are various opinions concerning teachers' views about the nature of science and scientific enquiry. According to Kim H K and Song J W (2004), a deficient conception about the nature of science in learning and teaching appeared to constitute an obstacle to the implementation of scientific enquiry. Whereas Osborne, et al, (2003) argue differently. They say that a teacher's understanding of the nature of science is only one of many factors that contribute to what they do when attempting to teach something of the core theme of 'ideas-about-science', which comprises the nature of science and scientific enquiry. Teachers' conception and understanding of the learning goals were regarded as more significant (Osborne, et al, 2003). Other research also argues that even though teachers have enough flexibility within the curriculum's constraint, they do not integrate scientific enquiry into their teaching (Schwartz, et al, 2004).

This study will mainly focus on high stakes external tests as it explores how assessment affects teachers' teaching of scientific enquiry.

1-2 Aim of the study

This study aims to explore how assessment affects teachers' perceptions of teaching of scientific enquiry by comparing two groups of teachers and the assessment tests set for their students. Thus, this study consists of a two-fold research approach, one exploring the assessment instruments and the other finding out teachers' perceptions of their teaching in order to discover the answer to the research question ***'What is the impact of assessment in scientific enquiry on the perception of teaching science at age 14 in a comparison between England Korea?'***

Although there are various assessments, which could have been used for the purpose of this research, external summative assessments seemed to be the most useful because of their perceived inference on classroom practice and their validity for international comparison. Performance assessments could have also been used for this purpose, but performance assessment varies with each individual school in terms of framework, type or form so it may not have been easy to compare the two groups of performance assessments objectively. Therefore, in this study, performance assessment is not included in the analysis. However an important part of the research is a survey of teachers as to how they teach and assess scientific enquiry.

The examination papers in both countries are analysed to demonstrate the commonalities and differences of each assessment method as well as indicating the range and nature of skills reflected by the national curricula and the contemporary view of science. The analysis may show how the assessment affects the school curricula and how the curricula can be improved.

Another part of the survey in this research concerns the teachers. As teachers play a pivotal role in improving the quality of education, it is necessary to find out teachers' perceptions about the nature of science and of scientific enquiry and how teachers teach and assess scientific enquiry. Then, the difficulties and dilemmas within the school curricula due to the complexity of implementing scientific enquiry into the classroom have also been investigated.

The next chapter will review and clarify the philosophical perspectives of the nature of science and of scientific enquiry as well as the explanations about scientific enquiry as found in the national curricula. Also reviewed are the learning, teaching and assessing of scientific enquiry along with the difficulties and dilemmas raised in literature and other research.

Chapter 2 Literature Review

This chapter explores the views about the nature of science and scientific enquiry in the national curricula in England and Korea. It also includes the nature of assessment and how educators recommend teaching and assessing the nature of science and scientific enquiry in classrooms and discusses potential difficulties in implementing scientific enquiry in both countries. Finally TIMSS survey data is considered concerning an international comparative study.

2-1 Introduction

According to McComas (1998), understanding the nature of science has been a common goal in science education for years. Society needs citizens who have opinions on the findings from science, are able to evaluate policies and weigh scientific evidence in order to make informed decisions in social, moral and political matters. In terms of quality of education, science educators also put their emphasis on understanding the nature of science because school science should reflect science in the *'real'* world and scientific enquiry becomes a central strategy to portray the real science to students (Ratcliffe, 1998, p4).

Thus, it might be expected that the aims of both national curricula will put an emphasis on scientific literacy, including elements of the nature of science and scientific enquiry, in order to improve public understanding of science as well as improving the quality of science education.

However, although understanding the nature of science and scientific enquiry has continued to hold a distinct place, classroom practice can prove problematic. As Lederman, et al, (2002) point out, there are considerable misconceptions along with naïve views about the nature of science amongst teachers and pupils alike. Consequently, teachers may not be able to articulate a clear perspective of their own views about the nature of science nor effectively transmit the values underlying science knowledge nor be able to link science knowledge with related enquiry activities (Lederman, et al, 2002). As Batholomew, et al, (2002) argue, for many science teachers, their prime aim in teaching science is to develop pupils' understanding of science concepts and the nature and methods of science. Consequently the elements of the nature of science lie beyond the boundaries of their teaching.

As a result, as Osborne et al argue, science education has generally failed to communicate *'the grand ideas of science'* that have both personal and cultural significance or to develop a deeper understanding of science (Osborne, et al, 2002, p7). As Osborne, et al, (2003) mention, implementing scientific enquiry seems to be a complex process: along with teachers' perceptions and intentions about the nature of science, there are interrelated factors including presentation in textbooks, the national curriculum, school policy and teaching methods. This chapter will set out to explore four areas. The first section evaluates the views about the nature of science in a historical perspective, along with the contemporary view of science and scientific enquiry in the national curricula in both England and Korea. The second section considers how educators recommend teaching and assessing scientific enquiry. The third section reviews main factors such as the nature of assessment and the actual science teachers, who can affect the implementation of scientific enquiry into the classrooms. Issues and difficulties in practice between England and Korea will also be discovered. Finally, the fourth section evaluates experiences in both countries. As an international comparative research, the nature including advantages and limitations of the comparative study as well as how TIMSS (Third International Mathematics and Science Study) survey has developed and contributed to curricula change will be considered.

2-2 Philosophical perspectives on the nature of science

There seem to be differences in the notion of the nature of science between philosophers, scientists, the national curriculum and science teachers in the classrooms.

The boundary between natural and social science is not clear. There is a longstanding debate about the extent to which there is, or should be, similarities and differences between the methods of the natural and social sciences (Driver, et al, 1996). Even within the natural sciences, there is considerable methodological diversity, of which some differences may have epistemological implications (Driver, et al, 1996). For instance, in many sciences, experimentation is an important way of gaining knowledge yet some sciences such as astronomy or geology cannot bring study objects into the laboratory for processing but planned and structured observation often take the place of experiment as a means of testing explanations and predictions (Driver, et al, 1996). In contrast, some sciences such as palaeontology and evolutionary biology seek historical explanations rather than experimentation and interpret commonly accepted views based on the available historical record. Thus, the key methodological challenge for such sciences is to legitimate their interpretations of the historical record because experimentation is not an option (Driver, et al, 1996).

Therefore, as Driver, et al, (1996) argue, differences in subject matter lead to differences in practice, which in turn rest on epistemological differences such as 'the multiple natures of sciences'. Driver, et al, (1996) conclude;

... the very fact, however, that we can recognize and talk about a group of disciplines as natural sciences implies a measure of similarity and a family resemblance. Further, since the sciences have quite distinctive areas of content, some of this similarity resides in shared epistemological and methodological commitments and institutional practices. It is to this common core of ideas about commitments, methods and practices that we refer when talking of the nature of science.... (Driver, et al, 1996, p26).

Thus, alongside the idea of multiple methods in sciences, this section reviews three prominent views, that of inductivist, the science of objective observation and experimentation, Popper's falsification approach and Kuhn's paradigm shift including relativist/positivist and contextualism/decontextualism in order to have a clear and consistent idea about how science works.

2-2-1 Inductivist and Empiricist view

The inductivist view is widely held as a common-sense view of science. This secure knowledge comes directly from experience. Induction is the process of inferring generalizations from a series of specific observations, experimentations and investigations in order to obtain data (Chalmers, 1982). Thus, this method is experimental, gathering data and developing from them hypotheses and rules. This method can be used in investigating and designing experiments that provide answers (Williams, 2006).

However, it is said that the fundamental problem in generalisation is that unlike deductive reasoning, where we start from a set of initial propositions and use logical rules of argument to reach a conclusion, we can never be completely sure that an inductive generalisation is true (Driver, et al, 1996).

Philosophers have amended this view of generalisation. In the twentieth century, inductive reasoning has been taken up and developed by the philosophical movement called 'logical positivism' (Anderson, et al, 1986). Logical positivism argues that the aim of philosophy is not to establish which propositions are true or false, but to clarify the meaning of statements. Such statements must be verifiable by observation at least in principle. Scientific knowledge is an inductive one with a particular emphasis on verifiability and observation. While accepting the logical problems of induction, logical positivists have claimed that using arguments based on formal logic and mathematical probability that induction can lead logically to generalisations, which are probably true and additional observations, can increase this probability (Driver, et al, 1996).

However, the inductivist view has also been known to lead to problems concerning the meaningfulness of scientific laws and theories. Furthermore, logical positivists were never clear about the status of the principle, for if it was to be regarded as a meaningful principle, then by its own test it was not, or could not be testable or verifiable (Anderson, et al, 1986).

Contrasted with the inductivist view of science, there is the Aristotelian 'deductive reasoning' more akin to 'cause and effect' (Williams, 2006). The following section states the deductivist view of science and its limitations.

2-2-2 Popper's view, hyphothetico- deductive view

Popper criticised induction by saying it cannot be shown to lead logically to true generalisations, or even to ones, which are 'probably true' (Chalmer, 1982). Popper claimed:

...Science is a method of conjecture and refutations – 'a hypothetico- deductive approach'. Science progresses by proposing testable hypotheses; these are then subjected to rigorous tests in which predictions deduced from the hypotheses are compared with observation with a view to falsifying the hypotheses (Driver, 1996, p.31)

Popper argues that science makes progress through the replacement of hypotheses by newer ones with greater empirical content, in which are included a larger number of observations. Popper solved problems in the inductivist approach by stating that science advances by deductive falsification through a process of conjectures and refutations. According to Popper, if a theory can be shown to be falsifiable then it is scientific, if it is not then it is not scientific. Thus, experiment and observations test theories but they do not necessarily produce theories (Williams, 2006).

In consequence, Popper's view is that science does not seek the confirmation of its predictions or of the generalisation, but their falsification. As Popper argues, scientific theories state the conditions under which they will count themselves as having failed. The aim is no longer the inference of generalisations from confirmatory evidence (Anderson, et al, 1986). Rather, it is a search for disconfirmation and rejection of conjectural hypotheses. Therefore, the history of science is not the story of an accumulating body of true generalisations but the heaping up of conjectures, which, as yet, have not been refuted (Anderson, et al, 1986).

However, there are a number of problems with this falsificationist view. First, the view that all experimentation is carried out within a hypothetico-deductive context seems narrow, and makes too many assumptions about science subjects (Phillips, 1987). Second, it is not always necessary to be struggling with falsification in order to progress in scientific knowledge (Phillips, 1987). In turn, this view can be criticised in that scientific theories are not abandoned simply because of one observation not fitting and scientists are also not striving to falsify their theories (Osborne, et al, 2003).

2-2-3 Theory-laden observation and scientific method

The theory-laden observation becomes a serious challenge both to the inductivist and the falsificationist approach with the argument that all observation is theory-laden (Driver, et al, 1996). Observation depends on the theoretical commitment of the observers. For example, in the context of science teaching, pupils who have seen a diagram of cells in textbooks may observe and draw a cell using a microscope differently from those who have not because observations depend on the theoretical commitment of the observers (Hanson, 1958, quoted in Driver, et al, 1996, p32). Although there are acknowledged difficulties in drawing any clear line between observation and theory, theory dependent observations have been known to serve as a foundation for science (Matthews, 2003)

The falsification approach can also be challenged because it depends on the idea that hypotheses can be tested by comparing them with predictions based upon observations. Popper then accepted the argument of theory-laden observation because these observations themselves incorporate theoretical ideas (Driver, et al, 1996).

Theory laden observation seems to be accepted as a major scientific method along with prediction and experimentation in general. According to Williams (2006) a model of how science works has been summarised by using observation, prediction, and experimentation in order to develop hypothesis and theory, which are commonly agreed and consistently applied to teaching science. This theory-laden observation can lead to a hypothesis, which in turn can generate predictions. From experimentation, new ideas arise which can either lead to further experimentation or a refined hypothesis. Once the observations and predictions from hypotheses are consistent a theory may be generated (Williams, 2006). Thus, it is said that a theory in science is a set of statements or principles devised to explain a group of facts or phenomena that has been repeatedly tested or is widely accepted (McComas, 1998). On the other hand, scientific laws are generalisations, which describe specific natural phenomena and do not explain things and do not change (McComas, 1998).

These scientific explanations have limitations in covering the development of history in science. Kuhn has adopted different models of scientific explanations called 'paradigm shift', which are better suited to the evidence. The Following describes Kuhn's revolution.

2-2-4 Kuhn's revolution

Kuhn was initially known as a historian with an inductivist view of science. However, Kuhn found that traditional accounts of science, whether inductivist or falsificationist, did not bear comparison with the historical evidence of science (Chalmers, 1982).

Kuhn regarded science as a way of life: normal science and revolutionary science as a history of stability, homogeneity and continuity as well as one of conflict, disruption, fission and change (Anderson, et al, 1986, p249). According to Driver et al's summary, a key feature of his theory is the emphasis placed on the revolutionary character of scientific progress, where a revolution involves the abandonment of one theoretical structure and its replacement by another, incompatible one (Driver, 1996, et al, p.35).

One of Kuhn's distinctive approaches is known as a paradigm shift. The disorganised and diverse activity that precedes the formation of science eventually becomes structured and directed when a scientific community adheres to a single paradigm. The paradigm is made up of the general theoretical assumptions and laws and the techniques of the application that the members of a particular scientific community adopt (Chalmers, 1982).

Kuhn also proposes two distinct types of scientific activity. One is called 'normal science'. This is the kind of science practised by most scientists most of the time. It involves working within existing frameworks of theory and practice, articulating the implications and working out further applications of the accepted theoretical ideas in that branch of science (Chalmers, 1982). From time to time, anomalous results may begin to accumulate in a branch of scientific activity. If it is impossible to accommodate these within the current theoretical framework, they will precipitate a crisis in the field. This is eventually resolved when an alternative theory emerges and is accepted by the community of practitioners in the field. This change, which can occur over a relatively short period, Kuhn called 'scientific revolution' (Chalmers, 1982).

However, the new model does not completely disregard the previous model and the two can co-exist to some degree (Williams, 2006). Critics are keen to point out the weakness of Kuhn's theories by challenging him that his suggestion does not represent progress and does not lead to a change of normal science (Chalmers, 1982). Thus, there is a problem in defining 'scientific progress' (Anderson, et al, 1986)

To sum up, there are three prominent perspectives concerning the nature of science, yet, even these have limitations in explaining different aspects of science. With philosophical perspectives, there are also different ways of interpreting scientific facts, laws and theories about natural world such as instrumentalism/realism, relativism/positivism and contextualism/ decontextualism.

2-2-5 Instrumentalism/Realism, Relativism/Positivism, Contextualism and Decontextualism

In the view of instrumentalism, there is a sharp distinction between concepts applicable to observable situations and theoretical concepts. Thus the aim of science is to produce theories that are convenient devices or instruments for connecting one set of observable situations with another (Chalmers, 1982). Therefore, scientific theories are useful if they lead to predictions being derived from observations and experience and nothing more than sets of rules for connecting one set of observable phenomena with another. However, there is no claim that the entities and processes correspond to anything in the world (Driver, et al, 1996).

The counterpart of instrumentalism may be the term realism which typically involves the notion of truth describing science as that which aims at true descriptions of what the world is really like (Chalmers, 1982). Thus, this realism corresponds to the traditional view of science that links reality directly to observation. According to Driver, et al (1996), scientists are usually characterised by an unproblematic, commonsense realism mentioning that science is taken to be an attempt to obtain knowledge of a real, physical, external world, which behaves as it does quite independently of our views about it (Driver, et al, 1996, p40).

However, the idea that science aims at a true characterisation of reality is often used as a counter to relativism which is the view that any and all explanations are equally valid or worthy and that truth is merely a matter of opinion with there being no way for one to determine which opinion or explanation is more accurate more likely to be correct, better supported and reasoned (Chalmers, 1982).

Therefore, when scientists consider one explanation is better than the other, it is because it is more consistent with known natural processes, and has more data to support the evidence and has more reliable or greater predictive power and has fewer anomalies or exceptions left unexplained (Anderson, et al, 1986).

The counterpart of relativism may be the term positivism, originally ascribed to Comte, and which developed into logical positivism already mentioned in the inductivist section. Comte's central positivist claims were that science is the highest form of knowledge and there is one scientific method common to all science. Positivism recognises empirical facts and observable phenomena as the raw material of science whilst rejecting enquiry into underlying causes and ultimate origins (McComas, 1998).

Therefore, positivists need a sharp distinction between observational statements and theoretical statements, which are regarded as 'meaningless' (McComas, 1998). The search for a distinction between observation and theory has been adapted by some positivists themselves or rejected because of the theory-ladeness of observation (Anderson, et al, 1986). As has been mentioned in the inductivism section, the positivist view of science has been revised to become the logical positivism of the 20th century being brought in by the empiricist tradition, which Comte refused (Anderson, et al, 1986). This view thus implies that knowledge is divided into theoretical and observable knowledge and that theoretical concepts and sentences must be defined in observational terms (Anderson, et al, 1986).

In terms of the values and the context of science, there is a strand regarding the relationship between social, cultural and educational contexts, which is characterised by their own aims and values (McComas, 1998). This strand has disregarded a traditional account of science, which advocates strong neutrality for science and portrays it as a valued independent activity aimed at the discovery of truths about the world (McComas, 1998). Thus, contextualism suggests that the values of science are dependent on the use, sources, power and consequence within the relationships of social, cultural and educational contexts. McComas (1998, p312) explains that contextualism implies that how one looks at things will determine, to some extent, which view most accurately reflects what scientists do. Consequently, science research may contrast with the traditional idea that in science, one proceeds from hypothesis to discovery in a linear fashion, guided by method and logic yet some science does conform to that traditional model. All the edge of knowledge, however, method and logic are insufficient, intuition and creative insight become just as important. Moreover, scientists frequently find themselves taking unplanned journeys to unexpected places, realising only later just what it is that they have discovered. Because experimental conditions cannot be controlled completely, unexpected but important results sometimes occur in all aspects of research (McComas, 1998). Decontextualism is the counterpart of contextualism that is that scientific knowledge and processes are independent of the cultural and sociological location (Nott & Wellington, 1993).

As shown above, there are variations in views and much ongoing discussion about the nature of science amongst scholars (Driver, et al, 1996). Thus, it is necessary to understand the philosophical perspectives of science in order to portray real science and how science works in order to improve the public understanding of science. Thus, the perception of science as being able to offer clear-cut answers to all problems or proof to all arguments can be changed to a more acceptable concept of science as still having areas of tentativeness but still be dynamic (Williams, 2006).

Although there is little agreement on the views about the nature of science, the following are some contemporary views of science in relation to the extent of consensus within the relevant communities. Then, on the basis of the contemporary views, what science educators refer to as the nature of science and scientific enquiry, their inter-relationship and their importance in science education are discussed.

2-3 Contemporary perspectives on the nature of science

Despite little agreement amongst philosophers, historians and sociologists on a specific definition about the nature of science, there is a general agreement within the current post modern view that acknowledges science as a human endeavour, culture reliant, directed by theory and empirical observation and subject to change as follows (Driver, et al, 1996).

Scientific knowledge is tentative
Scientific knowledge is empirical
Scientific knowledge is theory-laden
Scientific knowledge is partly the product of human imagination and creativity
(Schwartz, et al, 2004, p.7)

From this contemporary perspective, the nature of science refers to the epistemology of science, science as a way of knowing or the values and beliefs inherent to the development of scientific knowledge (Abd-El-Khalick, et al, 1998, p418)

Then, Abd-El-Khalick, et al (1998, p418) as science educators have generalised the nature of science, adding two important aspects to the above four statements: Two additional important aspects are the distinction between observations and inferences and the functions of and relations between scientific theories and laws. Therefore, science educators generally recognise the contemporary view of science and the importance of teaching the nature of science and scientific enquiry as a core of scientific literacy, which refers to one's understanding of the concepts, principles, theories and processes of science and one's awareness of the complex relationships between science, technology and society (Abd-El-Khalick, et al, 1998, p418). Schwartz et al, (2004) have also supported the importance of this by mentioning that without understanding the values and assumptions of the knowledge and the process by which knowledge is created, the learner can do little more than construct an image of science consisting of isolated 'facts' void of context that would make the knowledge relevant and applicable (Schwartz, et al, 2004, p2). Thus, scientific literacy is portrayed as the ability to make informed decisions on science and technology based issues and is linked to a deep understanding of scientific concepts, the process of scientific enquiry and the nature of science (Lederman and Bell, 2003).

The term 'scientific enquiry' refers to *'the methods and activities that lead to the development of scientific knowledge'* (NRC, 1996, p23, quoted in Schwartz, et al, 2004, p3). Thus, scientific enquiry comprises the characteristics of scientific enterprise and the processes by which scientific knowledge is acquired, including the conventions and ethics involved in the development, acceptance and use of scientific knowledge (Schwartz, et al, 2004). In an authentic context, scientific enquiry is that which scientists conduct in everyday practice (Schwartz, et al, 2004). Thus, scientific enquiry can vary as much as the method of scientific enquiry itself because scientists use various ways to find their scientific knowledge (Osborne, et al, 2002).

At this point, it seems to be necessary to distinguish between the terms 'the nature of science' and 'scientific enquiry' although there is an overlap and interaction between the two. For example, observing and hypothesising as scientists conduct their everyday practices refer to scientific enquiry activities or science processes. Relating this to the nature of science includes the understandings that observations are imaginative and creative and that both activities are inherently theory-laden (Kshife and Abd-El-Khalick, 2002). Likewise, the nature of science is less meaningful when separated from the process of science. For example, learning a statement concerning the nature of science such as *'science is tentative'* may give words but it does not provide meaning to those words (Schwartz and Lederman, 2002). Similarly, learning how to make careful observations is an important science process skill but such a skill does not automatically lead to understanding the logic of observation (Schwartz, et al, 2004). Therefore, scientific enquiry is a context for learning the nature of science. So it would be necessary to develop a better understanding of the nature of science as a result of engagement in enquiry activities or science process skills instruction (Schwartz, et al, 2004).

To sum up, although there has been little agreement about the definition of the nature of science, there is a general consensus concerning the contemporary view of science. Although there is no clear-cut boundary between the nature of science and scientific enquiry together, they form the core of scientific literacy as they overlap and have close interaction. The following section will explore how the National Curricula in both England and Korea describe scientific enquiry and will include the elements of the nature of science as set out in the aims and the content areas.

2-4 Scientific enquiry in the national curricula of England and Korea
Coupled with the demands of a changing society and of improving the quality of education, both curricula put emphasis on the nature of science and of scientific enquiry. Thus, one of the aims of science education in both countries is to nurture future citizens who are able to understand not only advanced science and technology but also to understand how that knowledge has developed (NCC, 1999, quoted in MOE, 2001b). Therefore, the current emphasis on scientific literacy extends beyond the boundary of the conventional national curricula and calls for knowledge of scientific concepts and methods of scientific investigations as well as understanding tenets of scientific enquiry and the nature of science, which are at the core of science literacy (NRC, 1996, quoted in Schwartz, et al, 2004)

According to Driver, et al, (1996), there should be three elements of science in the science curriculum: Firstly, *'understanding some aspects of science content'* involving an understanding of some of the facts, laws, concepts and theories, which make up accepted scientific knowledge about the natural world. Secondly, *'understanding scientific enquiry'* involves the ability to define 'scientific study'. This involves not only an understanding of empirical enquiry procedures, but also of the role of theoretical and conceptual ideas in framing any empirical enquiry and in interpreting its outcome (Driver, et al, 1996, p12-13). Thirdly, *'understanding science as a social enterprise'* involves an understanding of social organisation and the practices of science, whereby knowledge claims are transmuted into public knowledge, and of the influence of science on the wider culture (Driver, et al, 1996, p13).

In the National Science Curriculum in England (ENSC), scientific enquiry is defined as a process of science as shown in Table 1. The scientific enquiry area in the ENSC comprises 'ideas and evidence' and 'investigative skills'. 'Ideas and evidence' is a distinctive strand in scientific enquiry referring to interplay between empirical questions requiring evidence and scientific explanations using historical and contemporary examples (OCR, 2003; www.nc.uk.net/). Ideas and evidence are also mentioned to test explanations by using them to make predictions and by seeing if the evidence matches the predictions (OCR, 2003; www.nc.uk.net/).

The area of investigative skills comprises 'planning', 'obtaining and presenting evidence', 'considering evidence' and 'evaluating' (OCR, 2003; www.nc.uk.net/). This scientific investigation includes using scientific knowledge to plan and decide the appropriate approach, deciding uses of evidence, carrying out preliminary work, considering factors, deciding the extent and range of data to be collected. This also involves skills with equipment including ICT and making sufficient relevant observations and measurements to reduce errors. Also, skills of communication quality such as handling data, diagrams, and charts and tables are required. Moreover, this requires the use of diagrams, tables and charts to identify and describe patterns or relationships in data as well as using scientific knowledge and understanding to explain and interpret observations and measurements or other data. Finally this involves considering anomalies in observations or measurements and considering whether the evidence is sufficient to support any conclusions or interpretations made as well as suggesting improvements to the methods used (OCR, 2003; www.nc.uk.net/).

Therefore, the ideas and evidence seem to be important elements of the nature of science encouraging development of an understanding of the nature and limitations of scientific endeavour through historical and contemporary contexts (Ratcliffe, et al, 2004). In addition, 'the ideas and evidence' also explore not only 'what we know' but 'how we know' (Ratcliffe, et al, 2004).

Table 1 Scientific enquiry is defined as a '*process of science*' (DfES, 2001)

	Pupils' activities	**Different types of scientific enquiry**
Experiment	* Test out ideas experimentally * Develop practical skills * Appreciate the importance of experimental evidence	* Fair tests involving the control of variables * Using experimental models and analogies to explore an explanation, hypothesis or theory
Investigation	* Investigation	* Pattern seeking * Using first hand and secondary sources of information * Identification and classification
Application		* Using and evaluating a technique or technological application

In the Korean National Science Curriculum (KNSC), emphasis is also put on scientific enquiry as a process of learning science declaring

'... *every science lesson should be taught as a process of enquiry*'
(MOE, 2001b).

However, it does not mention detailed activities and the content of scientific enquiry for pupils. Instead, the KNSC includes more basic enquiry and less integrated enquiry for year 7 pupils whilst more integrated enquiry and less basic enquiry for year 8 and year 9 pupils (MOE, 2001b). The following shows the classification of scientific enquiry mentioned in the national curriculum.

Table 2 Scientific enquiry in the Korean National Science Curriculum (KNSC)

Inquiry	Content
Basic enquiry	Observation, classification, measurement, prediction, reasoning
Integrated enquiry	Finding problems, Setting up hypothesis, Transformation of information, Interpretation of data, Controlling factors, Drawing conclusions, Generalisation
Enquiry activities	Investigation, Discussion, Research, Presentation, Field trips

The term scientific enquiry is used differently in KNSC as it refers to a narrower range of processes and a more restricted method of acquiring scientific knowledge by the mixed use of enquiry based instruction. Thus, scientific enquiry in the classroom encompasses conceptual reasoning and experimental enquiry through problem solving, investigative works and in doing science projects (Sung M W, 1994).

According to the MOE report (2001b), the 7th National Curriculum has recommended enquiry-based instruction in the science classroom. Enquiry based instruction as the problem solving process, enables pupils to raise questions and leads them to explore the question. As cognitive activity occurs within learners, it is called enquiry-based instruction no matter what type of instruction is used (MOE, 2001b).

According to Sung M W (1994), enquiry based instruction was originally employed as a teaching methodology in contrast to a teacher centred way of imparting knowledge to pupils. This teaching methodology comprised not only laboratory activities but also questions and discussions in order to acquire scientific knowledge (Sung M W, 1994, P82; Sung M W, et al, 2000). Thus, this included investigative and research processes, comprising student centred, conceptual enquiry and open-ended enquiry activities such as experimentation, prediction, investigation, discussion and interpretation (Sung M W, et al, 2000). Therefore, scientific enquiry-based instruction is a teaching methodology to achieve understanding of science, to enhance problem solving ability, to acquire skills and practices, and to foster scientific literacy (Sung M W, et al, 2000). This enquiry-based instruction can apply not only to the science subjects themselves but also to other subjects in the school curriculum (Sung M W, 1994, p82).

The following figure 1 shows types of enquiry-based instruction suggested by the MOE.

Figure 1 Types of enquiry based instruction in science

Language		Image		Activity
Discussion/ instruction	→	Teachers' demonstration	→	Experimentation
Lecture/ presentation		Field trip		Research/Investigation
		↓		
		Cognitive activity		
		↓		
		Enquiry based learning		

To sum up, both national curricula seem to reflect the contemporary view of science emphasising scientific literacy but they may have to show a rather narrower range than in authentic and real science. As mentioned above, scientific enquiry as the methods and activities of science in the real world are varied; scientific enquiry in school science should be diverse rather than one way such as ' control variables' as it is in the ENSC (Osborne, et al, 2002).

In addition, scientific enquiry in the KNSC is described as being in line with the contemporary view of science as it includes the understanding of the nature of science, skills of enquiry and the understanding of science related to the STS (Science and Technology and Society) context, as well as having enquiry-based instruction as a teaching methodology in the aims of the KNSC. Yet, the curricular content does not include the elements of the nature of science or scientific enquiry.
The 'ideas-about-science' in the ENSC appear to be more comprehensive and embrace a wider range of issues in contemporary science. They include not only the aspects of the nature of science but also the social influences on science and technology, the maturity of casual links, risk and risk assessment and the impact of STS (Osborne, et al, 2002). The term 'scientific enquiry' (Sc1) in ENSC comprises the elements of the nature of science in the aims of the curriculum and in the area of 'ideas and evidence'. The comparison between curricula will be explored in more detail in chapter 4.

The following section will consider the ways in which science educators have encouraged the teaching of the elements of the nature of science and scientific enquiry.

2-5 Ideal approaches in teaching scientific enquiry

As Batholomew, et al, (2003, p6) have mentioned, school curricula are '*simplified and vulgarised components of science*' to the extent of consensus with the relevant communities. There is a gap between school science and authentic science in the real world and the ways in which scientists are able to learn from each other and extend the boundaries of scientific knowledge by using scientific enquiry. During the procedure of transferring from an authentic context of science to school science in the curricula there has often been an alteration in terms of the nature of science such as the tentativeness of the findings for the time being, being changed into definite truth and a variety of scientific methods into a single method such as controlling variables because of difficulties in having an authentic context for the science (Osborne, et al, 2002). Nevertheless, it is necessary for school science to reflect science in the real world by considering how to determine the nature of scientific knowledge, the method of science and processes and practices of a scientific community with a consideration of the applications and implications that should form an essential component of the school science curriculum (Batholomew, et al, 2003).

There are two ways of teaching the nature of science and scientific enquiry: one is the 'implicit approach' and the other is the 'explicit pedagogical approach' (Schwartz, et al, 2004). Implicit messages about the nature of science can be communicated in any science lesson whether it involves enquiry activities or not, because views of the nature of science are an inherent part of all science content (Swartz & Lederman, 2002). The implicit approach relies on implicit messages within acts of enquiry. Enquiry activities alone develop the nature of science aligned with accepted contemporary views (Khishfe & Abd-El-Khalick, 2002). In fact, many elements of scientific enquiry can be learnt by the implicit approach because many scientific enquiry elements include tacit knowledge such as process skills (Woolnough, 1991). Thus, enquiry oriented activities and projects can be a natural way to teach about science and the nature of science, providing pupils have opportunities to engage in activities that parallel those of scientists (Schwartz & Lederman, 2002).

However, research has consistently shown that the implicit approach is not effective in helping learners develop informed views about the nature of science ((Schwartz & Lederman, 2002). It is also said that traditional curricula adopted the implicit approach to most of the 60s and 70s curricula, yet the enquiry oriented curricula was no more effective than a traditional text book centred curriculum enhancing pupils' views about the nature of science (Khishfe & Abd-El-Khalick, 2002).

Much research has supported the explicit and reflective approach of teaching the nature of science. This approach intentionally draws learners' attention to aspects of the nature of science through instruction, discussion, guided reflection and specific questions in the context of activities, investigations and historical examples (Schwartz, et al, 2004). Thus, in this approach, teaching about the nature of science is done in a similar manner to teaching about any other cognitive learning outcome (Schwartz, et al, 2004). More recently reflective elements have been given prominence within the explicit approach, which involves the application of tacit knowledge in the context of activities, investigations and historical examples (Schwartz & Lederman, 2002). Other research also suggests the importance of the reflective manner of teaching the nature of science proposing that learners are introduced to certain aspects of the nature of science, and then, provided with structured opportunities to reflect on these aspects in the context of activities or science content and then, to articulate and develop coherent overarching frameworks about the nature of science (Kshishfe and Abd-El-Khalick, 2002). Batholomew, et al, (2003) stress the explicit and reflective approach mentioning:

The elements of the nature of science as well as practice and processes of science should be taught explicitly as a manner of teaching science concepts because developing and understanding practices and processes of science is a reflective endeavour. (Batholomew, et al, 2003, p6).

Therefore, both implicit and explicit approaches can be ways to transfer implicit and explicit messages about the nature of science and scientific enquiry yet the explicit and reflective approach is a more desirable way to teach the elements of the nature of science with tacit knowledge enquiry activities (Bell, et al, 2003). As a way to attempt to achieve pupils' reflection, science educators suggest argumentation as a counterpart of a practical task in science teaching (Osborne, et al, 2003). As Osborne, et al, (2003) argue, the teaching context is an integral part of thinking and reasoning in order to fit the argumentation in to the classroom activity. The thinking process is interwoven with the context of the problem being addressed and the problems are defined by answers, in turn, the answers are helping to shape other problems.

Thus, science lessons can incorporate scientific enquiry activities and explicit instruction concerning the nature of science and guided reflections (Schwartz, et al, 2004). Then the developing adequate understanding of the nature of science and scientific enquiry can ultimately be linked to the overarching goal of scientific literacy (Bell, et al, 2003).

As mentioned above in section 2-1, most science teachers in practice only consider the development of an understanding of science concepts and the methods of science as being essential (Batholomew, et al, 2002). The area in which the science content is interwoven with the relevant views of the nature of science and scientific enquiry activities as well as with contemporary social issues seems to be extremely marginal in the conventional classroom.

There may be a three-fold obstacle in implementing these necessary aspects of science. The first is derived from science teachers' belief about science, their intention to implement these aspects of science, their lack of knowledge about the nature of science and so on. The second is derived from transmitting the nature of science and scientific enquiry to their pupils. The third is derived from the national curriculum and assessment. Therefore, the following sections 2-6, 2-7, 2-8 and 2-9 will explore major stumbling blocks in implementing the nature of science and scientific enquiry into the classroom.

2-6 Obstacles related to science teachers

Research has identified a fundamental difficulty in implementing the nature of science and scientific enquiry into the classroom and argued that many science teachers themselves have had an education, which has largely ignored the epistemic base and the nature of its own discipline (Batholomew, et al, 2003, p5). Lederman, et al (2002) stress that teachers have rarely been educated to learn how science functions in their own studies, which has resulted in most science teachers having naïve conceptions about the nature of science.

An additional difficulty is that the understanding of the nature of science and scientific enquiry has undergone a significant transformation as a product of the growing and burgeoning studies, which may cause science teachers' problems in understanding (Batholomew, et al, 2003).

There has been much controversy in relation to the teachers' views of the nature of science and teachers' teaching practice in the classrooms. The research has revealed that even if teachers have a closer concept of the contemporary view of science, they rarely consider the nature of science when planning lessons or making instructional decisions (McComas, 1998; Lederman, 1999). Lederman (1999) has added that even if less experienced teachers show an interest in the nature of science, they felt that they were not ready to take on the challenge (Lederman, 1999). Ledeman (1999) continued that neither experienced teachers nor novice teachers intentionally attempt to teach in a manner consistent with their perceptions of the nature of science. In other words, teachers hardly attempt to teach in a manner consistent with their perceptions of the nature of science even if they have desirable perceptions about it. Therefore, implementing the nature of science and scientific enquiry into the classroom seems to more than understand the contemporary view of science. Teachers may also find more difficulty in incorporating their understanding of contemporary views about nature of science with the subject matter including content knowledge and enquiry activities.

However, Batholomew, et al, (2003) made the point that a teacher's understanding of the nature of science is only one of many factors that contribute to what these teachers actually do and feel when attempting to teach the nature of science and scientific enquiry (the core theme of 'ideas-about-science') and that teachers' conceptions and understanding of the learning goals were the more significant factors than teaching style. Other research shows that even though teachers have enough flexibility within the curriculum's constraint, they do not integrate scientific enquiry into their teaching (Schwartz, et al, 2004).

Nevertheless, when teachers teach science, they are not only imparting scientific knowledge but also demonstrating scientific ways of questioning, thinking, handling and facing particular problems (McComas, 1998). Likewise, teachers' demonstrations perform an important illustrative role of the nature of phenomena and the scientific worldview as well as teachers' laboratory activities convey much about science processes and construction of knowledge

(Osborne, et al, 2002). Therefore, despite many controversial arguments about teachers' views about the nature of science in implementing the nature of science, there is an agreement that teachers' views about the nature of science influence their decisions about how they plan, teach and assess. For example, if a teacher has inductivist views, he will regard theories as truths uncovered through rigid experimentation and his intent of instruction in the classroom will be for students to learn such truth (McComas, 1998). The teacher may tend to perceive scientific processes as inductive so that laboratory instruction will include precise procedures to acquire the right answer. In consequence, the assessment of students' performances will put the emphasis on results and the scientific processes will be neglected. If a teacher regards scientific knowledge as a result of human endeavour, the teacher may introduce a story about something interesting happening or as a way of thinking and talking about it as a point of view: what is being said in history and what those people had in mind, which students see it that way or what they can check at the laboratory bench (Millar & Lubben, 1996).

Therefore, in order to integrate the nature of science, teachers need to expand, enrich and elaborate their own knowledge systems so that they are enabled to translate their knowledge and intentions into practice (McComas, 1998). Teachers need to improve their view of the nature of science and the way in which they translate their understanding of the nature of science and internalise their view of the nature of science. Then, they also need to develop instructional skills and abilities to transform their knowledge into classroom practice (Schwartz, et al, 2004). Schwartz, et al, (2004) conclude that the realisation of and the ability to teach about the nature of science encompasses teachers' own learning, and teaching the nature of science includes knowledge, belief, intentions and pedagogical skills concerning the nature of science that enables a teacher to address it within the teacher's everyday science instruction in a manner that weaves the nature of science with other subject matter (Batholomew, et al, 2003; Schwartz, et al, 2004). Much research has shown the difficulties teachers have confronted as they teach the nature of science and scientific enquiry. According to Millar (2003), many science teachers do not yet fully know how investigative skills can be learned effectively, or what the teacher can contribute to this process in the area of scientific enquiry. Teachers also may find difficulty in explaining about the generation of knowledge, why a particular proposition is deemed warranted, why it is worth knowing and how it relates to other propositions both within the discipline and without (McComas, 1998). According to other research, teachers who have relatively poor knowledge about the nature of science, show loose connections to enquiry-based activities and the content of the nature of science. These teachers also tend to have difficulty in fitting and accommodating the contemporary view about the nature of science with their existing knowledge of science (Schwartz, et al, 2004). Thus, the depth of understanding about the nature of science, subject matter knowledge and the perceived relationship between the nature of science and scientific knowledge affects the teacher's own learning and teaching of the nature of science in spite of indirectly transferring the nature of science knowledge into instructional behaviour (Bell, et al, 2003; Schwartz and Lederman, 2002; Kim H K and Song J W, 2004).

To sum up, the implementation of the contemporary view of science into practice is a complex process. There are difficulties stemming from teachers because many teachers have rarely been educated in this way and the discipline itself is relatively new to them. Thus, teachers may need to improve their own understanding to be able to integrate into their subject matter their own knowledge in terms of views, beliefs and instructional skills. The whole process encompasses learning and teaching about the nature of science and scientific enquiry.

The following considers difficulties related to teaching in the classroom such as experimentation, investigation and discussion and practical work.

2-7 Difficulties related to teaching scientific enquiry

This section includes the difficulties imbedded in teaching science knowledge and scientific enquiry and in doing practical work. It also seeks to clarify the terms: practical work, experiment and investigations. Also to be considered will be difficulties in teaching by experiment and investigation as well as the advantages of teaching by argumentation.

There is a tendency to consider practical work as scientific enquiry. According to Wellington (1998), teachers and pupils need to become clearer about the range of the different types of practical work and the purposes they serve. Wellington (1998) suggested using three categories: exercises, experiences and investigations and that each type of practical work serves a different purpose with different types and different aims. The term experiment comprises exercises and experiences contrasted with the term investigation. Thus, the aim of experimentation is mainly for understanding scientific concepts in the classroom whilst the aim of investigation is mainly for enhancing pupils' investigative skills or inquiry ability (Wellington, 1998).

However, the term practical work seems to be used in a mixed sense: Often, it has been used as an integration of the three categories such as investigation, experimentation and teachers' demonstration and sometimes, practical work indicates only experimentation. There is no relevant word for practical work in Korean terms. Similar terms, experiment, exercise, research and investigation are used in the Korean National Science Curriculum (KNSC). However, in this study, the term practical work is used as an integration of the three categories investigation, experimentation and teachers' demonstration.

As mentioned above, the purpose of experiments is mainly seen by teachers to help give an understanding of scientific knowledge and to promote conceptual understanding by allowing pupils to visualise the laws and theories of science (Wellington, 1998). Wellington argues that practical work is motivating and exciting so that it helps learners to remember things. In addition, through this practical work, pupils develop not only manipulative or manual dexterity skills, but also promote a higher level of transferable skills such as observation, measurement, prediction and inference (Wellington, 1998). However, Osborne, et al, (2003) point out, that there is a significant imparity in terms of the activity of practical work and the need for reflection upon scientific knowledge. Kind (2003b) supports this mentioning *'doing is sometimes contrasted with knowing'* which is a similar contrast between working in the laboratory and reading and studying in the classroom (Kind, 2003b). The latter is regarded as using knowledge and understanding while the former is seen as using skills.

'Investigation' often involves a practical task, which the student undertakes without detailed instructions and it relates to reasoning and experiment (Wellington, 1998). The students thus have to make some decisions about which apparatus to use, the measurement to make, and how to interpret data in order to answer a given question rather than simply follow 'a recipe' like procedure (Millar, 1989).

However, in practice, it becomes a recipe by following a procedure. Sometimes, students are supposed to practise similar patterns of investigative works in order to familiarise themselves with processes of standardised assessments. In this case, the investigative work in school tends to be developed around specific types of task and followed by a theoretical framework with a focus on scientific skills (Kind, 2003a). Consequently, it may not be an investigation in a real sense because students have already known the results of the task.

As Oh P S & Shin M K (2005) suggested, investigation can be helpful to develop pupils' cognitive abilities as well as giving them time to think by themselves which can be an antidote complement to the above tendency by offering variety of content and context. This is because the method involves higher-level thinking tasks such as identifying information relevant to their research as well as even within a lesson it can provide pupils with a personal challenge and essential time for reflection and discussion. Pupils may extend and adapt their knowledge and understanding, and their skills and attitudes by experiencing a variety of methods and approaches (Osborne, et al, 2003). Yet, in pupils' construction of knowledge, by relating previous knowledge and the new knowledge produced by investigation requires much time and evolves slowly (Woolnough, 1991). For these reason so many teachers avoid this way of teaching.

In practice, the elements of scientific enquiry are often embedded in scientific knowledge and its context of teaching rather than being scientific enquiry by itself (Wellington, 1998). Thus, teaching scientific enquiry is difficult to identify in classroom activity (Wellington, 1998). Teachers often regard scientific enquiry as doing practical work or doing experiments and investigations followed by instruction in the laboratory or in the science classroom (Wellington, 1998).

However, Khishfe & Abd-El-Khalick (2002) argue that engaging in enquiry and learning about science and process skills are often not equivalent to learning about the nature of science. Indeed, much research has shown mismatches in the link between understanding ideas, process skills and the relevant views about the nature of science (Khishfe & Abd-El-Khalick 2002; Osborne, et al, 2003; Kind, 2003b). This is because teachers tend not to make the assigned skills an explicit aim of practical work or reflect on the investigative actions through discussions and pupils' own explanations. Osborne, et al, (2003) suggest a reflective manner in teaching in order that meaningful learning can take place, which links ideas to investigative skills. Teachers should encourage students to do a task and to think what they are doing.

Therefore, one of the attempts to build bridges between understanding and doing in the laboratory can be by making a link between experiments in the science classroom and experiments in real science depending on pupils' understanding of various aspects relevant to the task (Kind, 2003b).

To sum up, as mentioned above, implementing the nature of science and scientific enquiry seems to be a complex process: along with teachers' perceptions and intentions about the nature of science, various factors are inter-locking between textbooks, the national curriculum, assessment-driven teaching practices and so on. As Osborne et al, (2002) argue, this process brings changing cultures that form and mould a teacher and is a much harder task than simply changing the curriculum.

The following section will explore difficulties with related subject matters such as the national curriculum, policies and classroom practice. Batholomew, et al, (2003) make the point that teachers' understanding about the nature of science is only one of many factors that contribute to what these teachers actually do and feel when attempting to teach the core of the nature of science and that teachers' conceptions and understanding of the goals are the more significant factors. Thus, the learning objectives about the nature of science are often subjugated by constraint of the curriculum, classroom management, lack of time and student engagement with the topic (Batholomew, et al, 2003).

2-8 Obstacles related to subject matters

In this section, difficulties resulting from the aims, content and teaching of the national curriculum as the main context of teaching science in classrooms will be considered.

Firstly, as already dealt with in section 2-4 and 2-5, the national curriculum places an emphasis on the nature of science and scientific enquiry but teaching the nature of science has not been the goal of the curricula so the school curriculum does not explicitly include the nature of science (Osborne, et al, 2003). Thus, the asserted purpose or aims of the curriculum remain extremely marginal in the classroom. Research shows that many science teachers indicate the aims of science education as the development of an understanding of science concepts and the nature of the methods of science. The rest lies beyond the boundary of teaching science in the classroom (Osborne, et al, 2003). In fact, the national curricula in both countries mention 'everyday application' and the relationship of STS (Science-Technology-Society) to the aims, yet the curricula do not properly incorporate this into the curriculum content (MOE, 2001b; DfES, 2002). There is also evidence of a place for history and philosophy of science in science teaching in the ENSC (Duschl, 1990, quoted in Osborne et al, 2003). Therefore, there is a still a large gap between policy and practice although the inclusion of scientific enquiry as a separate strand in the National Curriculum in England (ENSC) has raised its profile and the importance of it in the curriculum (Batholomew, et al, 2003).

Secondly, although school science has been vulgarised and simplified in the curriculum content it should be relevant to reflect science in the real world (Batholomew, et al, 2003). During the transmitting of the content, it becomes more narrowly focused on 'what we know' rather than 'how we know'. As a result of this deliberation, the tentativeness of scientific knowledge or its social dimensions are perceived essentially marginal to science teachers (Duschl, 2000). Consequently, conventional science has placed much emphasis on scientific knowledge and neglected understanding about the methods and processes as well as the nature of science. The crux of the matter is that science teaching and textbooks emphasise the factual content of science to the near total exclusion of the knowledge generation process (Osborne, et al, 2003).

In addition, the simple curriculum reduction may result in fragmented and inconsistent curriculum content. It may be necessary to consider achieving a sense of coherence and the underlying educational purpose as well as embracing all the science subjects (Donelly, 2001; Osborne, et al, 2003). Fensham (2000) advocates that less content and more learning must be appropriate mentioning that a conventional curriculum would include too much scientific knowledge although all in the end rely on observation, theorizing, experiments testing refinement of theory leading to acceptance or rejection of theory so they do have something in common (Schwartz et al, 2004). As such, it may be necessary to implement the elements of the nature of science into the curriculum content in a holistic and practically integrated manner rather than having rhetoric policies. The curriculum content, can determine how science is taught and that is what affects pupils' experience in learning science and their subsequent attitude toward science (Kim J H & Lee M K, 2003).

Similarly, there is another shortcoming in the appropriateness of the content. As Delphi studies showed in England and Korea, no one method and no one group of individuals can provide a universal solution as to what should be the essential elements of a contemporary science curriculum (Kim J H & Lee M K, 2003; Osborne, et al, 2003). Yet educators in both countries recognise the inappropriateness of the factual science content through the Delphi study reports. According to Osborne, et al, (2003, p13), scientists are investigating questions about nature that remain extant, not exploring how others have answered their own question-answers which are now well understood and form consensual knowledge within the scientific community. Taking from the past, therefore, is only of value if it offers something, which is of significance to the present. Contemporary methodological tools and procedures have made earlier techniques irrelevant. Kim J H & Lee M K (2003) also argued that school science includes out-dated material which is, not applicable to real life and which too academically focused. This may lead to further difficulties for teachers as to how the elements of the nature of science and scientific enquiry fit into the existing area of scientific knowledge because of its outdated and irrelevancy to real life situations. In this respect, research shows that teachers find it rather easier to teach the current issues with scientific enquiry activities than to use the existing curriculum content (Schwartz, et al, 2004).

To sum up, difficulties stem from the aims and content of the curriculum. Firstly, conventional school curricula still remain content dominated with a traditional approach in spite of the emphasis on the nature of science and scientific enquiry. Thus, the asserted purpose or aims of the curriculum remain extremely marginal in the classroom and teachers regard the understanding of science concepts and skills as the main aims of science education. Secondly, the curriculum includes inappropriate content for contemporary science. Finally, the present curriculum content is too great to be able to implement the nature of science and scientific enquiry.

The following section will consider assessment in scientific enquiry because assessment has become a powerful determinant in teachers' teaching in the classroom. In particular, as the assessment involves higher stakes, assessment driven school curricula become prominent (Black, 2000). As assessment driven school curricula are known to be a great stumbling block hindering improvement in the quality of education. Thus, the following section will include the nature of assessment, different types of assessment, the quality of assessment, and the difficulties related to the assessment of scientific enquiry.

2-9 Assessment in scientific enquiry

Much research has claimed that there are considerable short-comings in the assessment of scientific enquiry and dissatisfaction among students in the assessment of scientific investigations: there are doubts about the validity of instrument and assessment content (Hur M, 1984; Millar and Osborne, 1998; Aikenhead, 2000; Robert s & Gott, 2004).

Assessment of scientific enquiry is difficult because it includes not only the area of empirical work and the actual execution of routine procedures but also the areas of theorizing, analysing and solving problems which refers to cognitive performance (Zuzovsky & Tamir, 1999). In addition, the nature of science and the scientific enquiry process is difficult to transform into pencil and paper mode as well as to identify an appropriate assessment context (McComas, 1998).

Standardised examinations as the end of key stage tests (KS tests) and the General Certificate of Secondary Education (GCSE) have become a high profile aspect of teachers' work, exercising a powerful influence over what is taught and the ways in which it is taught in schools (Brooks, 2002). This assessment-driven school curricula are a stumbling block to improving the quality of education (Black, 2000). Therefore, it may be necessary to consider in detail the nature of assessment and the difficulties inherent in the current assessment practice

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2-9-1 the nature of assessment

The main purposes of assessment are concerned with supporting learning, with producing certification and with satisfying the demands for public accountability (Black, 2003). Policies have emphasised formative assessment, which encourages supporting learning, yet this has been almost ignored due to the high-stake summative assessment being dominant in schools (Brooks, 2002). In addition, the judgements resulting from assessment have become an important feature of successive government policies when it is used in an attempt to monitor and raise educational standards and to increase the accountability of different sectors of the educational service (Bell, et al, 2000). Thus, the interaction between these purposes is varied, complex and involves certain constraints. Educators suggest that each assessment should serve its own purpose in order to minimise the constraints, which may occur (Bell, et al, 2000).

There are two different types of assessment: formative assessment and summative assessment. The former supports the process of learning with interactive activities in a classroom and is often regarded as a part of teaching rather than an assessment practice whereas the latter is often equated with tests and examinations including KS tests (the end of key Stage tests), end of topic tests, end of year tests or GCSEs. Summative assessment can be teachers' internal assessment and external public examinations. Generally it has been recognised that if test results are the sole or eventual partial arbiter of pupils' future educational or life choices, then the stakes are raised further (Black, 2000). Thus the more consequences dependent on the test results, the higher the stakes and the more powerful the influence on what is taught. Consequently, the higher the stakes, the more important will be the quality of assessment such as validity and reliability (Bell, et al, 2000).

2-9-2 Quality of summative assessment

According to Black (2000), the examination system should be designed so that the users of the results can have confidence in the results (Black, 2000). Thus, reliability and validity are the two main criteria as the basis for the quality of examination results. If a test is not reliable, the score that pupils actually get on a particular occasion will not reflect their capability and the results cannot be valid (Black, 2003).

Much research reveals the weaknesses of the assessment of scientific enquiry concerning the use of instruments and the techniques that have been used (McComas, 1998; Lederman, 1999). Fundamentally, it is difficult to measure the ability of scientific enquiry with a pencil and paper test because science comprises complex skills and experimental investigations in a laboratory. In addition, a test cannot cover a very large proportion of a syllabus, which covers over 1 to 3 years of pupils' learning within the National Curriculum (Black, 2003). Thus, two dimensions of limitations can be considered. One is related to the validity of the assessment instruments and the other is the interpretation of those scoring the tests (Lederman, 1999).

Particularly, where high-stakes testing is prevalent, a traditional view of the validity of assessment in the sense that it covers all the important aspects of a syllabus is inadequate. Instead, as Wiliam (2003) argues, it is necessary to take into account the traditional view, the meanings that people attach to results, the way results are used and what happens as a consequence. Thus, validity is a process rather than a property and needs to take into account the social consequences of test use. For example, assessments send a message about what is valued and important. If a question is being put in a test, it sends a message that a particular topic is considered to be important even though the question is not necessarily a good item (Wiliam, 2003).

In terms of reliability, pupils' levels are often being mis-classified and there can be very low correlation between the written test and the task done in a laboratory (Black, 2003). Thus, Black (2003) argues that the assessment should be more diverse and flexible in assessing methods and assessing content in order to improve the reliability of the assessment. In this respect, educators have advocated empowering teachers' assessment in scientific enquiry for practicing formative assessment as well as improving the reliability of the assessment (Black, 2003; Brooks, 2002). Osborne & Ratcliffe (2000) also support strengthening teachers' assessment mentioning that good assessment items which encourage the development of authentic skills needed in a real life context are suitable for teachers' assessment. Ultimately there should be more coursework assessment by teachers employing a moderation system and fewer external tests:

However, different teachers need to be working to common standards and have to understand one another's procedures for determining standards of grading (Harlen, 2003). Thus, communication of criteria and standards becomes more formal and clearer so that the information will be used to produce assessments on a shared basis or within a common external scheme. In accordance with this, the emphasis seems to be moving on to a common standard and a validity of teachers' assessment with respect to the quality of assessment. Additional pressure to achieve validity can be added (Brooks, 2002).

In the conventional assessment system, scientific enquiry is assessed by performance assessment by teachers and internal or external standardised examinations. Therefore, the following difficulties are considered in assessing scientific enquiry by performance assessment and external or internal examinations.

2-9-3 Performance assessment

Assessing pupils' performance is known to be a difficult task for teachers as they have not only to assess pupils' ability in certain skills but also to assess scientific enquiry, which includes observation, interpretation, reasoning skills, thinking skills, cooperative skills and even their attitude toward doing science.

Although performance assessment is important, research indicates that many teachers express a lack of experience with assessment methods aimed at assessing their students' understanding and performance in the science laboratory (Kim J S & Yoe C H, 2002; Osborne, et al, 2002). Other research supports the above argument, mentioning that teachers have been criticised for a lack of clarity in the criteria of assessment which have been applied when marking pupils' work, arguing that the confusion was compounded when separate criteria were poorly differentiated (Brooks, 2002; Robert & Gott, 2004; Park S H, 2003b).

Particularly, there is criticism concerning process oriented teaching and the assessing of scientific enquiry. Kind (2003b) criticises the process-based approaches in teaching and assessing scientific enquiry. He argues that much investigative work in school science has been developed around specific types of task with a focus on scientific process skills. Kind (2003b) is suspicious of the achievement results for English students aged 13 in TIMSS PA (Third International Mathematics and Science Study, Performance Assessment) which is known as an international study intended to measure a mixture of enquiry skills through investigative tasks. He believes that the highest attained by the English students in TIMSS PA does not necessarily mean the highest standard of science rather it is apparent that they have practiced the process based approaches for a long time (Kind, 2003b, p89). He pointed out mismatches between theory and results that go beyond the practical complexity of performance assessment. Kind (2003b) concludes that scientific skills only have meaning within a certain rationale. Russell & McGuigan's research seems to support Kind's argument. According to their research, pupils show better performance with familiar patterns of questions whilst most students show higher omission rates in the area of novel demands and questions and at very high discrimination levels, suggesting that the more proficient science thinkers perform well in the new type of item (Russell & McGuigan, 2003, PS2-B-Paper4).

At this point, educators suggest that although the empirical nature of science includes certain skills, the nature of science also includes abstracting and deducing scientific principles, applying scientific principles to solve problems, and applying, constructing, interpreting and utilising some prior knowledge (McComas, 1998). However, the conventional assessment regime seems unable to contain such items of scientific enquiry. In addition, the range of investigations which fit easily within the national curricula have been criticised as being limited, having an over emphasis on fair testing for example. This is to the detriment of other kinds of investigation such as classifying, identifying, pattern seeking, exploring, investigating models and making things and developing systems (Watson & Robinson, 1998).

In this respect, Jenkins (2000) advocates the importance of ownership in pupils' investigation, and learning science through investigation being a norm. A sense of ownership by students in their investigation is important to perform better in terms of commitment and collaboration in their work (Jenkins, 2000). Students should be involved at every stage in shaping, defining, developing and monitoring their solution to the problems with which they are engaged (Jenkins, 2000). Research reveals that student's autonomy is vital to develop pupil's competence in relevant processes and thinking ability because investigations involving practical work are essentially thinking activities (Watson & Robinson, 1998). In addition, if investigative work is carried out infrequently and only in association with performance assessment, then, it becomes onerous because pupils associate it with examinations. Therefore, it may be necessary to consider learner-centred teaching and learning, followed by the school curriculum being left open and flexible to accommodate the dynamic and particular requirement for scientific investigation projects (Jenkins, 2000).

At the same time, it also needs to develop the content of assessment and the methods and techniques of assessment as an integral part of teaching and learning. According to Jenkins (2000), students showed dissatisfaction with the way their works are graded; arguing that the grades are a devaluation of their work and that the real life evaluation, which they have encountered during the investigation is incommensurate with the formal grading (Jenkins, 2000).

Performance assessment could be a main method for assessing pupils' scientific enquiry ability along with standardised examinations. However, performance assessment through investigations presents intractable problems in the current school science concerning reliability and validity as well as restriction on assessing a wide range of ability (Robert & Gott, 2004; Kim J S & Yoe C H, 2002). As Woolnough (1991, p8) mentions, performance assessment impacts on the way investigations are taught. Thus, there are tensions between the reliability and validity of assessment tasks. Consequently, teachers and pupils alike see little point in carrying out investigations for performance assessment as those are given far less weight compared to the importance of scientific enquiry in the national curricula (Robert & Gott, 2004; Kim J S & Yoe C H, 2002).

On the other hand, standardised examinations have dominated teaching and learning in the classroom despite many criticisms, particularly when the examinations involve high-stakes. As Wiliam (2003, p81) argues, the assessments send messages about what is valued and important in the classroom. The assessment content tends to give validity to the curricular content. Therefore, high-stake examinations are focused on this study rather than performance assessment.

2-9-4 High-stakes standardised assessment

As mentioned above, the current standardised assessment and high-stake testing have been criticised for leading to impoverished teaching and learning (Black, 2000). Black (2000) argued that high-stake testing not only determines the content of the curriculum, but can also dictate how it is taught, offering a disincentive to a certain style of teachers' assessment in a system dominated by high-stakes tests. Rather, teachers have become used to summative approaches, which they perpetuate in the classroom (Black, 2000). Particularly, there is a tendency that students' concern about their grades has a strong influence on teachers' practice. Thus, some teachers may emphasise goals for learning and use teaching techniques that are aligned with a student's ability to earn high grades (Black, 2000).

Teachers look to examination questions for a more precise definition of what the intentions of any course may be (Osborne, et al, 2002). For it is much easier to identify the content, skills and processes required of a course from such questions than the often loose or vague language of a syllabus specification in the national curricula. Thus, the content of assessment becomes a powerful determinant of learning goals rather than the National Curricula (Black, 2000). As a result of this, teachers can place too much emphasis on a limited domain of the curriculum in the limited subset of skills. In addition, such assessment materials are often used for practice in examination questions, for homework and to familiarise the students with the level and demands of the course.

Coupled with the difficulty of assessing elements of scientific enquiry and the assessment content which was not properly incorporated in the aims of the National Curriculum, the assessment of scientific enquiry tends to have a low emphasis in the area of teachers' current practices contrasting with the emphasis in the curricula on scientific enquiry itself (Russell & McGuigan, 2003). Millar (2003) supports the above argument mentioning as follows,

... the assessment of scientific enquiry has received little attention because the

aim was not incorporated in the content of assessment or in the textbooks (Millar, 2003, PS3-F-Symp).

It may be necessary to accept that there will be teaching to the test because science teaching will focus on what is likely to be in the test. Under this assessment driven school curricula, a notable attempt at reform has been made in the area of high stakes testing. According to Russell and McGuignan's report, tests have been developed in the area of scientific enquiry concerning ideas and evidence and the management of variables. The report reveals two kinds of performance data: the quantitative outcomes, which are used for summative purposes, and the quality of pupils' responses, which have greater formative value for teachers' classroom practice. This report shows that the assessment enhance the possibility of summative materials being used by teachers for diagnostic and formative purposes albeit pupils struggles with some aspects of scientific enquiry have been identified. Russell and McGuigan (2003) argue as follows:

It is possible to develop assessment worth teaching to, when the assessment regime assesses scientific enquiry within ecologically valid contexts and illustrates exemplary practice in the kinds of demands made on pupils' thinking (Russell & McGuigan, 2003, p3).

It is therefore important to develop good measures at a time when the curriculum is changing to emphasise the nature of science and scientific enquiry. Thus, the aims of the curriculum can reflect the assessment content. In order to do this, the research suggests that it is particularly important to focus on this assessment area at a time when content reduction and a complementary increase in emphasis on science processes are being widely advocated (Russell & McGuigan, 2003).

In conclusion, much research has claimed that assessment in scientific enquiry is a great stumbling block in implementing scientific enquiry into the classroom. Firstly, there are constraints from different assessments, which serve different purposes. Secondly, the current high-stake summative assessment demands quality of assessment concerning validity and reliability. Thirdly, assessment in scientific enquiry is difficult because of its nature. Although the conventional curriculum has emphasized scientific enquiry, it has given less weight to that subject than to other attainment targets. As the method and context are varied in science, assessment should be varied. It also may be necessary to consider how the tests and examinations in scientific enquiry can be explicitly incorporated in to the examination programmes both in performance assessment and in high-stake standardised examinations. In addition, it has been considered how well scientific enquiry can be assessed in the light of assessment worth teaching as long as high-stake testing is prevalent.

In order to provide the background for more detailed comparative research, it is necessary to briefly consider experience in teaching and assessing scientific enquiry both in England and Korea. As mentioned above, both countries have shared difficulties concerning implementing more scientific enquiry into the classroom although their national curricula have different historical and cultural backgrounds.

2-10 Experiences in teaching and assessing scientific enquiry in both England and Korea

In the early 1980s, country after country began to recognise the importance of the science for all movement (Fensham, 2000). Based on the science for all movement, various approaches have taken place across the nations in order to redefine the content for school science (Fensham, 2000). In almost every case, there have been proposals that increase the range and extent of the content for school science including traditional conceptual content of physics, chemistry and biology included earth science and space sciences and applications of science and technology as well as various versions of the nature of science and scientific enquiry.

During the 1990s, England and Korea along with other countries implemented the above recommendation (Kim Y S, 1994; Fensham, 2000). However, there was only a pragmatic reduction in the range of content in practice rather than any principled excision. The result was the retention of much of the traditional content with little new material. Millar (1989) support the above as mentioned below.

In many senses, the curriculum itself remains fundamentally unchanged and the content would be easily recognisable to any child of the 1950s (Millar, 1989, p143).

The following sections include the background and experience in both England and Korea concerning the teaching and assessment of scientific enquiry.

2-10-1 England

The national curriculum in England was introduced in 1989. Since then, the variability of content taught in sciences was reduced and a degree of coherence was imposed on the content and innovative techniques of assessment were removed (Nicolson and Holman, 2003). For example, courses in 'agricultural science' and 'human biology' etc. were often titled as science. In addition, there were over 400 different science qualifications available at age 16. Thus, one effect of the national curriculum has been a one-type-of-science-for-all approach (Nicolson and Holman, 2003). In addition, mass education in science in secondary schooling has taken place. For example, in 1984 less than half of the pupils in secondary schools studied two or more of the subjects' biology, chemistry or physics. By 2001, over 90% of 16 year-olds were studying a balance of science or all three separate sciences. Thus, a majority of students between the ages of 5 and 16 are following the National Curriculum for science with a balanced across the subjects of biology, chemistry, physics and earth. Students are taught a systematic approach to scientific investigation. The National Curriculum programme of study (PoS) divided content into 'attainment targets', which were divided into 'strands'. Progression through each strand was then linked to a 10-point scale of increasing achievement. This has led to particular topics (attainment targets) being introduced and revisited at each key stage like a 'spiral curriculum' (Nicolson and Holman, 2003). Each of the two first versions of the PoS provided overlap of content between key stages to allow for differences in the rate of development of different children. Although this model of curriculum is effective the curriculum content can overlap and a lot of repetitions take place. Thus, the current curriculum revision in 2000 was concerned to avoid the repetitions (Nicolson and Holman, 2003).

With respect to practical work, a typical science lesson in England consists of practical work in a science laboratory. As early as 1887, the laboratory had already been identified as an essential item for school science education (Wellington, 1998). In the 20^{th} century, the school laboratory has become a symbol of the status of science in the curriculum. As a result of this tradition, in spite of the growing interest in scientific enquiry as broadly defined, teachers still seem to regard scientific enquiry as practical work in the laboratory. Woolnough (1991) also reported that in England, 11-13 year olds spend over half their science lesson time engaged in practical work.

As Woolnogh (1991) argues, there is no doubt that England has been a pioneer in developing school science practical work in general and investigative work in particular. The English National Science curriculum (ENSC) seems to have a unique feature of scientific enquiry (Sc1) describing the science enquiry (sc1) with other science subjects such as biology (sc2) chemistry (sc3) and physics (sc4) in the programme of study (PoS). Thus, the exemplar scheme of work even has a 9 lesson scheme on scientific investigations for year 9 (QCA, 2001a). The ENSC has also broadened the role of scientific investigations and has introduced aspects of the nature of science and scientific enquiry (Turner, 2000).

Furthermore, the QCA highlighted scientific enquiry as an area to be strengthened for the national assessment of science from the year 2003, with an increase in the number of questions assessing scientific enquiry (Kind, 2003b). Thus, the assessment items for evaluating the scientific enquiry (Sc1) component '*Ideas and Evidences*' has been implemented since 2002. It is regarded as being important to reflect curriculum intentions as well as to develop teaching methods which allow pupils to explore effectively how we know and what we know (Osborne and Ratcliffe, 2002).

However, assessment has been a dominant influence in teaching in schools due to the emphasis on school league tables. Teachers concentrate on rapid coverage of the factual material in the national curriculum content. According to a teachers' survey, teachers indicate that many omitted some of the activities, which had an emphasis on skill development (Nicolson and Holman, 2003). Teachers complain that there is so much content in the national curriculum and that there is little time for consolidation of learning or for reflective consideration of the applications of science. Shortage of time also appears to have affected the amount of time spent on practical work. Another factor is the method used for assessment of practical coursework in scientific investigation. According to Black (2003), there were weaknesses particularly in the attempts to represent progression and to achieve comparability across skills. Lacking good models or adequate training, the exercises teachers use have become stereotyped, dominated by the notion of fair testing. Many teachers set pupils the same stereotyped exercises year after year and so the work has reverted to the old cook book type of exercise (Black, 2003). Current assessment calls on more sophisticated and holistic skills than earlier assessment. In addition, as Osborne and Ratcliffe (2002) argue that assessment for scientific enquiry (AT1) should include more elements in the area of ideas and evidence.

2-10-2 Korea

The National Curriculum in Korea was implemented in 1945. The national curriculum specifies a detailed content of physics, chemistry and biology and sets time tables for primary and middle schools.

The ideology was based on a bureaucratic and rationalist notion in which accountability was the driving factor, rather than any consideration of its value for the child (MOE, 2001c). Korean science education has adopted international trends quickly and has continued to reflect them into the national science curriculum revisions. For instance, the 6^{th} National Curriculum implemented in 1992 described 3 dimensions of science: conceptual understanding, the process of science and contextual understanding (STS for short).

The aims of science education in the 7th national curriculum remain the same as the ones in the 6^{th} national curriculum, emphasising scientific enquiry. The importance of scientific enquiry in the national curriculum emerged in the 6^{th} national curriculum operational since 1992 (MOE, 2001c). Then, the national curriculum started to reduce its content accordingly.

Various attempts to improve school science have been made since 1995: by enquiry centred school curriculum, reduced content, reduced class-size, improved laboratory facilities and so on (Park S J, 2003a; Kim J. W, 2004). The Korean national science curriculum (KNSC) content was divided into knowledge and enquiry areas. Each school year has had different content, being structured in accordance with students' cognitive abilities. Thus, there is no overlap between different year groups. Yet, this model has been criticised as having led to fragmented and disintegrated curriculum content.

Traditionally, science in a Korean classroom was not much different from other subjects. Most science lessons were in the classroom with teachers explaining and summarising a content of knowledge. The national science curriculum was known as being 'academically based' with a great amount of scientific knowledge content until the 5th national curriculum in 1987-1992 (MOE, 2001c). Then, 'science for all' became the aim of the content of the current national curriculum in spite of the curriculum emphasising content knowledge and bringing the STS syllabus into the curriculum (MOE, 2001c).

The assessment regime in middle schools (children aged 11-14 years) has been used not from a social welfare perspective but as an individual privilege to open the gate of further education as a selective basis for subsequent school education. Although more than 99.4% of students go on to high school (15-17 years) after middle school, the assessment regime still remains based on a selective tradition, which has brought about normative, high stakes assessment within the rigid national curriculum (Kim J C, 1998). Thus, assessment has been a dominant influence in teaching in Korean schools although at a different level and stem from the one in English schools. According to a teachers' survey, Korean teachers indicated similar responses concerning the pressure of shortage of time to cover the national curriculum content. Teachers indicate that there is too much content to cover and too little time to do practical work and to teach in the way they would wish (Kim K M & Kim S W, 2002).

Indeed, although the 7th national curriculum mentions that all science lessons should involve scientific enquiry there still seems to have been less scientific enquiry and less practical work than in English schools. Recently, the MOE announced, a boosting plan for scientific enquiry with experiments and investigations in primary and middle schools (MOE, 2002). They also mentioned the shift from scientific knowledge based on work in the classroom to scientific enquiry in laboratory-based teaching (MOE, 2002). Behind this Boosting Plan, there were criticisms about the results of OECD (Organisation for Economic Cooperation and Development) and TIMMS (Third International Mathematics and Science Study) a comparison that revealed that in the OECD countries Korean children had reached the highest score but showed the lowest interest in science and dissatisfaction with the teachers' teaching of science (MOE, 2002; Park S J, 2003a).

Due to the limited practical work, there has been much emphasis on scientific knowledge (KICE, 2001). Thus, traditional Korean science has been criticised for being like a pupil having a driving licence without getting a car (Kim J C, 1998). As Kim Y S (1994) mentioned, there are few links between the understanding about the nature of science and scientific enquiry and the social context; rather Korean teachers regard STS (Science-Technology-Society) as a global trend of science education. Since the STS context has been employed, teachers have regarded STS as an additional chapter of science textbooks.

To sum up, although both countries have different backgrounds for their national curricula, yet they have been influenced by the science-for-all movement and have had similar difficulties in the teaching of science. Both curricula have been emphasising scientific enquiry in the National Curricula as well as seeking meaningful learning and a better understanding of science concepts. However, Korea tends to employ practical work in the classroom based more on the tradition which has emphasised the conceptual understanding of science whereas England tends to reinforce the elements of the nature of science such as 'ideas of evidence' based on doing more practical work in the science classroom. This assertion is tested more fully in the documentary analysis chapter 4. The following section will consider TIMSS as an international comparative study and deals with its background, development, influence and limitations internationally. Both curricula have been influenced by the science-for-all movement and have participated in TIMSS since 1995.

2-11 TIMSS survey as an international comparative study

The TIMSS survey has assessed 13-year-old students' performance in mathematics and science every 4 years (Kim C J, 2004). Thus TIMSS-2003 is the third in a series of surveys: 1995, 1999 and 2003.

As mentioned in the section above, the 'science-for-all' movement has led to curricula revisions in 1990s both in England and in Korea (Fensham, 2000). A project was developed to define the content for TIMSS and it was decided to test for MSL (mathematical and scientific literacy) in 1995 (Fensham, 2000, p 151). Originally, TIMSS-1995 started to include the recall of science content from a small group of topics by using more multiple-choice format and far less descriptive format of questions but some attention was given to societal impact, reasoning, social and historical developments and attitudes (Fensham, 2000). Yet, TIMSS-1999 made only minor changes to its test development, as

Rank	1995	Average	1999	Average	2003	Average
1	Singapore	580	Taiwan	569	Singapore	578
2	Taiwan		Singapore	568	Taiwan	571
3	Japan	554	Hungary	552	Korea	558
4	Korea	546	Japan	550	Hongkong	556
5	Hungary	537	Korea	549	Japan	552
6	England	533	Netherland	545	England	544
7			Australia			
8			Sweden			
9			England	538		

it continued to emphasise the recall of content knowledge taught in the early years of secondary schooling compared with reasoning and social utility. Each context had quite varying social, economic and political settings and relevance across the participating countries an aspect TIMSS acknowledged but could not alter because of its commitment to a test made up of common isolated items (Fensham, 2000).

Table 3 TIMSS-ranking of England and Korea in science performance (KICE, 2004)

The TIMSS-survey included other factors, which can affect students' schooling such as students' backgrounds, attitudes toward science, classroom characteristics and so on in order to make comparison more relevant rather than solely students' achievements (KICE, 2004). The proportion of scientific enquiry has been increased in TIMSS-2003 compared with TIMSS-1999 in order to make more relevant the contemporary views of science and reflecting the current trend of the emphasis on scientific enquiry. The proportion of multiple-choice format has also been reduced gradually in line with curricular trends (Kim C J, 2004).

England and Korea have participated in the TIMSS survey since 1995. Both countries have shown a much higher achievement than average. Korean students have consistently shown a higher achievement than their English counterparts. In 2003, it was not possible to achieve the TIMSS sampling requirements because not enough schools in England from the first choice sample would agree to participate. Thus, the data used for that year in England has been weighed using schools' performances in national tests and examinations to ensure that it is in fact representative (NFER, 2004).

According to this reweighed result, from among 46 countries, English students were in 6th place with 544 marks compared with Korean students being in 3rd place with 558 marks (NFER, 2004). In terms of international benchmarks in TIMSS-2003, 15% of English students reached the advanced benchmark (achieving over 625 marks) compared with 17% of Korean students and the international average being 7% (KICE, 2004). The TIMSS-2003 survey shows students in both countries do not have a long tail of underachievement as measured by the proportions of students reaching the low international benchmark; English students 96% and Korean students 98% and the international average of 84%. As analysed by gender in TIMSS-2003, boys in both England and Korea performed significantly higher than the girls. English boys scoring 550 compared with the girls 538 and Korean boys 564 compared with the girls' 552 (KICE, 2004; NFER, 2004). Therefore, there are similarities in the distributions of performance despite Korean as well as in performances of different genders.

However, in the area of attitudes in TIMSS-2003, there are considerable differences in confidence and preference for science subjects. The majority of English students are confident of their ability in science and enjoy their lessons (NFER, 2004). By contrast, only 20% of Korean students are confident of their ability in science compared with 53% of English students. Only 9% of Korean students indicate that they enjoy their science lessons very much compared with 28% of English students, 29 % of Korean students enjoy their science lessons compared with 41% of English students (KICE, 2004). In addition, Korean students do not want to carry on studying science subjects further nor to pursue science related jobs.

Despite the importance of the TIMSS data, a point criticism of TIMSS has been the ongoing debate about the content of TIMSS survey and criticism concerning evaluation and interpretation of the results.

Firstly, TIMSS tests for students have raised some doubts about how well their scores for TIMSS do reflect their actual learning of science. According to Kim C J, (2004), the assessment domain for TIMSS show a narrower range than other international studies such as PISA (Programme for International Student Assessment) being concentrated on Knowledge/ comprehension, process/enquiry and a part of attitude domains. Further problems about common approaches to summative assessment in science are raised by a study of performance across heterogeneous contexts, which showed that students' responses varied in kind and in extent across assessment contexts and formats (McGinn and Roth, 1998 quoted in Black, 2000). These difficulties may stem from the limitations of selection of content and context for over 30 different countries, which have different historical, cultural and social backgrounds. Thus, the main determinant of success about their ranking is whether or not the material in question as been taught at all. (Schmidt, et al, 1999 quoted in Black, 2000)

Secondly, there seems to be a difficulty in interpreting variations of test scores over time. It is hard for the public to accept that if both the curriculum aims and the methods of assessment have changed over the years, any question about whether standards of performance have risen calls for a value judgement and cannot be answered by simple comparison of any pair of test scores (Black, 2000).

Thirdly, the TIMSS survey data cannot explain why and how Korean students have performed well yet, they have shown lack of confidence and interest in science lessons. TIMSS background survey could not offer reasons why Korean students have performed well. For example, Korean students indicated that they did not get proper teachers' support. Korean students also show higher achievement despite the teachers putting little emphasis on homework. Thus, Kim C J, 2004) argued that qualitative research may be needed based on the TIMSS survey, in order to offer to evaluate the relevance and appropriateness of the National Curriculum in an international context at the KS3 level. Despite the criticisms, TIMSS survey results have been an important reference for making educational policies and revising the curriculum.

To sum up, the TIMSS survey has explored students' achievement internationally since 1995. Students in both countries have performed much higher than average. Particularly, Korean students have consistently achieved higher marks than their English counterparts. However, there are limitations in the content of assessment as well as the interpretation of the results. Nevertheless, the TIMSS survey has still been an important reference for making educational policy and revising curriculum in many countries.

Summary

Because of the demands of changing society and the need to improve the quality of education, understanding the nature of science and scientific enquiry has become a common goal for many years. Thus, the aims of both National Curricula put an emphasis on scientific literacy, including elements of the nature of science and scientific enquiry, in order to improve public understanding of science as well as the quality of science education. However, there has been a lack of consensus on the boundary of science and the nature of science. This chapter summarises some philosophical perspectives of science such as inductivist, deductivist, Theory-laden observation, Kuhn's revolution, Instrumentalism/Realism, Relativism/Positivism, contextualism, decontextualism and contemporary views about the nature of science. This chapter also explores how the national curricula in both England and Korea, describe the nature of science and scientific enquiry. Then, it is necessary to clarify the terms 'the nature of science' and 'scientific enquiry' although there is no clear-cut distinction between the two as they overlap. However, the nature of science refers to underlying values and assumptions whilst scientific enquiry refers to the methods and activities of science involving societal, cultural and political implications.

Then, this chapter included how educators recommend teaching the elements of the nature of science and scientific enquiry. Implementing the nature of science and scientific enquiry seems to be a complex process: along with teachers' perceptions and intentions about the nature of science, various factors are inter-locking between textbooks, the national curriculum, assessment-driven teaching practices and so on. The assessment driven school curricula have been known as a great stumbling block in implementing scientific enquiry. Thus, it is important to develop good measures in the content of assessment so that high-stakes testing can be used for formative purpose.

For further comparative research, it is necessary to consider a brief experience in teaching and assessing scientific enquiry both in England and in Korea. Both countries have shared difficulties concerning implementing more scientific enquiry into the classroom although they have different historical and cultural backgrounds in the national curriculum. TIMSS as a large comparative study has dealt with achievement for 13-year-old students in mathematics and science including other factors such as students' attitude. Although the TIMSS survey has limitations in terms of definition of content and interpretation of the test results, it has been an important reference for making educational policy and revising curriculum in many countries. Therefore, the TIMSS survey will be used as a reference for an international comparative study, for exploring how assessment in scientific enquiry affects teachers' teaching in England and Korea. The following chapter describes the methodology used for this research.

Chapter 3 Research methodology

3-1 Introduction

The research focus is ***'What is the impact of assessment in scientific enquiry on the perception of teaching science at age 14 in a comparison between England and Korea?'*** This study follows the research question, instead of setting any hypotheses. The research question can be divided into two sub-questions in a broad sense: one asks what is taught and assessed in scientific enquiry in the national curricula in England and Korea, the other investigates how teachers perceive they teach scientific enquiry and their perceptions about the nature of science and scientific enquiry. This study will then make comparisons and make inferences on an international level, before considering the implications of a changing society and the need for the quality of science education to keep in step with such change.

According to Charles (1988), the word 'research', from the French '*rechercher*', is to travel through or to survey an object or entity, and is defined as a careful, systematic, patient investigation undertaken to discover or establish facts and relationships (Charles, 1988, p9).

Educational research, therefore, can be referred to as a detailed systematic investigation, that leads to new knowledge through the use of a process which involves clarifying a problem, formulating research questions or hypotheses, obtaining valid and reliable information, analysing data, describing the findings, and drawing conclusions that answer the questions or test the hypotheses (Charles, 1988).

In terms of the classification of educational research, various educators present their own categorizations, which indicate the absence of a standardized classification scheme. However, types of research can be differentiated as follows (Charles, 1988);

1. *whether the research is done with a practical end in mind,*
2. *the overall methodology employed,*
3. *the kind of questions that prompt the research.*

Firstly, research done in order to find practical solutions to pressing problems is called 'applied research', whereas research done with no practical application in mind is called 'basic research'.

Secondly, research is also categorized in terms of the general methodology it employs. Four different research methods can be used in educational research: 'qualitative', 'quantitative', 'experimental' and 'non-experimental'. Any investigation is characterized by two of these labels; an investigation may be qualitative and non-experimental.

Lastly, the third means of categorizing research focuses on the nature of the research questions addressed. Eight types of research are commonly identified from their central questions. These types are ethnographic, historical, descriptive, co-relational, action, evaluation, casual-comparative and experimental research (Charles, 1988).

Therefore, the research in this study is defined as 'applied research' in the first category, 'qualitative and non experimental research' in the second category and 'descriptive research' in the third category, which is done to depict people, situations, events and conditions, as they now exist. The major sources from which information is obtained are physical settings, records, documents, objects, materials and people who possess knowledge of the situation but were not directly involved. Findings are presented in narrative form enhanced by numerical categorical and graphic illustrations (Charles, 1988). The nature of this study is an international comparative research comparing the curricula, the assessment and the teachers' perceptions between England and Korea.

The aims of research are to discover the facts and relationships concerning the national curricula and assessment, as well as to explore the teachers' perceptions and practices of teachers by using scientific methods such as analysis and survey. Using a scientific approach, this research sets out to obtain reliable information by comparing both English and Korean curricula and examination papers. Once data are collected and knowledge established by analysing all related documentation, possible relationships can be explored between the teachers' perceptions and practices obtained by survey research methods using questionnaires and focus group interviews. Finally, this data will be analysed, compared and used to describe findings and to draw a conclusion that answers the research question. Therefore, this chapter is to address:

1. the nature of comparative education,
2. research design,
3. procedures used in collecting data
4. the nature of main methodology including strengths and weakness
5. analysing data
6.categorising and making comparison in order to synthesise the data
7. considerations for the quality of research and ethical issues

Prior to consider the research design, it may be necessary to consider the nature of comparative research including the strengths and the weaknesses of comparative research in general as well as in this study in particular.

3-2 The nature of comparative research

According to Noah & Eckstein (1998, p58), the field of comparative education is best defined as an intersection of the social sciences, education and cross-national study. It is said that comparative education has developed through five stages since the beginning of the 19th century. Comparative research was prompted by a simple curiosity to emphasise the exotic information such as general descriptions of institutions and foreign ways of raising children. As the national education system began to be set up in the 19th century in Europe, the main concern of comparative research was to discover information useful for charting the course of education in their own countries. This modern comparative education was done predominantly by educational politicians, experts and activists (Arnove, et al, 1982; Noah & Eckstein, 1998). They were concerned with educational theory, methodology, finance, organisation, teacher training, instructional methods and the curricula in order to use as an important reference for educational reform (Arnove, et al, 1982; Kim S S, 2004). Then, international education cooperation was stressed in the interests of world harmony and mutual improvement among nations as many scholars, students and publications, have been exchanged (Noah & Eckstein, 1998). The resulting network of international contacts would help to promote international understanding as well as improving social and educational institutions around the world. In the 20th century, two more stages have appeared; both were concerned with seeking explanations for the wide variety of educational and social phenomena observed around the globe (Noah & Eckstein, 1998). One notable feature of comparative education during this time was the recognition of the importance of dynamic relationships knitting education and society. Schools were seen as miniatures of the society, yet the society was moulded partly by education. Changes in one were revealed in the other (Noah & Eckstein, 1998; Kim Y C and Cho J S, 2005). Thus, comparative education began to consider the possibility of using the conclusions to steer education reform and to engineer the future shape of the society (Noah & Eckstein, 1998; Kim C J, 2004). The latest approaches are attempting social science explanation, which uses the empirical and quantitative methods to clarify relationships between the education and the society (Noah & Eckstein, 1998; Kim Y C and Cho J S, 2005). Due to the nature of comparative education, prior to the 1950s, it had a long tradition as an applied field that assisted in educational reform, domestically and internationally (Kelly, et al, 1982). In practice, comparative education can deepen the understanding of their own education and society because people can truly comprehend themselves only in the context of secure knowledge of other societies (Noah & Eckstein, 1998; Kim C J, 2004).

Therefore, by its nature, comparative education has strengths as well as having weaknesses due to its complexity. The following address its strengths and weaknesses. Then it discusses possible ways to minimise the weaknesses in this study.

Firstly, comparative education incorporates what other countries are doing, not doing, planning and abandoning, or changing in their educational enterprises by accurate description. Often it reveals a great power of observing, assimilation and reporting (Arnove, et al, 1982; Noah & Eckstein, 1998; Kim S S, 2004).

Secondly, through the results from comparative research, it can help the decision-making in educational policies and curriculum revision (Kelly, et al, 1982, Han J H, 1995). An accurate, reliable description often shows that its own problems are not unique and such knowledge can be most useful. It directs us to search out and try to understand forces and factors at work that transcend the boundaries of our own society. Thus, exercises in mapping the experiences of other countries can feed directly into policy making and decision-taking (Kim S S, 2004)

Thirdly, comparative education can be a fruitful approach towards understanding the values, culture, and achievements of other societies because the state of schools may be an indicator of more than just the educational condition. For example, indifference in the schools to the value of intellectual activity may be a token of a more general anti-intellectualism in society (Noah & Eckstein, 1998).

Lastly, it is said that comparative education has the potential for generalisation. This is because a comparative approach enlarges the frame work within which can be seen the results obtained in a single country, by providing counter instances. It can also make theories refine out and test their validity against the reality of different societies (Noah & Eckstein, 1990).

However, comparative education remains a field characterised by methodological debates and diversity of opinions (Kelly, et al, 1982). In broad sense, the debates can be classified into three areas: one is in the use of the content for the comparative education, such as a national systems or pupils' achievement or being compared at different point of time. Two is in the use of the methods in order to discover universal patterns or principles (Arnove, et al, 1982). Third is in the area of interpretation of the findings. As Arnove, et al (1982, p5) suggest, comparative educators often assume that societies follow the same path to development and a country at a different stage of development and represents a different point on the same continuum or trajectory. Similarly, Comparative educators can be preoccupied with problems of cause and effect but inevitably their discussion tends to descend to a familiar circularity, national character, which determines education and education determines national character (Kelly, et al, 1982). Yet, the question does not seem to be answered easily as to where to break in to this perplexing circle.

The following are weaknesses of comparative education in general. **Firstly**, there is the danger of making a case, when the advocates of change rely heavily on reports of a successful programme abroad (Noah & Eckstein, 1998). Even if the original report is a balanced account, it can be superseded by exaggerated and distorted reports of what has been going on in a relatively few examples. The authentic use of comparative study resides not in the propagation of foreign practices, but in a careful analysis of the conditions under which certain foreign practices deliver desirable results, followed by a consideration of ways to adapt those practices to conditions found at home (Noah & Eckstein, 1998, p63).

Secondly, there is the possibility of misinterpreting the results due to carelessness, ignorance or a certain intention (Noah & Eckstein, 1998). Behavioural and social sciences and historical and philosophical inquiry tend to require tentativeness in advancing conclusions. Sometimes explanatory models are not overly strong, data is often defective and criteria for confidence in making inferences are subject to dispute. In order to strengthen the explanatory powers of comparative education, various efforts have been made to increase data and improve techniques in social science research. According to Noah & Eckstein (1998), these trends have been accelerated and the empirical orientation of the social sciences has begun to reshape comparative education. In contemporary cross-national study in education, this is founded upon the twin bases of vastly increased data and improved techniques in social science research (Kyriakides and Charalambous, 2005).

Finally, one of the most difficult problems of comparative education is ethnocentrism; which is the fault of looking at the world from the point of view of the observer's own culture and values (Noah & Eckstein 1998). It is said that ethnocentrism has the potential for bedevilling comparative education at every stage from choice of topic to study, through choice of procedures to apply and to judgement concerning the meaning of the results of inquiry (Noah & Eckstein 1998).

This study includes a comparative research with a qualitative approach rather than quantitative. The research explores what is taught and assesses scientific enquiry and how teachers teach scientific enquiry in England and Korea. As a researcher, I have had experience in teaching and learning in both countries. This can give the researcher a deeper understanding of the societies and their education. In terms of the content and the context of this research, examinations and curricula have been known as a typical subject in comparative education because they can reach into many corners of a country's context by increasing attention given to the various roles and forms of national examinations (Little, 1990). It may be necessary to consider the content and context of this research in order to address the many social and educational problems that beset societies and to do a careful analysis of the conditions under which, certain results and practices are needed to give explanations. In addition, this research is not to examine attainment targets or achievements but to exploring the area of theory and practice in assessment. Instead, the TIMSS results already affect curricular revision and policy making in both countries (Fensham, 2000). Yet, there seems to be a limitation in giving a strong explanation of how to improve and to implement scientific enquiry in classrooms.

Apparently, comparative study has potential and is the most desirable way of approach to understanding education. As Arnove, et al, (1982, p4) argue, intelligent and cautious comparison may still be the best analytic tool to make generalisations about social or educational reality. This is because that comparison assists in discovering that which is common and that which is unique to any society. Then, only when one knows what is unique on a comparative scale can one begin to ask significant questions about causal relationships within a country.

However, there is a danger of misuse, and also misinterpretation of the results and ethnocentrism of researchers (Noah & Eckstein 1998). Partly, in response to these possibilities, comparative study came to rely more and more upon qualitative methods (Noah & Eckstein, 1998, Kim Y C & Cho J S, 2005). At the same time, the researchers are required to be more objective and to have depth of understanding of the complex and dynamic relationships between the societies and education. As Noah & Eckstein (1998) point out, the ultimate aim of comparative approach is to test how well the research can be used in the most desirable way.

There is a need to consider the best way to do this research in order to maximise strength and minimise weaknesses. The following section describes the research design, which attempts to do this.

3-3 Research design

As mentioned above, this study will explore the *facts* and *relationships* in teaching the national curricula in both countries, as well as discovering teachers' perceptions about how they teach and assess.

3-3-1 Theory-practice triangulation as a framework

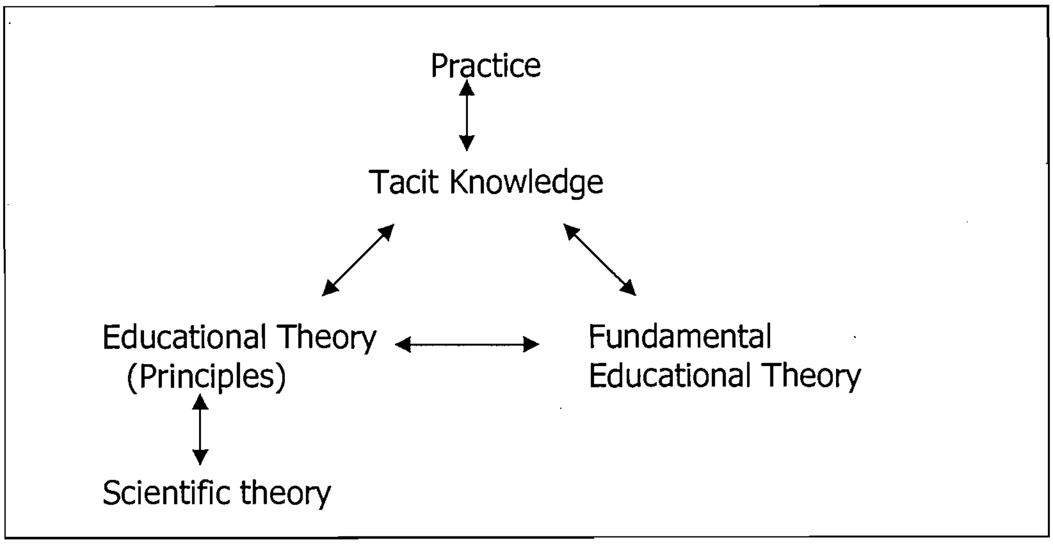
' *Theory-practice triangulation* ' can be employed because it is useful for exploring the relationships between theory and practice in educational research (Grenfell, 1998). Although educational research employs scientific methods in order to collect the data in a more objective, reliable and valid manner, scientific theory is not completely appropriate as regards educational research (Hirst, 1966). Hirst (1966) argues that scientific theory may tell you how to mend your car, but it could not tell you how to teach the perfect lesson. This is simply because the human world is not like the physical world (Hirst, 1966, p49). Instead, Hirst (1966) claims that educational theory acts as an intermediary between scientific theory and practice.

Later on, Vandenburg criticizes Hirst for not providing '*criteria of coherence to unify the educational principles*' for the selection of resources from sociology, psychology, history and philosophy. Vandenberg attempts to build a more rigorous view of educational theory out of a 'correction' to Hirst's claim by positioning these terms on a triangular structure in order to make their relationship explicit (Grenfell, 1998). According to Grenfell (1998), this triangulation can be applied to educational research, it being implicated in many concrete and uncontrolled contexts to which only non-scientific factors are pertinent. Moreover, it can also be applied in order to explore the relationships between theory and practice in the classroom, as outlined below (Grenfell, 1998):

Hirst's scheme remains essentially one of applied science: that is, empirical data worked on through the human sciences is claimed to provide the basic rationale for what to do with pupils in the classroom in that in their claims to general applicability, they necessarily ignore many of the practical, context dependent particularities of classroom teaching itself (Grenfell, 1998, p19).

Figure 2 shows the triangulation diagram, based on a discussion by Vandenburg (1998, Grenfell, p19)

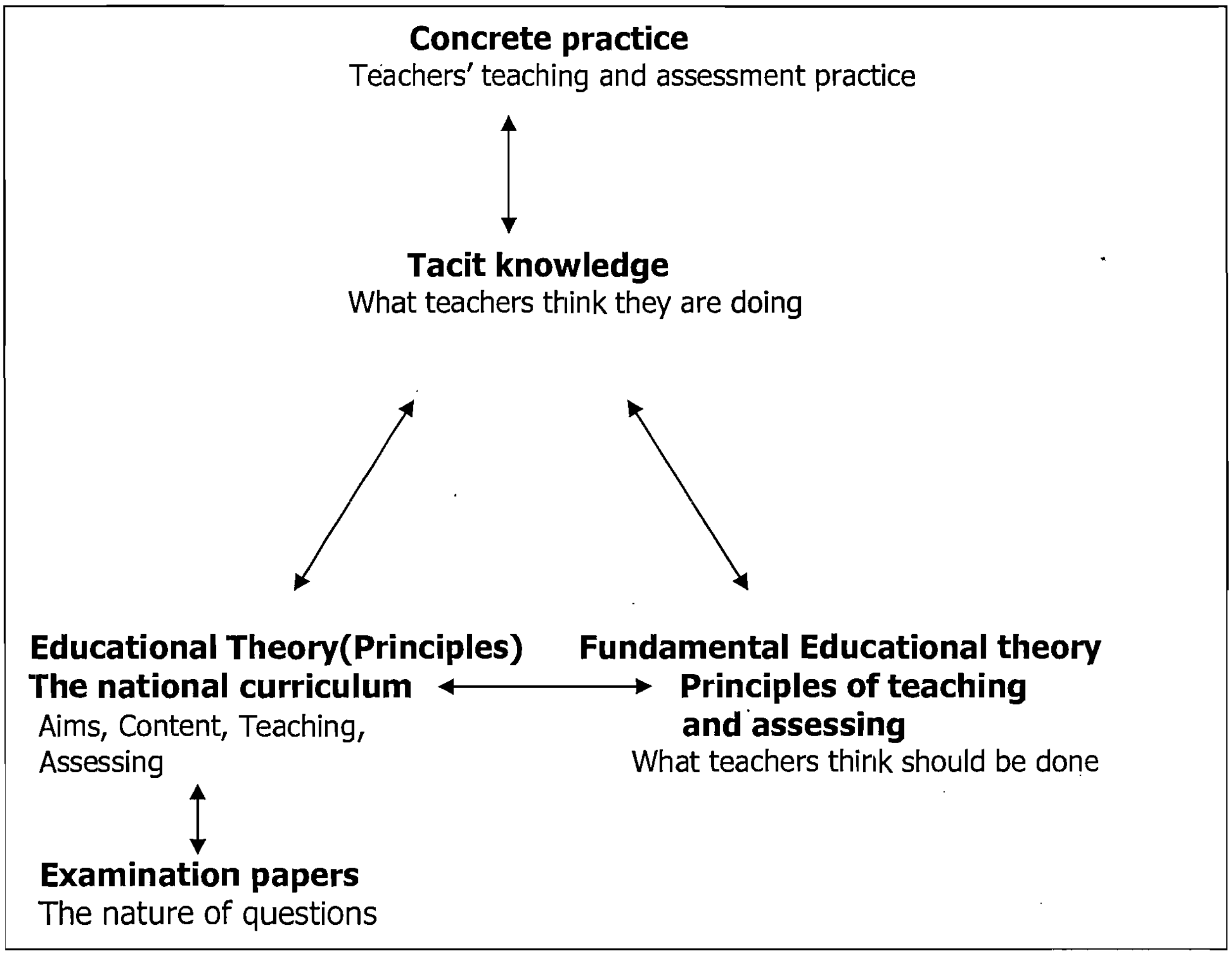
Figure 2 Theory-practice triangulation (Grenfell, 1995)



This theory-practice triangulation may be illustrated as any one individual's relationship to theory and practice in a particular pedagogic context.

According to Grenfell's explanations (1995), this scheme attempts to ground educational theory in a more actual concrete practice. It is said that '*concrete practice'* is the current classroom teaching. It may involve planning and production of lessons and resources. As a practitioner, a teacher's understanding of education is developed through the concrete experience of classroom practice (Grenfell, 1995). This understanding may be called *'Tacit knowledge'* (Polanyi and Prosch 1975, p30, quoted in Grenfell, 1995). This is 'unconscious' implicit horse sense or know-how, which can never be fully articulated (Grenfell, 1998, p19). In Vandenberg's terms, *Fundamental Educational Theory* refers to when practitioners' tacit knowledge is rigorously explicated. Thus, it is a partial articulation of this tacit knowledge (Grenfell, 1998). It also may include explicit beliefs, routines and motives in shaping practice. The term *Educational theory (principles)* indicates a formal expression of knowledge that is organized for determining some practical activity (Hirst, 1966, Grenfell, 1998). Finally, *Human Science (Scientific theory)* relates to educational theory by providing it with research evidence and scientific theory to justify such generalised principles. Such knowledge can be seen as an end in itself, obtained by specialist researchers and writers who have no necessity to develop empirical truth (Grenfell, 1998). Based on the above illustration, this research may be applied to the following figure 3

Figure 3 The research structure based on Theory-practice triangulation



This diagram shows the whole picture of this research flow. In order to explore the research question ***'What is the impact of assessment in scientific enquiry on the perception of teaching science at age 14 comparison between England and Korea?'*** this research will be two-dimensional.

'Educational theory (principles)' will be analysed indicating what is taught in science in the classroom according to the national curricula, KS3 tests and

HE examinations. TIMSS-2003 questions will be considered as an indicator in order to make a comparison relevant as shown in Figure 4-1.

Figure 4 The process of documentary analysis

The national curricula		**Examination papers**
Aims, Content, Teaching, Assessing	←→	The nature of tests, The nature of questions

The analysis of the national curricula will be the primary task. Firstly, the elements of scientific enquiry cannot be independent, but instead be integrated into the curriculum content with other subject matters, for which the analysis of the whole national curricula in terms of aims, content, teaching and assessment is necessary. Secondly, the national curricula are closely related to assessment content, types and purposes. Based on the curricula analysis, analyses of examination papers will be carried out in depth. Subsequently, a comparison will be made in discovering commonalities and differences, including the level of reflections between the national curricular aims, content as well as assessment content. As mentioned above, this documentary analysis aims to discover the answer to the first sub-question, namely '*what teachers are expected to teach as regards to scientific enquiry in the national curricula in England and Korea*'.

The other dimension of this research as shown in figure 4-2, is to survey teachers' perceptions of the nature of science and scientific enquiry as well as perceptions and opinions of how teachers teach and assess scientific enquiry. According to the Vandenburg theory-practice triangulation, this area can be called '*fundamental educational theory*', closely linked to '*tacit knowledge*' in which teachers' explicit beliefs, routines and motives are included in shaping their practices, as shown in figure 5 (Grenfell, 1998). Thus, it includes factors, which may affect how teachers plan their teaching methods, how teachers interpret the national curricula and how they apply their pedagogy to their teaching. It also includes teachers' perceptions and opinions of their teaching and how they assess science and scientific enquiry.

Figure 5 The process of survey

Teachers' perceptions of *NOS and scientific enquiry	←→	Teachers' perceptions of how to teach and assess scientific enquiry	←→	Teachers' tacit Knowledge

*NOS: nature of science

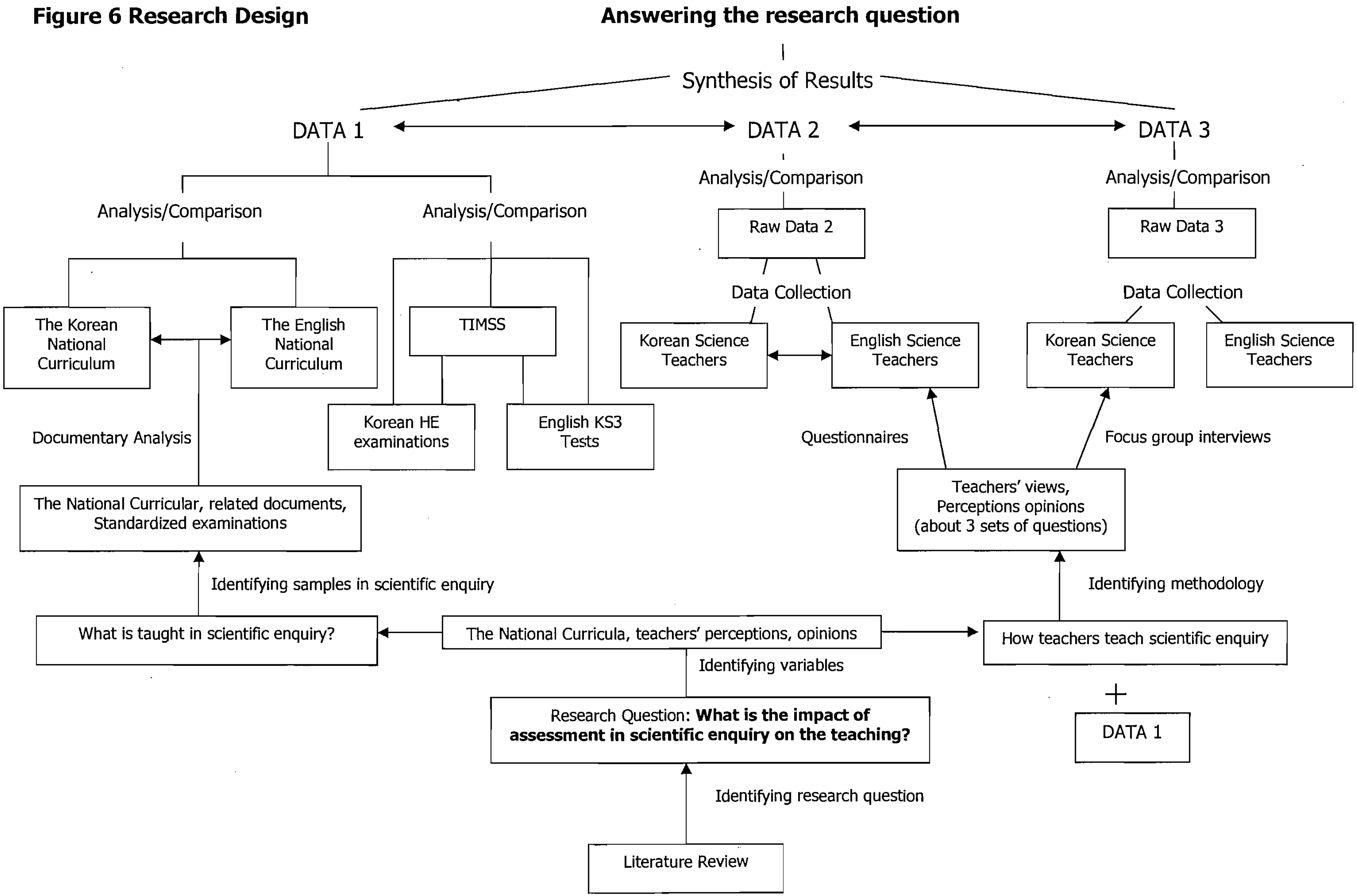
As shown in figure 3, the *concrete practice* is partly constituted by *tacit knowledge* articulated in *fundamental educational theory* and generalised in order to eventually form *justifying educational principles*. Thus, the *concrete practice* refers to teachers' current teaching practice in the classrooms, which can be identified by classroom observations. However, *the concrete practice* will not be included in this research because the main research focus is to discover teachers' views, perceptions and opinions concerning their teaching in the classrooms. . Observation of classroom practice is outside the scope of this study.

This teachers' survey may not show clear distinctions between teachers' views, perceptions and opinions. For example, as other research shows (Bell, et al, 2000; Shwartz and Lederman, 2002) there may not be clear-cut distinctions such as the relationship between teachers' views and their perceptions as well as between teachers' perceptions and their teaching practice in the classrooms. Thus, this survey may need cautious interpretations by taking into account each educational context and the literature review.

With the results of the two dimensions of research, a comparison between England and Korea will be made in order to find out answers to the research question. The inferences of this international comparative research in the light of the contemporary view of science will also be included. Moreover, the implications for the quality of science education will be based on the results of the two areas of research and the literature review.

To sum up, the theory-practice triangulation as represented in Figure 3, is a useful conceptual framework for this research. The following Figure 6 shows (p55) research design as a whole, based on Vandenburg's triangulation.

Figure 6 Research Design



3-3-2 Research design

As shown in figure 5, the research question has been identified through literature review. Accordingly, important variables have been identified such as the national curricula, and assessment as well as teachers' perceptions and opinions.

Thus, two sub-questions have been developed in order to explore the research question. The first sub-question is what is taught in scientific enquiry and is explored by a twofold documentary analysis: one is the national curricula related documents and the other is examination papers from both countries along with TIMSS-2003 questions. Through analysis and comparison, **data 1** is obtained. The second sub-question is how the teachers teach scientific enquiry. In order to explore the second sub-question, survey research methodology is employed. This survey research is also twofold: one is by using questionnaires and the other is by using focus group interviews.

Based on Data 1 from the documentary analysis, a questionnaire is developed. In turn, **raw data 2** is collected through questionnaires from two different groups of teachers and **data 2** is obtained by making analysis and comparison of the results of **raw data 2**. Based on section D in the questionnaire, the structured interview questions are developed. **Raw data 3** is collected from the focus group interviews. Then, **data 3** is obtained by analysing and making a comparison **the raw data 3**. Finally data 1, data 2 and data 3 are synthesised and discussed. Then the conclusion is drawn for answering the research question.

The following section will address details in collecting data including procedures used and the nature of main methods employed in this study. These are principally documentary analysis and survey research by using questionnaires and focus group interviews. Thus, the section describes the nature of each method including strengths and weaknesses in its application for this study.

3-4 Procedures used in collecting data

It is said that the obtained information concerning people, settings, objects and procedures is called 'data' (Charles, 1988). It can be recorded in verbal, or numerical form (Charles, 1988). Data are obtained from primary sources and secondary sources, which is from previous investigations or literature.

In this study, data are collected from two different sources: one from the documentary analysis of the national curricula and achievement tests from England and Korea and the other from survey research for science teachers in both countries. Considering the nature of this research, documentary analysis is suitable for acquiring data from valid and reliable sources concerning what is taught and assessed. Nowadays, the examination content can provide critical information because the end of KS3 tests and

HE examinations have become more powerfully determinant for teachers' teaching practice since those tests are external summative assessments.
In the respect of discovering teachers' perceptions about how they teach and assess scientific enquiry, survey method is suitable for this. The survey method is particularly useful on 'gathering factual data, verbatim statements about motives, intentions and satisfactions and in tracing out the interconnections so as to offer a possible explanation of the data' (Ruddock, 1981, p47). Data from the two different sources enable to give explanations to the research question.

Prior to survey research, it is necessary to carry out documentary analysis concerning what is taught and assess scientific enquiry in the national curricula and examination papers from both England and Korea. This may help to specify questions for the survey. The following section addresses the nature of documentary analysis including strengths and weaknesses as well as possible ways to complement its limitation for this study.

3-4-1 Documentary analysis

Analysis involves the breaking down of entities into constituent parts in order to determine their composition, how they are organized, and how they function. Many sources can be accessed through analysis, but this procedure is especially useful in obtaining data about objects, relics, documents and procedures (Charles, 1988). The documentary analysis may use a wide variety of documents and record such as archival record, and private records as a source of data (Cohen, et al, 2000). It is said that the methods of analysis are similar to those used by historians and the activity may be classified as descriptive research for problem identification, hypothesis, formulation, sampling, and systematic observation of variable relationships (Best, 1981). Generally, documentary analysis aims to produce valuable information to describe specific conditions and practices that exist in schools and society (Dalen, 1962). It can spot the trends and disclose differences in the practices of various areas, states or countries as well as evaluating the relationships of stated objectives and what is being taught (Dalen, 1962). Most of all, it is easy to access the information, often at low cost (Cohen, et al, 2000). As Mertens (1998) argued,

'The researcher can not be in all places at all times, therefore, documents and records give the researcher access to information that would otherwise be unavailable' (Mertens, 1998, p324).

However, the documentary analysis has certain limitations. It tends to be rather superficial and mechanical. It can describe what the situation or practice is but it cannot show the reasons why (Best, 1981). For example, an analysis of examination papers may indicate what difficulties pupils encounter but does not reveal why they made the errors. It is also said that documentary analysis can easily draw faulty conclusions from the data. Many documents used in research were not originally intended for research purposes. The various goals and purposes for which documents are written can bias them in various ways (Best, 1981). Therefore, it can be important to select authentic and valid document in order to avoid drawing faulty conclusions. At the same time, the distinction between records and documents is also important in that the use of extant materials must always be tempered with an understanding of the time, context, and intended use for which the materials were originally created (Mertens, 1998).

In this study, official documentations and their counterparts are used mainly. Then research reports, academic literature, textbooks and their counterpart are used in order to validate data, as well as interpret the data in appropriate objective ways. More details about the sample documentations used will be described on chapters 4 and 5. In practice, the documentary analysis is twofold: one is to analyse the national science curricula and the other is to analysis examination papers shown in detail at chapter 4 and chapter 5. This study will focus on the Key stage 3 science curriculum, and the end of key stage 3 tests which are relevant to the science curriculum for middle schools and the examinations taken during year 9 in Korea. For analysing examination questions, the frameworks of Bloom's taxonomy and Kopfer's specifications are to be used (Osborne and Ratcliffe, 2000). These are useful devices representing the nature of examination questions. Details will be detailed in chapter 5. Some findings from analysing the national curricula and from examination papers can overlap or be complimenting for each other.

Therefore, the first national curricula analysis consists of three sets of comparisons:

1. Content of the National Curricula
2. Teaching and learning,
3. Assessment.

The second assessment analysis also consists of three sets of comparisons

1. General findings,
2. Bloom's taxonomy,
3. Klopfer's classifications.

3-4-2 Questioning

The second subset of questions relates to teachers' perceptions. Thus, the questioning method is employed. According to Ruddock (1981), this questioning method involves direct questions to participants or informants. It uses both **surveys** and **personal interviews**, which can be carried out though correspondence, telephone contact or personal contact (Ruddock, 1981).

3-4-2-1 Survey

The survey method has been essential for fact-finding and is the main instrument for measurement (Charles, 1988). It has also been known as a useful instrument for establishing relations between different processes in education, and opening up for further questions (Charles, 1988). This is useful to determine such things as opinions about education, attitudes toward the school system, home reading habits, and teachers' perceptions of their workloads. Surveys typically make use of questionnaires whose formats and contents are carefully prepared and refined before final use (Ruddock, 1981).

Thus, a survey is a form of planned data collection for the purpose of description or prediction as a guide to action or for the purpose of analysing the relationships between certain variables (Oppenheim, 1966). As Wellington mentioned, a survey research most commonly uses a questionnaire, to give a 'wide picture' or 'an overview' by obtaining 'rapid data' (Wellington, 1998). Survey research is also known as qualitative in nature, such as people's views and perceptions of an issue, through using open-ended questions. Thus, the data can contribute to the development of a theory as much as interviews or observational data (Wellington, 1998).

Therefore, the qualitative survey research methods are to be used for this research, exploring the sub-research question 'How teachers perceive that they teach and assess scientific enquiry including teachers' perceptions about the nature of science and scientific enquiry and opinions about the sample questions. This is to be done by means of a questionnaire and focus group interviews. In practice, a questionnaire seems to be a suitable way of collecting data in this instance because this research will explore teachers' perceptions and opinions. As Wellington argues (1998), data collected by questionnaires may even be richer and perhaps more truthful than data collected in a face-to-face interview. In addition, the respondents may be more articulate in writing or perhaps more willing to divulge views especially if anonymity is assured. Indeed, there must be potential with a suitably designed questionnaire for allowing free, honest and articulate expression and this is valuable.

However, survey research by using questionnaires has disadvantages. As Wellington (1996) points out, survey research can provide answers to the questions about what, where, when and how, but often, does not find out why (Wellington, 1996). Thus, it can easily be superficial and may not be able to give an answer about reasons. In addition, if the design and planning of the survey is insufficient, the weaknesses in the design are frequently not realised until the results have to be interpreted (Oppenheim, 1966). So, the results could lead to defective conclusions based on faulty inferences from insufficient evidence wrongly assembled and misguidedly collected (Oppenheim, 1966). Moreover, the survey research may find that the great interest lies in the facts about what people are thinking and saying rather than the facts of objective circumstances (Ruddock, 1981). However, one can never assume that what people say is true in any sense, even as an expression of what they are thinking. What they say about themselves and others is likely to have a measure of truth, but the relationship will always be problematic (Ruddock, 1981).

In order to avoid any of these, two attempts are applied. Firstly, the questionnaire needs to be incisive to be able to collect as sound as possible by several times piloting. Secondly, focus group interviews as a different method for the survey is employed based on the questionnaire part D to support and complement the findings from the questionnaire.

In practice, several schemes of pilot research were carried out during July 2004, March 2005 and April 2005 in order to improve the quality of survey instruments. As mentioned by Oppenheim (1966), if the design and planning of the survey is insufficient, the weaknesses in the design are frequently not realised until the results have to be interpreted (Oppenheim, 1966). In addition, the research area tends to be complex and relatively new for teachers as shown in chapter 2. Consequently, the wording of the questionnaire and the type of questions used are taken into account in developing the questionnaire.

Following this pilot research, the questionnaire was revised accordingly. Firstly, this pilot research focused on whether the content of the questionnaire is intimately related to the general plan or design of the survey in terms of wording and order of the questions. Secondly, the pilot research will suggest whether the result of the questionnaire is satisfactory in answering the research question in relation to the results of the documentary analysis of the examination papers. Finally, although the questionnaire is rather long with descriptive questions, it is considered to be the best option in finding an answer to the research question.

However, the method of using the questionnaire seems insufficient for obtaining robust information. Particularly, it is difficult in asking teachers of their opinions about the sample questions, which have been selected from each test paper. So, an interviewing method for focus groups is employed in order to get a higher quality of information from each group of teachers.

3-4-2-2 Focus group discussion

There are many definitions of a focus group in literature. But features like 'organised discussion' (KitZinger, 1995) or 'collective activity' (Powell, et al, 1996) social events (Goss & Leinbach, 1996) and interaction (Kitzinger, 1995) identify the contribution that focus groups make to social research.

Powell, et al (1996) define a focus group as

a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research. (Powel, et al, 1996, p499)

Therefore, focus group research involves organised discussion with a selected group of individuals to gain information about their views and experiences of a topic. It is known that focus interviewing is particularly suited for obtaining several perspectives about the same topic as well as being beneficial in obtaining people's shared understandings of everyday life (Powell, et al, 1996).

In comparison to other methods, focus group research has benefits. **Firstly**, it draws upon respondents' attitudes, feelings, beliefs, experiences and reactions in such a way as would not be feasible using other methods, for example observation, one-to-one interviewing, or questionnaire surveys (Morgan, 1988). These attitudes, feelings and beliefs may be partially independent of a group or its social setting, but are more likely to be revealed via the social gathering and the interaction which being in a focus group entails (Morgan, 1988). Compared to individual interviews, which aim to obtain individual attitudes, beliefs and feelings, focus groups elicit a multiplicity of views and emotional processes within a group context.

Secondly, compared to observation, a focus group enables a researcher to gain a larger amount of information in a shorter period of time. Observational methods tend to depend on waiting for things to happen, whereas focus group research can be guided by a structured interview by the researcher (Morgan & Kreuger 1993). In this sense focus groups are not natural but organised events.

According to Morgan (1988), focus group interviewing is a form of group interviewing but there is a difference between the two. Group interviewing involves interviewing a number of people at the same time, the emphasis being on questions and responses between the researcher and participants. On the other hand, focus groups rely on interaction within the group based on topics that are supplied by the researcher (Morgan, 1988, p12).

Kitzinger (1995) argues that interaction is the crucial feature of focus groups because the interaction between participants highlights their view of the world, the language they use about an issue and their values and beliefs about a situation. Interaction also enables participants to ask questions of each other, as well as to re-evaluate and reconsider their own understandings of their specific experiences. As a result, the gap between what people say and what they do can be better understood.

However, problems arise when attempting to identify the individual view from the group view at first. According to Morgan (1988), the focus group researcher has less control over the data produced than in one-to-one interviewing. Participants are to allow each other to discuss together, ask questions and express doubts and opinions, while having very little control over the interaction other than generally keeping participants focused on the topic. By its nature, focus group research is open-ended and cannot be entirely predetermined. In addition, it could not be assumed that the individuals in a focus group are expressing their own definitive individual view. They are speaking in a specific context, within a specific culture, and so sometimes it may be difficult to clearly identify an individual message (Morgan, 1988).

Secondly, there is a difficulty in the practical arrangements for conducting focus groups (Kitzinger, 1995). It may not be easy to get a representative sample in practice. It is said that organising focus group interviews usually requires more planning than other types of interviewing, as getting people to group gatherings can be difficult and setting up appropriate venues with adequate recording facilities requires a lot of time (Kitzinger, 1995).

Thirdly, the focus group research has limitations in terms of their ability to generalise findings to a whole population, mainly because of the likelihood that the participants will not be representative samples (Kitzinger, 1995). Therefore, it can only be used as a complement to other methods, especially for triangulation and validity checking (Morgan, 1988).

Finally, the recommended number of people per group is usually six to ten but some researchers have used up to fifteen people (Goss & Leinbach 1996) or as few as four (Kitzinger 1995). Numbers of groups vary, some studies using only one meeting with each of several focus groups, others meeting the same group several times. Focus group sessions usually last from one to two hours (Kitzinger 1995).

Therefore, in this research, focus group research is to be used as a complementary means and used for the purpose of the triangulation of the survey research. The questions for the focus group research are related to how participants teach scientific enquiry in terms of their perceptions and practices, how they find out the selected questions from each test paper and what they think concerning ways in which teaching scientific enquiry can be improved.

To sum up, the purpose of this survey research using a questionnaire and focus group interview, is to discuss and discover teachers' views about the nature of science and scientific enquiry and their opinions about teaching and assessment within the area of scientific enquiry, including how teachers overcome the difficulties inherent within the element of the nature of science and of scientific enquiry as a way of teaching science. In addition, the research will include teachers' views of sample questions, which have been selected from the test papers.

3-5 Data analysis

This refers to the process of transforming 'raw' data into variables that can be analysed to produce the information found in the results (Swift, 1996).

The data, on which the research question is based, is not ' found in the world' but is constructed by researchers (Swift, 1996). In other words, knowledge is constructed because it all depends not just on perception but on interpretation of what we experience (Swift, 1996). Therefore, the main point of data analysis is how to get data into the best shape for analysis in order to answer the research questions.

This research will be collected threefold: documentary analysis of the National Curricula and examination papers using assessment framework, survey research for teachers in both groups and focus group research in both groups.

The analysis of examination papers will be carried out by numerical data analysis using spread-sheet programme with general analysis of the examination papers. The questionnaires for science teachers are to be analysed quantitatively. Finally, the focus group research will be Tran scripted and coded for analysing qualitatively by using appropriate computer programmes.

3-6 Data categorisation and comparison

After the data is collected and analysed accordingly, a comparison will be made in order to find out the answers to the research question. The first step is to find out commonalities and differences. Then, inferences as an international comparative study and implications for the quality of education will be added in the light of the contemporary views about science with literature review. This process will involve various interpretations of the data acquired from the research in order to find out appropriate explanations for the results. Thus, it may be useful to take account of section 3-2 comparative education which referred to the strengths and weaknesses of comparative education. This stage may involve a danger of misinterpretation and ethnocentrism while the data collected and analysed is being interpreted. Thus, as mentioned at 3-2, the interpretation of the data should be to maximise strengths and minimise weaknesses. The following section describes the quality of the research, including how to maximise strength and minimise weaknesses. Then ethical issues will be added for consideration while the research is being carried out.

3-7 Quality required in research data

Research conclusions cannot be taken seriously if there is any question about the quality of the data from which the conclusions are drawn. Researchers, therefore, scrutinize data to make sure it is authentic, believable, valid and reliable.

In the analysis of curricula, the authenticity and believability of the documents are important. It may also be important to use cross-references when referring to similar topics in different literature in order to reduce interpretational errors. Updated references as a first source may also be important because the national curriculum and related policies can be revised from time to time.

In the analysis of examination papers, objectivity and fairness are crucial because the examination papers have different purposes, types, structures and numbers in one given test paper. As the questions are analysed and categorized, it is important to keep using the same measurement. The detailed explanations are in each chapter.

In the analysis of data from questionnaires and focus group interviews, these processes are mainly analysed qualitatively. Thus, it is crucial for the researcher to take into account objectivity and fairness. Then, it also needs to consider factors, which can affect interpretations of the data. As the data is compared with the results of documentary analysis, the data may be interpreted accurately without being biased.

3-8 Ethical issues

Recent concerns about the quality of data involve ethical issues, as the data is manipulated for the purpose of research. A study population may be adversely affected by some of the questions directly or indirectly.

Consideration must be given to anonymity. In this research, individual teachers' names, schools and institutions are not revealed. In most cases this is easily achieved by the use of fictional names and the exclusion of information that would enable institutions and or individuals to be identified (Brown and Dowling, 1998). Another consideration must be given to the possible use of information in a way that directly or indirectly adversely affects respondents, which of course is unethical. Thus, it is necessary to consider whether information can be used to adversely affect the study population and if so, how the study population can be protected (Brown and Dowling, 1998). Thus, in this research, all the data collected from the teachers by completing questionnaires and participating in focus group discussions are dealt with confidentially and anonymously. Teachers are to be told how the given information is to be used and to be informed that the information is only being used for academic purposes.

Finally, there is a danger of being biased, particularly in a comparative study. It is said that bias is different from subjectivity, which is related to a person's educational background, training and competence in research and philosophical perspective (Brown and Dowling, 1998). Bias is rather a deliberate attempt either to hide what the research reveals or highlight something disproportionately to its true existence. Bias on the part of the searcher is unethical (Brown and Dowling, 1998).

This chapter has included the research structure and main research methodology, which has been employed in order to collect data. In addition, it includes advantages and disadvantages of each methodology and describes the quality of data and process of data analysis.

The following chapter is a documentary analysis of the national curricula in respect of goals, content, teaching and assessing.

Chapter 4 Documentary analysis in the National Curricula

This chapter is to explore the sub-question mentioned at 3-1: *'What is taught in scientific enquiry in the national curricula in England and Korea?'.* Prior to carrying out a documentary analysis of the national curricula, it may be necessary to consider the backgrounds of education in order to understand and interpret data from the results through analysing the sample documents. This chapter will, then, include similarities and differences in the aims, content, teaching and learning and assessment in the national curricula between two countries through documentary analysis. Finally, it will discuss the emerged commonalities and differences in the results in the light of the contemporary view of science and quality of education.

4-1 Background

This section includes a brief history of the national curricula, a brief structure of education and its distinctive characteristics and outlines the new direction in which the national curricula are heading.

4-1-1 Korea

The Korean National Curriculum covering the entire range of schooling from primary school (6-11yrs), middle school (12-14 yrs) through to high school (15-17yrs) has been implemented since 1948 (KEDI, 1988).

Traditionally, the MOE (Ministry of Education) has developed the National Curriculum specifying not only school curricula, but also the number of required school days and the time to be allotted at each school level, in accordance with which the hours of instruction and other specific management details relating to each individual subject are further determined (Han J H, 1995).

According to the time allotment standards, science in middle schools is classified as a required subject so that children in yr7 are supposed to have 3 lessons a week and pupils in yrs 8 and 9 should have 4 lessons a week (MOE, 2001b). Those lessons refer to minimum allotted times and a lesson lasts 45 minutes.

One notable feature of the national curriculum in Korea is that it has an inextricably close-knit relationship with textbooks (Han J H, 1995). The textbooks have developed and been revised on the basis of the National Curriculum to provide detailed guidance on how to implement the National Curriculum into daily classroom teaching (Han J H, 1995). As a result of this, the teachers' guide to a textbook not only identifies the National Curriculum content and teaching methods but also the level of achievement to be reached by their pupils (Han J H 1995).

Science textbooks combine physics, biology, chemistry and earth science for middle schools and similarly for high schools up until year10, but science textbooks are divided into 4 subjects for yrs 11 and 12 (MOE, 2001a). As a consequence, Korean schools are regarded as having become standardised and unified in terms of curriculum. Kim J C describes this as follows:

There seems to be only one school in Korea for all schools have the same curriculum content and the same teaching methods (Kim J C, 1998, p20).

There are 4 school-based assessments in Korean middle schools. These scores are taken into consideration when applying for high school. High schools (15-17) in Korea are basically decided on a selective basis. The majority of children choose academic high schools, which prepare them for entry into colleges and universities. Children who have a lower achievement are not encouraged to go to academic high schools but to go to commercial or industrial high schools (Kim J C, 1998). Special purpose high schools for those with outstanding achievements in areas such as science or art arrange their own screening process (Han J H, 1995). In major cities, where an 'equalization policy' (KEDI, 2001) is applied, there is no entrance examination for high schools upon graduation from middle schools. In non-equalisation policy areas, qualifying examinations are administered by individual high schools, taking into account the school based examination results (Han J H, 1995).

4-1-2 England

The national curriculum in England was implemented in schools in 1988, much later than in Korea. It was defined as 'the minimum educational entitlement' for pupils of compulsory school age (QCA, 2003a). It now covers Key Stage1 (5-7yrs), Key Stage 2 (7-11yrs), Key Stage 3 (11-14yrs) and Key Stage 4 (14-16yrs).

It is said that the national curriculum does not constitute the whole curriculum for schools. Rather, schools have discretion in developing the whole curriculum to reflect their particular needs and circumstances (QCA, 2003a). It is also mentioned that the national curriculum applies to all pupils aged 5-16 in maintained schools but it does not apply to children in independent schools, although those schools may choose to follow it (QCA, 2003a). The National curriculum encompasses common requirements, programmes of study and attainment targets (QCA, 2003a).

Basically, teachers refer to the national curriculum as a guide for their teaching, although individual schools develop their own school curriculum. Therefore, individual schools seem to have more autonomy than Korean schools in terms of making decisions regarding the content of the school curriculum and allotting time for lessons and subject-related activities (KEDI, 2001). Although there is slight variation between individual schools, science lessons are generally 3 hours per week for those children who are supposed to sit the end of Key Stage 3 test (Keys, et al, 2000). Therefore, the allotted time for sciences is more or less similar to that of Korea, which is 3 hours a week for yrs 8 and 9 (MOE, 2001b).

The national curriculum tests in England are based on criterion reference system indicating the level of achievement. For example, the majority of children at the end of Key stage 3 are expected to reach level 6 out of a possible range of 4-7 in science. It is said that the QCA (Qualifications and Curriculum Authority) provides optional tasks to support teacher assessment of pupils working above or below the level of the tests (QCA, 2003b). In addition, there are two overlapping types of examination papers at the end of Key Stage 3, those relating to levels 3-6 and those for levels 5-7 so that the examination can be chosen in accordance with the children's abilities (QCA, 2003b). The Korean examination papers have only one indicating norm referencing in Korea.

However, despite its more recent introduction, it is clear that the national curriculum in England has become more influential in schools over the past 10 years due to the requirements made by it and by the imperatives imposed by more tests (Brooks, 2002). Particularly, in England, schools have been required to set targets for the percentage of pupils achieving more than level 5 in Science, Mathematics and English at the end of Key Stage 3 (Brooks, 2002). It is said that this approach entails performance norms and the setting of individual performances against themselves (Brooks, 2002).

4-1-3 The direction of the national curricula in England and Korea

The implementation of the 'science for all' recommendation in the English science curriculum during the 1990s resulted in the compass of the science content in the national curriculum being extended beyond the traditional conceptual content of physics, chemistry and biology to include earth and space sciences and applications of science and technology, as well as various versions of the nature of science and technology (Fensham, 2000).

At the same time, 'the science for all' movement influenced the revision of the national curriculum in Korea as well (Fensham, 2000). It seemed to be well accepted within the Korean educational situation, which had already recognised the need for change and was concerned about radical educational reform for scientific enquiry, scientific creativity and new values (Kim J C, 1998). The latest revision, called 'the 7th national curriculum', was implemented in middle schools in 2001(MOE, 2001d).

Both England and Korea have similarities in education although they have different historical backgrounds and educational systems. Firstly, students from both countries have achieved much higher marks than other OECD countries in the international comparative studies. The 'Science for all movement' has also influenced the national curricula in both countries.

Secondly, there are some common features within English and Korean schools when children are in primary school and up until Key Stage 3 in secondary school (i.e. primary to middle school) in terms of compulsory education. Thirdly science is regarded as a universal subject, along with mathematics so that many elements overlap in both the Korean and English science curricula.

However the Korean National Curriculum (KNSC) has been developing toward more flexibility and diversity from the rigidly structured curriculum reflected in the 7^{th} national curriculum. By contrast, the English National Curriculum (ENSC) has brought more structure and assessment into secondary education in order to maintain the standard of achievement (Brooks, 2002).

At this point, it seems timely to compare both science curricula objectively in terms of aims, content, teaching & learning and assessment, in order to support further research of curriculum development. Additionally, it may also be necessary to provide information to enable further comparative studies to be carried out as to how high-stake examinations affect teachers' teaching in the area of scientific enquiry.

4- 2 Research Methodology

This part of the study is to carry out a documentary analysis looking into the National Science Curricula, textbooks, examination papers, standard of achievement, schemes of work, other official documents and related research. The focus of this study will also be on the Key stage 3 science curriculum and the end of Key Stage 3 tests relevant to the national science curriculum for middle schools and the examinations taken during year 9 in Korea. Therefore, this study consists of three sets of comparisons.

1. *Content of the National Curricula*
2. *Teaching and learning*
3. *Assessment*

4-2-1 Sampling

In this study, the comparison will focus on the Key stage 3 Science Curriculum (ENSC) and tests at the end of Key stage 3(KS3 test) relevant to the National Science Curriculum (KNSC) for middle schools and the examinations during year 9 in Korea. Due to the differences in the way the content and assessment of the curricula are structured in both countries, it is necessary to look at the entire Key Stage 3 science curriculum in terms of content analysis.

Although the Korean examination papers are not nationally based, most Korean schools are regarded as having tests with a similar content and method of assessment because the schools use authorised textbooks. The high school entrance examination (HE examination) papers are from Kyunggi-Do, which is known as a non-equalised area taking high school entrance examinations, while school based examination papers are from P Middle School in Seoul, which is known as an equalised area, not taking HE examinations. The HE papers are obtained from KICE (Korean Institute of Curriculum and Evaluation) and school based examinations are from the Zocbo company (www.zocbo.com) which sells examination papers commercially. Both school based and high school entrance examination papers are chosen randomly in accordance with the practice of non-equalisation areas and equalisation areas in 2003. Table 4 shows sampling documents and the KS3 examination papers and their counterpart examination papers in Korea.

Table 4 Sampling documents

	English		Korean	
Curriculum content	*Key stage 3 National Strategy *A scheme of work for key stage 3		*Korean National Science curriculum (KNSC)	
Teaching & learning	*Key stage 3 National Strategy *A scheme of work for key stage 3		*Explanation of the 7th National curriculum in Science * Textbooks (Middle school science 1,2,and 3)	
Assessment	*Common requirements, *Attainment targets		*Target achievement, *Standard of assessment	
Examination papers (2003)	Tier 3-6, paper 1	3-6-1	Year9, first mid term	3-1-1
	Tier 3-6, paper 2	3-6-2	Year9 first end term	3-1-2
	Tier 5-7, paper 1	5-7-1	Year9 last mid term	3-2-1
	Tier 5-7, paper 2	5-7-2	Year9 last end term	3-2-2
	Mark scheme		HE examination	4

In order to look into teaching and learning, Key stage 3 National Strategy (DfES, 2002) and a scheme of work for Key Stage 3 (QCA, 2001c) for England and Explanation of the 7th National Curriculum in science (MOE, 2001b) and textbooks (Lee S M, et al, 2000; 2001; 2002) are used. These documents provide detailed descriptions of the national curricula content along with teaching and learning each year. As mentioned in the background section, Korean textbooks provide detailed guidance on how to implement the national curriculum into daily classroom teaching (Han J H, 1995).

Common requirements and target attainments include the national curriculum in England along with the relevant programme of study, a description of each level pupils would reach however, whilst Target achievement and Standard of assessment are separate from the national curriculum in Korea it includes similar content to common requirements and target attainments in England but with suggested examples and assessment instruments ((KICE, 2001).

4-2-2 Limitations of this documentary analysis

There are limitations in making comparisons objectively and directly because both countries have different educational systems and assessment regimes in terms of curriculum structure, types and purposes of assessment, administration and so on. For example, Korean assessments for middle schools are not externally standardised tests but school based tests plus locally administrated tests depending on the area. Although most middle schools in Korea use authorised textbooks, it may still be a limitation for making an objective comparison. Thus, the content of KNSC is re-arranged in a way in which the ENSC is structured in order to find out common or unique areas from the national curricula. In terms of sample examination papers, the Korean examination papers are selected from P middle school (Seoul, state boys school) where 'equalization policy' is applied and HE examination papers from the area where non-equalisation policy is applied. There is a difficulty in making a comparison between KS3 tests and school-based examinations because school based examinations are rather similar to the end of topic tests, which are likely to cover certain topics. Whilst HE examinations comprise a whole range of the middle school curricular content as well as external standardised examinations. So, for the further analysis in chapter 5, it may be necessary to explore both school based examinations and HE examinations in order to make a comparison relevant and to be able to consider generalisation. The marking scheme for KS 3 tests is used as a standard in analysing examination questions. Details are addressed in section 4-3-4.

4-3 Results and analysis

4-3-1 Content of the National Science Curricula

The English National Science Curriculum (ENSC) consists of areas of scientific ideas and scientific enquiry. There are 5 areas of scientific ideas, which include cells, interdependence, particles, forces and energy (QCA, 2001a). The requirements of what pupils should understand, know and be able to do in each area are specified, so the teaching plan and formative assessments should centre on them (QCA, 2001a). Scientific enquiry is regarded as having a central place in science and directly links practical experience with scientific ideas (QCA, 2001a). It is suggested that the principles of scientific enquiry generally link with scientific ideas rather than being left to special 'investigative science' (QCA, 2001a). Scientific enquiry also include in scientific investigations as one of the topics in the Key Stage 3 study programme (QCA, 2001a).

In addition, it is said that the ENSC develops like a spiral structure so that the content of each category is studied in more and more depth each year. Table 5 shows the areas of the programme of study in the ENSC.

Table 5 The ENSC content at KS3 (DfES, 2001)

ENSC	Content
Scientific enquiry	Scientific enquiry
Biology	-Cells -Interdependence
Chemistry	-Particles
Physics	-Energy -Forces

The content of the Korean National Science Curriculum (KNSC) comprises scientific knowledge ('scientific ideas' in the ENSC) and scientific enquiry. The scientific knowledge areas consist of energy, materials, life and the Earth. Then, each area is divided into 4 sub-sections; such as the energy area being divided into force/motion, electricity, waves/sounds and energy as shown in Table 6.

Table 6 The KNSC content at middle school(MOE,2001b)

	Middle areas
Energy	_Force/Motion -Electricity -Waves -Energy
Materials	-The properties of materials -The structures of materials -The changes of materials -The changes of energy
Life	_Diversity of life -Ecology -Continuity of life -Metabolism and Stimulus/Response
Earth	-Circulation of water/Atmosphere -Materials of the Earth -The movement of the Earth -The solar system and our galaxy

The curriculum content in each year 7, 8 and 9 is different because it is determined by the children's ability of conceptual understanding (MOE, 2001c). According to the 7th National curriculum explanation paper, the content for year 7 is designed to include more phenomenon and less conceptual contents, whereas the content for year 8 and year 9 include more conceptual ideas (MOE, 2001a).

Due to the way the curricular content from both countries is structured differently, making a comparison seems to be difficult. Thus, the content of KNSC has been re-organised in the way that the ENSC is structured, such as 'cell' and 'particle' because the KNSC contains far more content areas that can cover all the areas of the ENSC except for scientific enquiry. Table 7 shows the area of scientific ideas in both curricula. Although the latest 7th national curriculum in Korea seems to have similar features to that in

England in terms of greater autonomy being given to individual schools in organising their own school curriculum and less curriculum content than in the previous one, the Korean curriculum content is still more extensive than the English one, while overlapping in most of the science idea areas. In addition, they seem to have a unified school curriculum because the schools use authorised textbooks, as specified by the MOE.

Table 7 The areas of scientific ideas in both curricula

	ENSC	KNSC
Yr 7	Cells Reproduction Environment and feeding relationships Variation and classification Acids and Alkalis Simple chemical reactions Particle model of solids, liquids and gases Solutions Energy resources Electrical circuits Forces and their effects The solar system and beyond	Microscope and cells Digestion and circulation Respiration and excretion Motions of molecules Materials in earth's crust Composition and motions of sea water Force Waves Structure of the Earth The changes of state and energy Particle model of solids, liquids and gases Light
Yr 8	Food and digestion Respiration Microbes and disease Ecological relationships Atoms and elements Compounds and mixtures Rocks and weathering Rock cycle Heating and cooling Magnets and electromagnets Light, Sounds and hearing	Various motions Properties of materials The earth and space Structure and function of plants Stimulus and response History of the earth and its crustal disturbances Electricity Separation of mixtures
Yr9	Fitness and health Inheritance and selection Plants and photosynthesis Reactions of metals and metal compounds Using chemistry Environmental chemistry Energy and electricity Pressure and moments Investigating scientific questions	Reproduction and development Work and energy Composition of materials Water circulation and weather changes Pattern in chemical changes Magnetic field and electrical energy Movement of solar system Inheritance and evolution

In this section, in order to show details of the content of each curriculum, the KNSC has been re-arranged to correspond with 6 categories of the ENSC plus the area of earth science, which the ENSC does not consider separately but as a part of physics.

1. Cells

In this section, the KNCS is more extensive and in depth than its English counterpart, having more detail in terms of structure and function of plants, inheritance, and evolution as shown in Appendix 1. There are many common topics in year 7, such as a simple model for cells, a one cell organism, nutrients, digestion, circulation, respiration and so on.

2. Particles

The amount of content in both curricula seems to be similar in the area of particles. However, the ENSC seems to describe particle theory more as *'phenomenon'* and *'in less conceptual ways'* than in the Korean one (MOE, 2001b). For example, the content of the KNSC contains the gas reaction law, Avogadro's law, and so on, which are taught in a higher year group in English schools. The KNSC contains more abstract forms of knowledge demanding mathematical ability to understand concept such as the relationship between pressure, volume and temperature. The details are shown in Appendix 2.

3. Forces

In the area of forces, both curricula seem to be similar in content. However, the content of the KNCS seems to be rather fragmentary. It also includes more mathematical content such as calculating 'work' and 'efficiency' is shown in Appendix 3.

4.Energy

There are differences in structure between the two curricula at this point, so it may be difficult to compare them directly. This is mainly because the counterpart of energy in the KNSC spreads out into other areas, such as forces, particles, and interdependence. For example, 'electrical energy' is not found in the area of energy but in the forces-electricity section. However, the KNSC still seems to cover the majority of the ENCS under this heading of energy. The details of this area are shown in Appendix 4.

5.Interdependence

In the KNSC, the interdependence area is mainly found in the topic of 'human and environment' in year 9. However, due to an increased emphasis on the environment, the 7th National curriculum began to separate this from the science curriculum, forming a new subject called 'Environment' (MOE, 2001b). As a result of this, the 7th National Science Curriculum does not contain the interdependence area. Instead, the subject of 'Environment' was implemented in 2003, so that it may be necessary to look at the 'human and environment' part in the previous National Curriculum (Kang D H, et al, 2000). The details are shown in Appendix 5.

6. Earth science

The Earth science area is far more prominent in the KNSC compared with the ENSC because it contains far more content in that area. Basically, the KNCS consists of the same proportion of content in this area as in the other areas of science such as life (Biology), energy (Physics) and matter (Chemistry). This area also involves a lot of mathematical content and demands a higher conceptual understanding, such as the brightness and distance of stars and the size of the moon, sun and earth and so on. However, the ENCS puts earth science as either a part of physics or a part of Geography. The details are shown in Appendix 6.

7. Scientific enquiry areas

Although both curricula place great emphasis on their scientific enquiry areas as the aims, they show different applications in the curriculum content as shown below.

England:

..... because it helps pupils to understand how scientific ideas are developed and because the skills and processes of scientific enquiry are useful in many everyday applications. Scientific enquiry provides opportunities for pupils to consider the benefits and developments and in the environment, health care and quality of life (DfES, 2002)

Korea:

....in order to foster scientific literacy for the citizen of the future through scientific enquiry, pupils should be taught scientific concepts enabling them to make everyday applications and to foster enquiry with the ability to investigate natural phenomena and to understand the relationship between science, technology and society(MOE,2001b)

The ENSC describes scientific enquiry as part of a programme of study as well as the method of teaching science (DfES, 2002). The ENSC scrutinise what pupils should be taught each year as a part of a programme of study as shown in Table 8. Like other key areas of science, the elements of scientific enquiry are described such as ideas and evidence, planning, obtaining and presenting evidence, considering evidence and evaluating. In addition, there is a scientific investigation unit in the scheme of work for year 9, which is expected to take 7-12 hours (QCA, 2001b).

On the other hand, the KNSC does not specifically mention scientific enquiry in the curriculum content. Instead, it says that *'scientific enquiry areas are integrated into every science lesson'* even though no practical work or experiments are involved (MOE, 2001b). Thus, the KNSC seems to be putting its emphasis on teaching the science content with enquiry rather than on scientific enquiry itself. In the KNSC, there is no specification of a scientific investigation unit. Instead, pupils are expected to carry out scientific investigation once a year (MOE, 2001a). The details of scientific enquiry in the National Curricula are explained in Chapter 2.

Table 8 is shows the inclusion of scientific enquiry in the ENSC whereas the KNSC does not mention it as a separate content of curriculum, as shown in table 2 in chapter 2.

Table 2 Scientific enquiry in the Korean National Science curriculum (KNSC)

Inquiry	Content
Basic enquiry	Observation, classification, measurement, prediction, reasoning
Integrated enquiry	Finding problems, Setting up hypothesis, Transformation of information, Interpretation of data, Controlling factors, Drawing conclusions, Generalisation
Enquiry activities	Investigation, Discussion, Research, Presentation, Field trips

In the KNSC, scientific enquiry seems to be limited within the national curriculum as a teaching method or ways to enhance understanding of science content. For example, in the 6th national curriculum, the area of scientific enquiry was structured in a way that each section relating to science knowledge was organised according to relevant scientific enquiry activities. For example, 'classification', was integrated into elements, plants and animals. 'Research' was integrated into 'use of energy', 'use of electrical energy' and 'brightness of stars' (Kang D H, et al, 2001). However, in the 7th national curriculum (KNSC) it does not mention scientific enquiry activities. Thus, teachers are required to set up relevant enquiry activities relating to the scientific knowledge in the classrooms.

Table 8 Details of scientific enquiry in the ENSC

Scientific Enquiry		
Year 7	**Year 8**	**Year 9**
*Consider early scientific ideas: – experimental evidence and creative thinking -scientific explanation *Use of scientific knowledge –how ideas and questions can be tested * Identify and control the key factors * Select and use appropriate equipment * Use repeat measurement to reduce error *Present and interpret experimental results drawing conclusions *Evaluate the strength of evidence (in bar charts, graphs)	*Consider some early scientific ideas not matching present-day evidence -new creative thinking -scientific explanation *Identify more than one strategy for investigating questions : -recognise that one enquiry might yield stronger evidence than another *Recognise required resources -information or data *Use a range of first-hand experience, -use secondary sources of information -use ICT to collect, store and present information in a variety of ways including the generating of graphs *Use appropriate range, precision and sampling when collecting data -explain why these and controlled experiments are important *Draw conclusions from their own data -describe how their conclusions are consistent with the evidence obtained using scientific knowledge and understanding to explain them * Consider whether an enquiry could have been improved	*Explain how scientific ideas have changed over time -describe some of the positive and negative effects of scientific and technological developments *Select a suitable strategy for solving problems. -identify strategies appropriate to different questions, including those in which variables cannot be easily controlled *Carry out preliminary work such as trial runs to help refine predictions to suggest improvement to the method *Make sufficient systematic and repeated observations and measurements with precision *Select appropriate methods for communicating qualitative data *Describe patterns in data -use scientific knowledge and understanding to interpret the patterns, make predictions and check reliability * Describe how evidence or the quality of the product supports or does not support a conclusion from their own and other enquiries. * Consider whether an enquiry could have been improved

To sum up, science is a universal subject, taught with similar content and with more or less the same amount of time at the KS3 level in both countries. There are slight differences, however. Primarily the KNSC contains more content knowledge than the ENSC. Secondly, the most prominent areas are scientific enquiry in the ENSC as opposed to earth science in the KNSC. In addition, the KNSC contains more abstract forms of knowledge such as laws, principles, theories and more mathematical content. The following concerns teaching and learning in accordance with the curriculum content.

4-3-2 Teaching and learning

The 7th national curriculum was implemented in the middle school year 7 in Korea in 2001 and in years 8 and 9 in 2002. As a result of this, some middle schools have not yet completed the whole school curriculum but have been following teaching and learning according to the new text books (MOE, 2001d). Therefore, only now will middle schools have been able to pursue the 7th national curriculum at all levels. Although they have been teaching according to the new textbooks it remains to be seen how well the curriculum has been integrated.

As shown in Appendix 1-6, the KNSC contains an extensive coverage of areas of scientific knowledge ('scientific ideas' in the ENSC) and less application of the scientific enquiry area, in spite of the statement '*Every lesson should be a process of enquiry*' in the 7th national curriculum. The KNSC contains greater detail of scientific knowledge and demands a higher conceptual understanding. Consequently, teaching practice may involve a greater emphasis on conceptual understanding rather than on its application. Also lesson time in Korean classrooms only lasts 45 minutes, which many teachers claim is too short in which to do any practical work (MOE, 2002). Another factor is that in Korea, pupils stay in the same classroom for most lessons whilst the teachers move from room to room. As a result of this, practical work and experiments in the laboratory seem to be less apparent than in English schools. Thus, science lessons do not seem much different from lessons in other subjects.

On the other hand, in England, pupils move from classroom to classroom and science lessons normally take place in a laboratory and at least 50% of science lessons involve practical work (Woolnough, 1991). The ENSC develops like a spiral structure so that the content of each category is studied in more and more depth each year. On the other hand, the KNSC is more like a staircase that is structured and determined by pupils' ability in conceptual understanding (MOE, 2001c). Due to the staircase like structure, the KNSC tends to be a rather fragmented structure, for example 'natural phenomena' related topics to lower year groups and higher conceptual topics are allocated to higher year groups (MOE, 2001c). In addition, although individual schools are different, a teacher usually teaches a certain year group within one academic year whereas in England a teacher teaches a range of different year groups. Therefore, this may affect teaching and learning in Korea where a teacher is segregated and isolated from other year groups.

In addition, although the KNSC in Korea mentions the differentiation of groups according to a student's ability, most classes seem to comprise students of varying abilities. Because of this, teachers tend to give some tasks to the more able pupils and different tasks to the less able. These are normally completed during the supplementary lessons, which make up 20% of the allocated lessons (MOE, 2001a). During this allotted time, teachers are encouraged to get the pupils to do scientific enquiry activities (MOE, 2001a).

To sum up, there may be differences between England and Korea in science lessons mainly because of differences in the nature of the curriculum content and in school management. Some aspects are explained further in the teacher survey in chapter 7.

4-3-3 Assessment

For the English national curriculum, year 9 pupils sit tests at the end of Key Stage 3. This is a nationally based examination, which is supposed to examine whether the target attainments of the national curriculum have been achieved by year 9 students. It is also aimed at evaluating not only individual schools but also the curriculum content (QCA, 2001b).

In school based summative tests, individual schools have different ways of assessing pupils. Once pupils take tests, they have finished a particular topic, including homework and performance assessments. Pupils in most schools are also assessed using end of year tests. The outcome of the assessments can be used to group pupils according to their ability, to report to parents about their progress and for the keeping of achievement records.

On the other hand, in the Korean curriculum, pupils sit school-based tests 4 times an academic year during their middle school schooling, alongside various performance assessments and homework. All the achievement records of pupils play a critical role when considering their entry into high school. In some areas, there are provincial based entrance examinations along with the achievement records for year 9 pupils. A particular exception is in the cities where there are no entrance examinations. However, pupils who want to go to special purpose high schools specialising in subjects such as art, science, foreign languages and commercial high schools are still required to take entrance examinations administered by each high school as well as their achievement records from middle school being taken into consideration.

In England, with regard to achievements, the Department for Education and Skills (DfES) mentions that most pupils at Key Stage 3 in English schools are expected to achieve level 6 in year 9 with slower learners expected to get level 4/5 and better learners expected to achieve 7/8 as indicated in Table 9. It is said that the level descriptions are designed to be used as a best-fit model at the end of a key stage to encompass this variation in performance (QCA 2001a).

Table 9 The target achievement for each level in English schools

End of year	Expected attainment		
	Slower learners	Most pupils	Faster learners
7	level3/4	level4/5	level6
8	level4	level5	level6/7
9	level4/5	Level6	level7/8, level7/7*

In contrast, the standard of achievement in the KNSC is divided into 3 levels without any reference to the equivalent level of each year group, simply stating High level, Medium level and Low level in each year group. It is assumed that most pupils will attain a 'Medium' or ' High' level (KICE, 2001) as shown in the table below.

Table 10 The target achievement of each level in Korean Middle schools

End of year	Expected attainment		
	Less able pupils	Most pupils	More able learners
7	Low	Medium	High
8	Low	Medium	High
9	Low	Medium	High

Despite the clear developments in assessment procedures for a nationally based examination have not yet been developed for Korean schools. It may be necessary to develop an assessment system in order to evaluate the 7th national curriculum to support its implementation in individual schools and to maintain standards in terms of content, teaching and assessment of the curriculum (KICE, 2001b). Although the 7th national curriculum recommends middle schools to use a criterion referencing assessment, traditionally the entrance examination is used on a selective basis, taking into account the records of achievement that are conducted 4 times a year in middle school. Thus, in Korea, the norm referencing and selection continues to be the major purpose of assessment rather than monitoring and diagnosis. In addition, although there are the quarterly school-based examinations, the examinations' content and context are similar across middle schools, as mentioned in the background section (Kim J C, 1998). Therefore, the next step of analysis is to study the examination papers themselves.

4-3-4 Examination papers

There is a difference in the assessment regime between England and Korea as mentioned above. In order to make a fair comparison, two different sets of Korean examination papers have been used: high school entrance examination (HE) papers and quarterly school based examination papers for year 9 from a randomly chosen middle school (p) as a counterpart to the KS3 examinations papers. These were obtained through the commercial website (www.zocbo.com). The former represents the non-equalisation policy applied in areas where pupils have to sit the high school entrance examinations, the latter represents the 'equalisation' policy applied in areas where pupils do not take HE examinations as explained at 4-1.

This analysis is based on the marking scheme used for papers 1 and 2 in 2003 in order to give comparability and objectivity to this analysis of examination papers. All the questions in each paper have been categorised into scientific enquiry (Sc1), biology (Sc2), chemistry (Sc3) and physics (Sc4). As the ENSC puts earth science as a part of physics, earth science content in the Korean questions were classified under physics (Sc4). Table 11 shows the total mark given to questions and the proportions of each examination paper and the percentage of experimentation related questions. Thus, the proportion of scientific enquiry in each examination paper represents either the percentage of integrated scientific enquiry with other subjects or of discrete scientific enquiry. In terms of the types of questions this will be described in the next chapter with detail.

Table 11 The results of the analysis of examination papers in 2003

Sc1: Scientific enquiry
Sc2: Biology
Sc3: Chemistry
Sc4; Physics and ( ) shows percentage of earth science

Samples of papers		Total mark	Sc1 (%)	Sc2 (%)	Sc3 (%)	Sc4 (%)	Experiment (%)
English KS3 tests (2003)	3-6-1	86	21	35	34	31(10)	33
	3-6-2	86	23	37	15	47(10)	16
	5-7-1	74	12	35	32	33(7)	39
	5-7-2	70	34	37	26	37(0)	35
Korean 4 times school based examinations (2003)	3-1-1	30	13	33	50	17(0)	7
	3-1-2	31	23	39	19	42(42)	16
	3-2-1	30	20	33	0	67(0)	27
	3-2-2	24	20	33	0	67(63)	0
	Means		18	34	18	48(26)	12
Korean HE examinations	4	28	25	28	32	40(19)	19

Generally, the examination papers seem to reflect the structure of the national curriculum content. Korean examination papers require pupils to know the concepts of laws, principles and theory in order to answer questions such as mass conservation law, proportional ratio law, gas reaction law, Avogadro's law and so on. Thus, the Korean examination papers tend to focus on more objective facts or principles, whilst the English KS3 test papers contain more conceptualised questions from pupils' everyday lives. English KS3 test papers show higher proportions of scientific enquiry and experimentation-orientated questions whilst Korean examinations have higher proportions of physics questions. This is because the KNSC contains higher proportions of earth science areas. In English KS3 tests as the tiers reflect the degree of difficulty in the English examination papers, 3-6-1 and 3-6-2 papers contain easier content than 5-7-1 and 5-7-2 papers, whilst Korean examinations papers have no variety in the degree of difficulty.

There are differences in the types of questions between the three sets of questions. Multiple-choice questions dominate the Korean examination papers whereas they form only a small proportion of the English examinations. In particular, the Korean HE examination paper consists of 100% multiple-choice questions whereas the English examination papers consist of simple answer questions. The quarterly school based examination papers consist of simple answer questions from 0-33% and a multiple-choice format. They show a lower percentage of scientific enquiry and experimentation orientated questions. However, the nature of the questions seems to be not much different from the questions in HE examinations, which demands more understanding of scientific facts, principles and laws.

4-4 Discussions

From this documentary analysis, it is evident that the KNSC covers most of the programme of study in the ENSC because the KNSC comprises more content knowledge. However, the most prominent area in ENSC is scientific enquiry and in KNSC it is earth science.

Firstly, although both curricula place great emphasis on scientific enquiry, there seem to be different interpretations and different levels of reflection on the curriculum content and assessment. The ENSC also has an emphasis on students' understanding and conducting of discrete investigations and describes what pupils should be taught in some detail (e.g. that it is important to test explanations by using them to make predictions and by seeing if evidence matches the prediction: make sufficient relevant observations and measurements to reduce error and obtain reliable evidence DfES, 2001). Those curriculum specifications about scientific enquiry seem to be reflected in the KS3 tests, so that discrete investigative questions are found in them which demand identifying variables, planning, predicting, matching evidence, and so on. Therefore the inclusion of scientific enquiry as a separate strand in the ENSC has raised its profile and importance in spite of the gap between policy and practice (Batholomew, et al, 2002).

On the other hand, the KNSC does not mention scientific enquiry specifically in its content. Instead, it says that the scientific enquiry area is integrated into every science lesson even though no practical work or experiments are involved (MOE, 2001b). Thus, the KNSC seems to be putting its emphasis on the teaching of science content with enquiry rather than on scientific enquiry itself. The main aim of scientific enquiry seems to be to enhance understanding of science knowledge. However, the aims of the KNSC with its emphasis on scientific enquiry do not seem to be fully reflected in the curriculum content nor in the assessment content. According to the KICE report, the KNSC places emphasis on '*hands-on*' practical experiences, '*minds-on*' learning processes and *authentic* real life contexts (KICE, 2001). The report also mentioned that the KNSC attempts to get pupils to understand the important concepts of science deeply rather than going through many scientific ideas superficially, the notion being 'less is more'

(KICE, 2001). As a result of this, the recent 7th national curriculum content has been reduced considerably compared with the previous 6th national curriculum (KICE, 2001). Nevertheless, the KNSC still has far more content than the programme of study in the ENSC. In addition, the simple curriculum reduction may result in the content being fragmented and inconsistent curriculum. The 7th national curriculum has omitted a considerable amount of abstract form of content knowledge such as the 'structure of living things and their life style' and ' water circulation and weather change' for year 7 (Kang D H, et al, 2001). Yet, the everyday real life context or application of STS (Science-Technology-Society) or the nature of science is hardly seen in the 7th national curriculum content. Consequently, Korean examination papers have far less experiment oriented questions, everyday, real life context or application of STS issues. However, there are no discrete investigative questions found in the Korean examinations but the questions integrated with other subjects. This may be partly due to the fact that the 7th national curriculum has not yet been fully implemented.

Secondly, as shown above, the KNSC contains far more in the area of earth science, which has lots of abstract forms of science knowledge along with a mathematical context. Generally, the KNSC consists of 4 subjects: biology, chemistry, physics and earth science. The national curricular content distributes science knowledge evenly among each subject. According to the report based on this (Kim J H & Lee M K, 2003), even the distribution of science subjects in the national curriculum, the teacher training system has been set up to train equal proportions of teachers who specialise in different science subjects.

In addition, this abstract form of science knowledge along with a mathematical context often demands a higher conceptual understanding. Then, it would be more difficult to implement the relevant elements of the nature of science and scientific knowledge such as how this knowledge has developed. As Taber (2003) argues, even A-level students aged 16 find abstract thinking in science difficult especially in physics although it is clearly something they aim to develop. Therefore there seems to be a need to examine whether this detailed content is relevant to pupils' cognitive abilities. This may lead children to learn the scientific ideas by rote even if they do not fully understand the concepts. Larger curriculum content with an abstract form of scientific knowledge seems to be a traditional feature of the KNSC as a 'content-based curriculum' emphasising scientific knowledge (KICE, 2001). Consequently, teachers tend to view the task of imparting knowledge to students like displaying information (KICE, 2001). Although the KNSC has since reduced its content, it still seems to have too many detailed concepts to teach. The present curriculum content is too great to be able to implement the nature of science and scientific enquiry. This traditional curriculum content can determine how science is taught and that is what affects pupils' experience in learning science and their subsequent attitude toward science (Kim J H & Lee M K, 2003).

On the other hand, as Kind (2003a) argues, there is no doubt England has been a pioneer in developing school science practical work in general and investigative work in particular. The effort that has been placed in the ENSC, describing scientific enquiry not only in the curriculum guidelines but also in the curriculum content as a strand of programme of study, seems to be unique internationally. The elements of 'ideas and evidence' as the content of scientific enquiry have been strengthened in the national curriculum in science since 2003 (Kind, 2003b). Indeed, the English examination papers contain more investigative questions and experiment related questions than the Korean examinations.

Lastly, there are considerable proportions of common content of both national curricula, which have remained the same for the past 50 years (Osborne, et al, 2003; Kim J H & Lee M K, 2003). This traditional curricular content includes out-dated materials, which are not applicable to real life context as well as having a lack of issues of STS and elements of the nature of science (Kim J H & Lee M K, 2003). As the delphi studies from both England and Korea (Osborne, et al, 2003; Kim J H & Lee M K, 2003) show, no one group of individuals can provide a universal solution as to what the essential elements of a contemporary science curriculum should be. Yet, in order to nurture the future citizenship of young people, the contemporary context should be taught since the aim of both curricula is to ensure that students have acquired the skills and the understanding needed to participate effectively in society. Thus, the goals of science education are not about assessing how well students have mastered the curriculum content, but rather what general skills and broad understanding they have acquired (Harlen, 2003).

4-5 Summary

The analysis of data has shown that the elements of the nature of science and scientific enquiry are not fully demonstrated in the content of the national curricula in both countries. The shortcomings are far more evident in KNSC.

The most distinctive feature in the ENSC is the area of scientific enquiry whilst earth science features prominently in the KNSC. In England, the content of the ENSC and assessment reflect more fully the aims of the curriculum. In Korea, there is less consistency between the aims of the curriculum, its content and the assessment.

Both of the national curricula are known to have too much content yet the KNSC has more curricular content than that of the ENSC. The curriculum content and assessment content of the ENSC reflect the aims more fully than the Korean counterpart. Both still remain content dominated with a traditional approach in spite of the emphasis on the nature of science and scientific enquiry. Thus, the asserted purpose or aims of the curriculum may remain marginal in the classroom. Similarly, the curriculum includes inappropriate content for contemporary science. Finally, the examination papers include more experiment-orientated questions reflecting distinctive feature of the curriculum content.

Through the documentary analysis it is revealed that the content of the KNSC contains more areas of scientific ideas, including a greater amount of earth science but less scientific enquiry areas. The examination papers tend to reflect the structure of the content.

Although the KNSC mentions the importance of scientific enquiry, the content and examination papers show little evidence of that aspect. Rather examination questions include far more conceptual science. By contrast, the ENSC contains less conceptual science and more experiment related questions, scientific enquiry and investigations, which are not found in the Korean examinations.

To sum up, this study has been designed to explore similarities and differences in curriculum, assessment policy and practice in order to see whether there is anything to be learnt from each other's curriculum. It is intriguing, therefore, that despite these differences, pupils in both countries have achieved highly in an international comparative study, such as OECD and TIMSS. This similarity in achievement has promoted the detailed analysis in this study in order to explore the similarities and differences in detail of assessment practice. The next chapter shows a detailed analysis of examination papers.

Chapter 5 Documentary Analysis of Examination Papers

5-1 Introduction

This chapter is to explore the sub-question mentioned at 3-1: *'What is assessed in scientific enquiry in the national curricula in England and Korea?'.* This chapter aims to analyse the examination papers in both England and Korea through documentary analysis following a curricular analysis in chapter 4. Considering the influence of examinations on school curricula and the close-knit relationship between the national curricula, teaching and assessment, it is necessary to investigate the similarities and differences in what the national curricula assess in England and Korea. In particular, both the end of KS3 tests and the high school entrance examinations comprise a whole range of programmes of study within the national curriculum. They also strongly influence the patterns and tendencies of other school examinations, such as end of topic tests and end of year examinations. In addition, although the performance assessment could be used for the purpose of this research, external summative assessment seems to be the most appropriate choice as standardised examinations because they have validity for international comparison.

Therefore, despite the differences in purpose, tradition and format of each examination, a detailed analysis of examination papers is worth carrying out not only to explore the research question but also to develop a questionnaire for teachers concerning how they think about and teach scientific enquiry. In doing so, sub-questions were developed as follows.

1. *What are the differences and similarities between the test papers in general?*
2. *How different is the testing of scientific enquiry between the test papers?*
3. *Are there any differences or similarities in the nature and range of skills tested?*
4. *Are relevant test items of scientific enquiry included in the aims of the National Curricula? (STS, ideas and evidence, contexts, higher thinking order, scientific reasoning and so on)*
5. *How do the test items match up with the contemporary view of science?*

Finally, in order to compare test items in both the KS3 examination papers and HE examination papers, TIMSS sample test items are used as an indicator, using the following methodology.

5-2 Methodology

Examination papers have been selected from those set in 2003 and 2004 of both countries because of the new Curriculum and the new policies employed since

2003. TIMSS sample tests have been used in order to act as an indicator of this comparison because pupils in both countries participated in the TIMSS comparative study in 2003.

5-2-1 Samples

For the purpose of analysis, the following sample test papers were selected from the end of KS3 examination papers (KS3 tests) and the high school entrance (HE examinations) papers. As mentioned in 4-3-4, the KS3 tests have two sets of papers (paper 1 and 2) with two different levels of difficulty (3-6 and 5-7). Whilst HE examination papers are different from in different parts of the country yet having no different degree of difficulty as shown in table 12

Table 12 Samples used in analysing examination papers

England	Korea	TIMSS sample tests-2003
Eng.3-6-1,2003	Common,2003	So1, So2, So3, So4, So9 So13
Eng.3-6-2,2003	Kyungi,2003	
Eng.5-7-1,2003		
Eng.5-7-2,2003		
Eng.3-6-1,2004	Common,2004	
Eng.3-6-1,2004	Kyungi,2004	
Eng.5-7-1,2004	Junnam,2004	
Eng.5-7-2,2004		

5-2-2 Nature of papers

Table 13 Nature of each examination paper

Papers	Purposes	Testing time	No of questions	Remarks
KS3 test papers	Assessing pupils' achievement tasks in the programme of study	Each type 1 hour	3-6 tier:85 5-7 tier:75-	Each question, less than one minute
High school entrance examination papers	Selecting able pupils	1 hour	25-29 questions during class 3 (1 hour long), pupils take 60 questions comprising 24 English questions 26 Science questions and 10 Music questions	Each question, one minute Feasibility has been known to range from 25-80%
TIMSS papers	International comparison of pupils' scientific literacy	90 minutes	95 questions	Each question, Less than one minutes

(KICE, QCA, TIMSS & PIRS ISC, 2003, 2004)

Prior to the analysis of examination papers, it may be necessary to consider the nature of each examination, including the purposes, the testing time, the number of questions and the time taken to solve a question in both sets of questions. Each set of examination papers has a different purpose: one is to assess pupils' achievement in the national curriculum and the other is to select able pupils for high schools. English KS3 tests have two tiers of examination papers: 3-6 tiers for slow learners with 85 marks and 5-7 tiers for normal or faster learners with 75 marks. In contrast, the Korean HE examinations have no variations for pupils instead one tie with 25-85% of feasibility (Kim J C, 2004). However, the time taken for a question in both sets of examinations is more or less the same: which is one minute for each mark in the question.

5-2-3 General findings

This is to find out the general features of each test according to the content of the assessment, types of questions, total number of questions, and similarities and differences in the questions in general. General findings are based on the classification of the National Curriculum analysis, as mentioned in the previous chapter. In the first instance, each question is allocated one mark. If a question has 4 marks it is counted as 4 questions in order to categorise them easily and compare them fairly.

Subjects

Subjects are divided into 4 categories following the classification of the national curriculum: Scientific enquiry, Biology, Chemistry and Physics including Earth Science. Scientific enquiry is found either in the form of integration with other subjects or in the form of scientific investigation, including a problem- solving format.

Types of questions

There are 5 categories of types of questions: Multiple choice, Simple answer, Short sentence answer, Drawing, and Description.

Table 14 Types of questions

Type of questions	Descriptions
Multiple Choice	These include a multiple choice format, drawing a line to the relevant answers, true or false format
Short answer	One or two words or letters
Short sentence answer	One or two sentence answers
Drawing	Drawing graphs or pictures
Description	Explanations : longer than short sentence answers

Scientific enquiry
Scientific questions are classified into two different types. Some questions are classified as scientific enquiry questions, which are integrated with biology, chemistry and physics. The others are scientific investigative questions with discrete new context. This may show a difference in the ways in which the scientific enquiry is described by the national curricula in the two countries.

Similarities and differences
This section includes a comparison which includes general features such as the compactness of questions, the types of questions, the context of questions and demanding skills and so on. Although questions may be similar in terms of the context yet the level of skills demanded and cognitive ability can be different.

5-2-4 Frameworks used
There are many different types of framework that can be used in order to classify the aims of science education. In this analysis, Bloom's taxonomy (1956), and Klopfer's specifications (Bloom, 1971) are selected because those frameworks are well known in both countries. They also are in line with the purposes of this analysis, which can cover the content of the national curricula and being able to cover a wider range of other assessment area as shown below. Table 15 shows that each framework can cover the domains; Bloom's taxonomy can be categorised in to cognitive, affective and psychomotor domains, whereas Klopfer's specifications can cover scientific enquiry and STS domains.
Table 16 shows details of each domain.

Table 15 The domain of general goal of science education (Woo, et al, 1998)

Section	Cognitive domain	Affective domain	Psychomotor domain	Enquiry domain	STS domain
Bloom's taxonomy	o	o	O	–	–
Klopfer's specifications	o	o	O	o	o

Table 16 The selected assessment domain on science learning (Kim K M & Kim S W, 2002)

Cognitive domain	Affective domain	Enquiry domain
Knowledge	Value	Identifying Problem & hypothesising
Comprehension	Interest	Plan of enquiry
Application	Attitude	Practice of Enquiry
		Analysis of data
		Conclusion & Evaluation

In this analysis, Bloom's taxonomy is used for classifying the cognitive domain and Klopfer's specification is used for not only being able to show cognitive domain but also scientific enquiry, affective domain and STS domain. Each framework has its own advantage in assessment areas so they may be able to support and supplement each other. All the questions in each test paper are analysed according to the following frameworks. Questions are assigned to unique categories in order to find a certain domain of knowledge and skills.

Bloom's taxonomy

Bloom's taxonomy is a simple but useful device to classify questions as it shows cognitive domains from 'recall', 'comprehension', 'application', 'analysis', 'evaluation', and 'synthesis' (Kwon J S, 2003). This shows which area of cognitive domain each question requires in order for a question to be solved. For questions that fall into 'application', 'comprehension' or 'recall', their value is recognised as lower order cognitive skills. However, for questions that fall into 'analysis', 'evaluation' or 'synthesis', their value is recognised as higher order cognitive skills (Kwon J S, 2003). Categories and examples from each group of test papers are shown in appendix 7

Klopfer's specifications

Klopfer's specifications are known as a comprehensive attempt to classify the learning and assessment expectations of science education (Osborne & Ratcliffe, 2000). They include reference to the details of the processes of scientific enquiry, attitudes and interests, as well as knowledge and comprehension. Although it is known for being slightly complicated to use, but it is still useful for showing the scientific enquiry domain, which is not in Bloom's taxonomy. In particular, the KNSC uses details of the specifications in the area of scientific enquiry, such as *'observing and measuring', 'seeing a problem and seeking ways to solve it, 'interpreting data and formulating generalisations* and so on. However, it seems to be difficult to include *'attitude and interests'* as well as *'building, testing and revising a theoretical model', 'application of scientific knowledge and methods', 'manual skills'* and *'orientation'* in standardised examinations and those at KS3 level. Neither Korean nor KS3 test papers cover those items in Klopfer's classification.

Nevertheless, Klopfer's specifications are a comprehensive and useful framework because they include reference to the details of scientific enquiry processes, indicating *'observing and measuring', 'seeing a problem and seeking ways to solve it', 'Interpreting data and formulating generalisations'* and *'building, testing and revising a theoretical model'*, as follows in appendix 8. The table also includes the nature of each category, with relevant examples.

Each question is categorised independently, according to the items in each framework. They are classified into the main categories first, then into sub-categories. Most questions fall relatively easily into a certain category. A few questions are more complicated to apply to a certain framework. Bloom's taxonomy seems to be easier to apply than Klopfer's specifications. Below, Klopfer's specification is being applied to an example.

The question (3-6-1-15, 2004 in appendix 9) integrates scientific enquiry into physics so that it can be classified under '*knowledge and comprehension*' or '*interpreting data and formulating generalisations*'. However, in this chapter, the questions are classified into '*interpreting data and formulating generalisations*' as a main category because the question seems to be weighted more in the area of scientific enquiry. Table 17 shows an example of classification.

Table 17 Example of classification, 3-6-1-15, 2004

Questions	Bloom's taxonomy	Klopfer's specification
15-a-1	Application	d3 (can be a5)
15-a-2	Application	d3 (can be a5)
15-a-3	Application	d3 (can be a5)
15-a-3'	Application	d3 (can be a5)
15-b	Comprehension	a2 (can be a2)
15-c	Synthesis	d5(can be a10)

Using these frameworks, if a question seems to contain more than one category, the item chosen will be toward the higher cognitive domain and the more outstanding demands made for answering the question. If a question requires comprehension and application in Bloom's taxonomy, application will be the category selected in this case. For example, 3-6-2-10, 2004 (appendix 9-1) is physics light and sound question. In order to answer the sub-questions, they demand pupils' 'comprehension' and 'application'. In this research, the sub-questions are classified into 'application' category. Nevertheless, using two complementary typologies independently may allow firmer general conclusions to be made about the nature of demand in answering each question.

There must also be variations in analysing questions using frameworks depending on how a researcher has acquired those concepts and has chosen ways to answer the questions as pointed out in the report by Osborne & Ratcliffe (2000, p3);

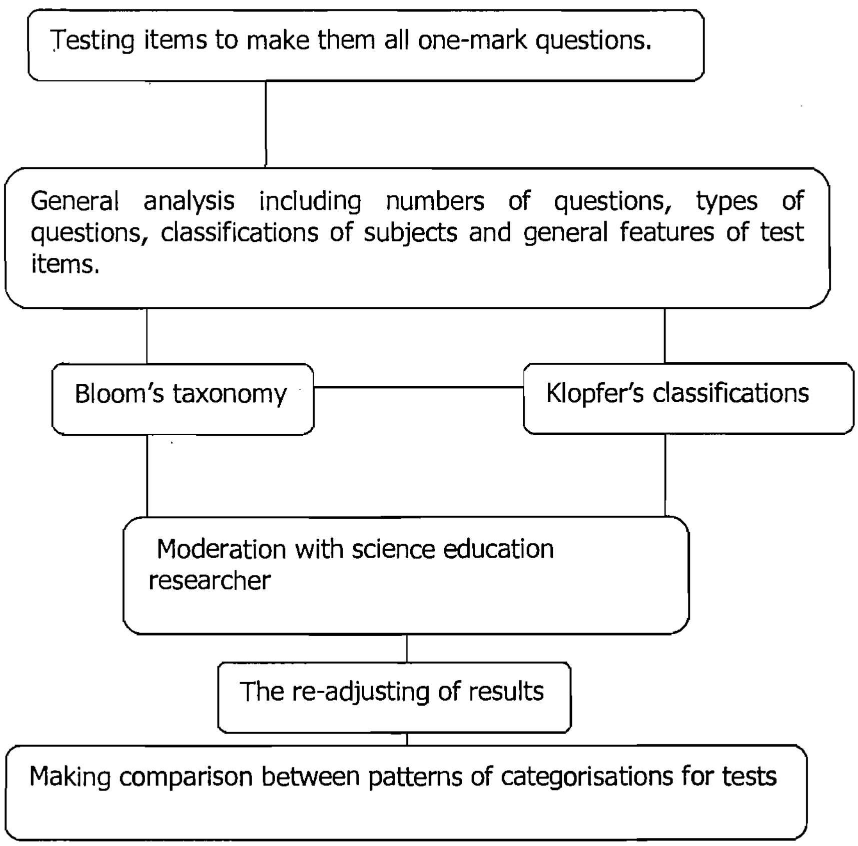
> ... *we are aware of the difficulties of assigning questions to unique categories as items are open to slightly different interpretation and the demand for the individual pupil can depend on prior experience..."*

Therefore, it is necessary to moderate the results of the analysis in order to reach more objective conclusions. At the same time, it is important to maintain consistency in assigning questions to certain categories. As mentioned above, variations may be inevitable depending on the researcher. Thus, in order to validate this categorisation by maintaining consistency, all the questions have undergone the categorisation process three times. Then the questions, which have shown inconsistency, were discussed and underwent moderation process with a supervisor.

5-2-5 Procedure

The procedure used when analysing test items in each examination paper is illustrated below. All the questions turn into one-mark questions. There is three fold analysis; one is to find out general features of each question, the other is to undertake analysis by using Bloom's taxonomy and the last by using Klopfer's specifications. Then, the data is analysed and comparisons are made.

Figure 7 Procedure of analysing test papers



5-2-6 Difficulties in classification

Some scientific enquiry questions, which are integrated with other subjects are difficult to categorise into a certain domain.

Firstly, with respect to the classification of subject matter, most questions are clearly distinguishable. Some questions have integrated scientific enquiry with other subjects, such as scientific enquiry with biology, chemistry and physics or subjects combined with each other. In particular, scientific enquiry may be integrated with another subject at a different level so that it makes classification difficult. Thus, although some questions are of a similar pattern, one may fall into its own subject and the other will fall into scientific enquiry depending on the level of enquiry. The following are examples.

5-7-2-10, 2004 (appendix10) shows the complexity of classification between scientific enquiry and Physics. It has 5 mark sub-questions: two of them demand interpretation and the drawing of a graph, and one of them requires the interpretation of the graph and application of physics knowledge. Thus, this sub-question can fall into either the physics or scientific enquiry areas. However, 5-7-2-10-a-1 seems to be weighed more on physics knowledge rather than on scientific enquiry. Therefore, 5-7-2-10, 2004 has two scientific enquiry questions and 3 physics questions. 3-6-1-6, 2003 (appendix 11) also shows difficulties in distinguishing between scientific enquiry, physics and chemistry. It has 5 mark sub-questions: 3-6-1-6-d can fall into chemistry, 3-6-1-6-e into physics but for 3-6-1-6-a to c, there is not a clear-cut division between scientific enquiry and chemistry because all three of them demand data interpretation with chemistry knowledge. However, these questions can be solved by reading the table without content knowledge whereas b and c weigh more on demanding chemistry knowledge. Therefore, 3-6-1-6 has sub-questions: one on scientific enquiry, three on chemistry and one on physics. In these cases, the classifications will coincide with those in Mark Scheme 3-7, 2004. Therefore, in this chapter, classifications of other tests will be consistent with the standard of Mark Scheme 3-7, 2004 and Mark Scheme 3-7, 2003.

Secondly, in general, Korean HE examinations contain many compact type questions that include a large amount of content in one question, compared to the question from English KS3 tests. These questions require more than one category in Bloom's taxonomy, and subcategories in Kopfer's specifications. For example, Korean Common-30, and 2004 (appendix 12) are classified as scientific enquiry with chemistry. Each 5 choices demands a certain cognitive level such as comprehension for choice 1, application for choice 2, choice 3 and choice 4, synthesis for choice 5. 5 choices demand scientific enquiry and chemistry knowledge. Thus, the question is categorised as 'Application' and 'Synthesis' in Bloom's taxonomy and 'd3' (interpretation of experimental data and observations) and 'd5' (evolution of a hypothesis under test in the light of data obtained) in Klopfer's subcategories. These results make analysis conclusions difficult to compare objectively because the questions from English KS3 tests are classified into one category for one mark. Thus, in Korean questions, the total number of questions is different from the total number of categories and subcategories of the test in question. The following section includes the results of analysis, describing the general analysis and results from using frameworks.

5-3 Results

5-3-1 General findings

Total number and types of questions

In England, the lower tier test papers contain more questions than the higher tier, for example 90 items in the 3-6 tier and 75 items in the 5-7 tier. In the case of 'Common' examinations in Korea, students have to take an English test (24 items) and a Music test (10 items), along with Science (26 items) all within one hour. So there is less than one minute for each item in the English test papers and exactly one minute given per item in the Korean test papers.

In terms of question types there is a significant difference between English and Korean papers: the former is varied with multiple-choice, simple answer, short answer, drawing and description questions, while the latter contains 100% multiple choice items.

In addition, although items are classified as following a multiple choice format, Korean questions consisted of a 100% 4 option choice format in 2003 and 5 option format in 2004, whereas items which fall into multiple choice format in English test papers are varied, including a typical multiple choice format, drawing lines to relevant words or sentences, true and false format etc. (5-7-2-15, 2003, appendix 13)

Simple answer items refer to questions demanding answers with names, symbols or specific words. In contrast, short answer items are those questions demanding answers with short sentences or clauses. Description items are categorised as questions demanding longer sentences than in short answer items. Drawing items are not frequently found in test papers but can consist of questions demanding the drawing of circuits, graphs, and so on. Table 10 shows details of each test paper in terms of question types. In English test papers, the 2003 papers contain more multiple-choice items than the 2004 papers. The 3-6 tier test papers contain more multiple-choice than the 5-7 tier test papers.

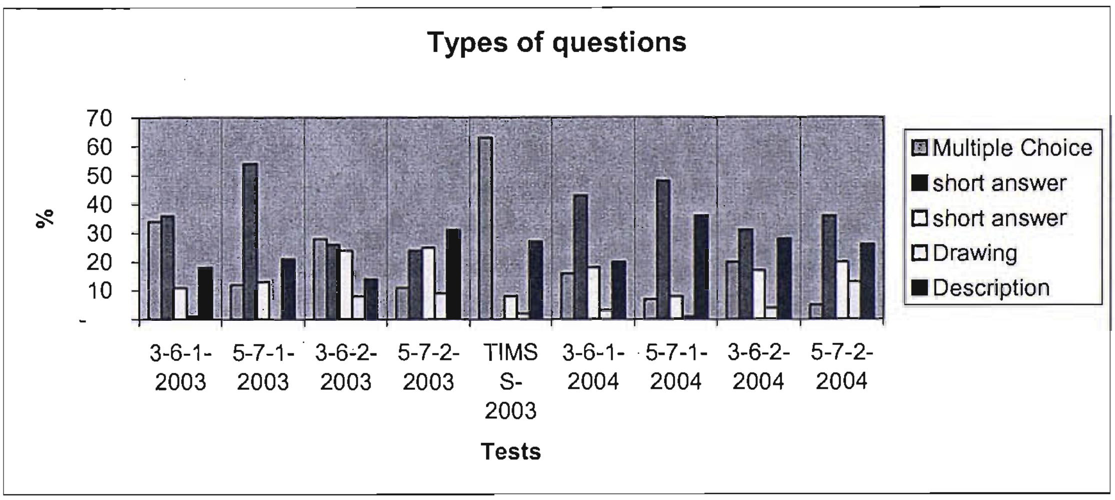
The proportions of simple answer and description items in the English examination papers look similar, whereas the distribution of multiple- choice seems to vary with each examination paper.

Table 18 Types and total numbers of each test

Tests		Multiple – choice (M)	Simple-Answer(S)	Short Answer (SA)	Description (D)	Drawing (DR)	Total Numbers
Eng.2003	3-6-1-2003	31	32	10	16	1	90
	5-7-1-2003	9	40	10	16	-	75
	3-6-2-2003	25	23	22	13	7	90
	5-7-2-2003	8	18	19	23	7	75
Kor.2003	Common-2003	26	-	-	-	-	26
	Kyungi-2003	28	-	-		-	28
TIMMS	TIMSS-2003	58	-6	-	29	2	95
Eng.2004	3-6-1-2004	14	39	16	18	3	90
	5-7-1-2004	5	36	6	27	1	75
	3-6-2-2004	18	28	15	25	4	90
	5-7-2-2004	4	27	15	19	10	75
Kor.2004	Common-2004	26	-	-	-	-	26
	Kyungi-2004	28	-	-	-	-	28
	Junnam-2004	26	-	-	-	-	26

In conclusion, English test papers use a greater variety of question types than TIMSS' and Korean ones. In addition, the 2004 English papers demand more descriptive types of answers than multiple choice and simple answer items, as shown in the 2003 test papers. The following figure 8 shows 2003 and 2004 KS3 test papers and TIMSS items in % of each type.

Figure 8 Types of questions (%)



Distributions of subjects and scientific enquiry

All the test items are divided into Biology, Chemistry, Physics and scientific enquiry, following the same standards used in the analysis of the National Curricula in the previous chapter. Korean and TIMSS-2003 items contain a higher proportion of physics than the English one. In particular, TIMSS-2003 and Korean test items contain a considerably higher proportion of Earth Science. Whilst having a lesser content of Physics items, English test papers contain a higher portion of scientific enquiry items than in the other two. One interesting feature of English test papers is that they contain scientific investigation items not integrated with other subjects (5-7-1-14, 2004, appendix 14). This is rarely found in TIMSS-2003 or Korean test papers.

However, 65-70% of the Korean test items having common content with English ones demand a different level of conceptual understanding in order to answer the questions. This may reflect the fact that the national curricular content includes common content with regards to the traditional curriculum content. Table 19 shows the common content area of Korean examination papers with English ones.

Table 19 Numbers of common items in Korean and English test papers

Korean test papers	Total number of questions	Number of common content with English test papers
Common-2003	26	18
Kyungi-2003	28	20
Common-2004	26	18
Kyungi-2004	28	20
Junnam-2004	26	17

Most items in English test papers are fairly easy to categorise into each subject area because each item falls into a subject area, except for a few questions, which are integrated into scientific enquiry with other subjects such as 3-6-1-5, 2004 (appendix 15) or 5-7-2-10, 2004 (appendix 10). In contrast, items in TIMSS and Korean test papers are more compacted, including more than one knowledge domain in a one-mark item. Additionally, all scientific enquiry items in Korean test papers are integrated with other subjects as one-mark question types (Common-30, 2004 (appendix 12), TIMSS-2003-7 (appendix 16)).

Thus, those items, which contain scientific enquiry with other subjects are categorised twice: once under scientific enquiry and again under its subject. Table 20 shows details of each test paper.

Table 20 Composition of each subject (%)

	Test papers	Scientific enquiry (SC1)	Biology (Bio)	Chemistry (Chem)	Physics (Phy)
English-2003	3-6-1-2003	19	28	32	21
	5-7-1-2003	12	32	32	24
	3-6-2-2003	22	27	11	40
	5-7-2-2003	32	23	19	26
Korean-2003	Common-2003	21	24	24	31
	Kyungi-2003	22	25	25	28
TIMSS-2003	TIMSS 2003	24	22	23	31
English-2004	3-6-1-2004	24	23	17	36
	5-7-1-2004	16	22	35	27
	3-6-2-2004	32	30	22	16
	5-7-2-2004	40	23	17	20
Korean-2004	Common-2004	21	21	18	40
	Kyungi-2004	22	22	20	36
	Junnam-2004	22	19	22	37

As the table 20 shows, the proportion of scientific enquiry in 2004 English test papers has increased considerably compared with that of those set in 2003. This tendency seems to reflect the new assessment policy in that KS3 tests should contain at least 30% scientific enquiry. In particular, 5-7-2, 2004 includes 40% of scientific enquiry.

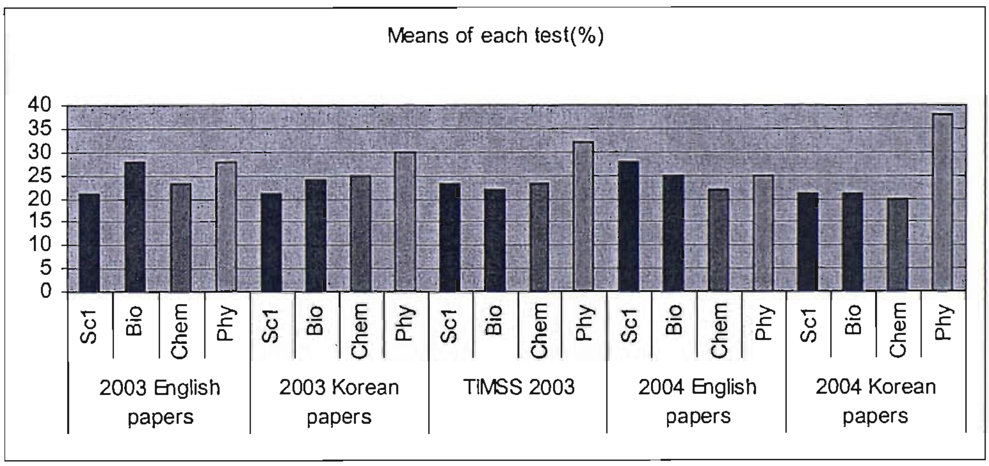
On the other hand, TIMSS-2003 and Korean test papers contain a similar proportion of scientific enquiry each other in 2003. Additionally, Korean test papers retain a similar proportion of scientific enquiry, as well as similar features of distribution in other subjects between 2003 and 2004. Table 21 and Figure 9 show the mean and standard deviation of each year in order to show the distribution and tendencies of each year's test papers.

Table 21 Means and SD (standard deviation) of each subject

Test papers	Subjects	Means of each test(%)	Standard Deviation(SD)
2003 English papers	Sc1	21	7.2
	Bio	28	3.2
	Chem	23	9.0
	Phy	28	7.3
2003 Korean papers	Sc1	21	0.5
	Bio	24	0.5
	Chem	25	0.5
	Phy	30	1.5
TIMSS 2003	Sc1	23	-
	Bio	22	-
	Chem	23	-
	Phy	32	-
2004 English papers	Sc1	28	8.9
	Bio	25	3.2
	Chem	22	7.4
	Phy	25	7.6
2004 Korean papers	Sc1	21	1.5
	Bio	21	0.6
	Chem	20	1.5
	Phy	38	2.1

TIMSS-2003 and Korean test papers show a greater proportion of Physics than English ones. Korean test papers also show an even distribution of subjects in each paper with less standard deviation. In contrast, English test papers show greater standard deviations, reflecting that each test paper has a varied composition of subjects. Generally, 3-6 tier test papers contain less scientific enquiry than 5-7 tier, as well as paper 2 showing more scientific enquiry items.

Figure 9 Subject proportions in the test papers (%)



Analysis of scientific enquiry questions

Table 22-1, table 22-2 and Figure 10 show the nature of scientific enquiry questions in each set of papers.

Table 22-1 Content of scientific enquiry (number of items)

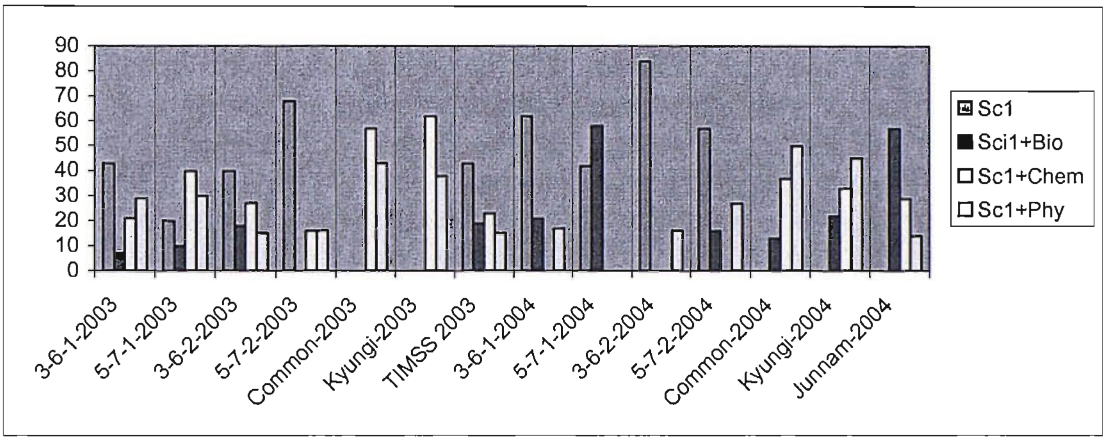
Test papers		*Sc1	*Sci1+Bio	*Sc1+Chem	*Sc1+Phy	*Total numbers
English 2003	3-6-1-2003	12	2	6	8	28
	5-7-1-2003	4	2	8	6	20
	3-6-2-2003	13	6	9	5	33
	5-7-2-2003	22	-	5	5	32
Korean, 2003	Common-2003		-	4	3	7
	Kyungi-2003		-	5	3	8
TIMSS test items, 2003		11	5	6	4	26
English 2004	3-6-1-2004	15	5	-	4	24
	5-7-1-2004	8	11	-	-	19
	3-6-2-2004	26	-	-	5	31
	5-7-2-2004	21	6	-	10	37
Korean, 2004	Common-2004		1	3	4	8
	Kyungi-2004		2	3	4	9
	Junnam-2004		4	2	1	7

*Sc1: discrete scientific investigation question
*Sc1+Bio: scientific enquiry question integrated with biology
*Sc1+Chem: scientific enquiry question integrated with biology
*Sc1+Phy: scientific enquiry question integrated with physics
*Total numbers; total number of scientific enquiry question
*Sub-total of integrated with subjects: Proportions of Sc1+Biology, Sc1+Chem and Sc1+Phy

Table 22-2 Content of scientific enquiry (%)

Test papers	Sc1	Sci1+Bio	Sc1+Chem	Sc1+Phy	*Sub-total of integrated with subjects
3-6-1-2003	43	7	21	29	57
5-7-1-2003	20	10	40	30	80
3-6-2-2003	40	18	27	15	60
5-7-2-2003	68	-	16	16	32
Common-2003	-	-	57	43	100
Kyungi-2003	-	-	62	38	100
TIMSS 2003	43	19	23	15	56
3-6-1-2004	62	21	-	17	38
5-7-1-2004	42	58	-	-	58
3-6-2-2004	84	-		16	16
5-7-2-2004	57	16		27	43
Common-2004	0	13	37	50	100
Kyungi-2004	0	22	33	45	100
Junnam-2004	0	57	29	14	100

Figure 10 Content of scientific enquiry (%)



Firstly, although there is not a great difference in the overall percentage of scientific enquiry in each test, the content of scientific enquiry seems to be significantly different amongst test papers. Korean test papers do not include single scientific enquiry items but instead include items integrated with other subjects. Thus, no planning parts of scientific investigation or scientific research questions are found in Korean test papers. English test papers contain higher proportions of single scientific enquiry items than TIMSS-2003 ones or Korean ones.

Secondly, TIMSS 2003 and 3-6-1, 2003 show a similar feature of scientific enquiry content, showing 43% of single scientific enquiry and 57% of integrated scientific enquiry with other subjects. However, there is a significant tendency towards an increased proportion of single scientific enquiry in English 2004 test papers, despite a great variation of single scientific enquiry distributions in each English test paper from 20% to 84%. In particular, 3-6-2,2004 shows 84% of single scientific enquiry items in contrast with 20% in 5-7-1, 2003.

Finally, Korean test papers show the same proportions in scientific enquiry for both 2003 and 2004. Korean test papers also show similar patterns in the distribution of other subjects in 2003 and 2004. In contrast, English test papers show variations in the proportion of single scientific enquiry, scientific enquiry and distribution in other subjects.

Similarities and differences in the nature of each set of questions

English test items give a considerable amount of information to students in the actual test papers. It could be argued that some answers can be found simply by reading the questions, using generic skills or deducing answers from the given information, as shown in 3-6-1-12, 2004 and 3-6-1-8, 2003 (appendix 17 and appendix 18). In addition, English test papers contain more everyday context and application-based questions as shown in 3-6-1-6, 2004 (appendix 19).

By contrast, Korean questions require students to have a prior understanding of the content of the questions, including specific terminology and basic concepts, theory, principles and laws reflecting the emphasis on scientific knowledge, based on major conceptual schemes. Therefore, if a student does not know one fact, he/she may not be able to get any marks. As shown in Common- 37, 38, 39, 40, 2004, Junnam-52-2004 (appendix 20) and Common-38, 2004, students need to know all about the concepts of kinetic energy, potential energy and how total energy is conserved and changed into another form of energy, before being able to solve the problems.

Similarly, one question in the Korean HE examinations tends to cover a greater range of content knowledge than one question in English KS3 test papers does. For example, although 3-6-1-15, 2004 (appendix 9) and Common-27, 2004 (appendix 21) have similar content and context demanding different cognitive levels, there are differences in the compactness of the questions. 3-6-1-15,2004 includes 6 sub-questions (6 marks) demanding 2-3 items in order to get 6 marks, whereas Common-27, 2004 question requires a comprehensive understanding and application in different instances in order to get one mark, as shown in table 23.

Table 23 Demanding content knowledge

3-6-1-2004-15	Common-2004-27
* To understand changes of state (solid, liquid, gas) in a different temperature * To understand the ways in which thermal energy can transfer (conduction, evaporation, convection, radiation) 6 marks	*To understand changes of state in different examples such as a melted candle, the drying process of washing, Naphthalene, melted ice cubes and water drops occurring outside ice water * To understand particles' changes in different states 1 mark

Generally Korean test papers contain more questions, which demand a higher conceptual understanding than English test papers. For example, 3-6-1-1, 2004 (appendix 22) and common-50, 2004 (appendix 23) are about inheritance. 3-6-1-2004-1 requires the name of the organ and the characteristics, as well as the name of what will be inherited by children from their parents. However, in order to be able to get the answer to Common-50, 2004 students should know how colour-blind genes are inherited in sex chromosomes, based on the fact that characteristics will be inherited from parents by their children. In addition, it also requires them to know why there is a higher possibility of colour blindness in males than in females. 3-6-1-17,2004 appendix, 24) Junnam-45, 2004 and Common-43, 2004 (appendix 25) also show good examples of the nature of different circuits used to show relationships between volt, current, resistance in

Common-43, 2004 and volt, resistance and heat in Junnam-45, 2004.

Along with the emphasis on theory, questions in Korean test papers also show more mathematical content. In particular, Junnam-2004 test paper contains 7 questions with a mathematical content such as calculating speed, force, work and efficacy of work and probability as seen in Junnam-50, 2004 and Junnam-32, 2004 (appendix 26).

Finally, English test papers contain not only open-ended questions but also questions, which can have several answers. In particular, scientific enquiry questions in English test papers are unique in their openness and creativeness of the questions. 5-7-1-14,2004 (appendix 27) shows the openness of the question demanding a plan investigation, which includes identifying independent variables, dependent variables and control factors. This would give 4 marks. In addition, single scientific enquiry questions require more open answers than other questions, encouraging students' creativity. An example of openness is in answers required for 5-7-2-6, 2004 (appendix 28). In particular, the answers for 5-7-1-14, 2004 (appendix 27) can be varied such as 'season' or 'location' or duration of observation time. The answers for 5-7-2-6, 2004 (appendix 28) can also be varied: they could be 'data from 'last year' to years earlier than 2002. Moreover, most questions require reasons to be given as to why students have chosen their particular answers, asking why or how, and requiring support for their own answers based on evidence. Korean questions tend to be very structured, demanding definite answers. This may be partly because of the multiple- choice format.

TIMSS 2003 also contains single scientific enquiry questions and content with the nature of science. However, English test papers seem to show a more openness in terms of how a question can be answered, as shown in S1308A (appendix 29). The answer can be varied in as far as it can refer to cats preying on other animals resulting in a reduction in population. The mark scheme gives possible examples as follows.

Examples: *They will eat the birds and other animals.*
The cats help them by eating the rats and mice
Their prey will become extinct.
They might pass on diseases to other animals
(TIMSS2003, Mark scheme)

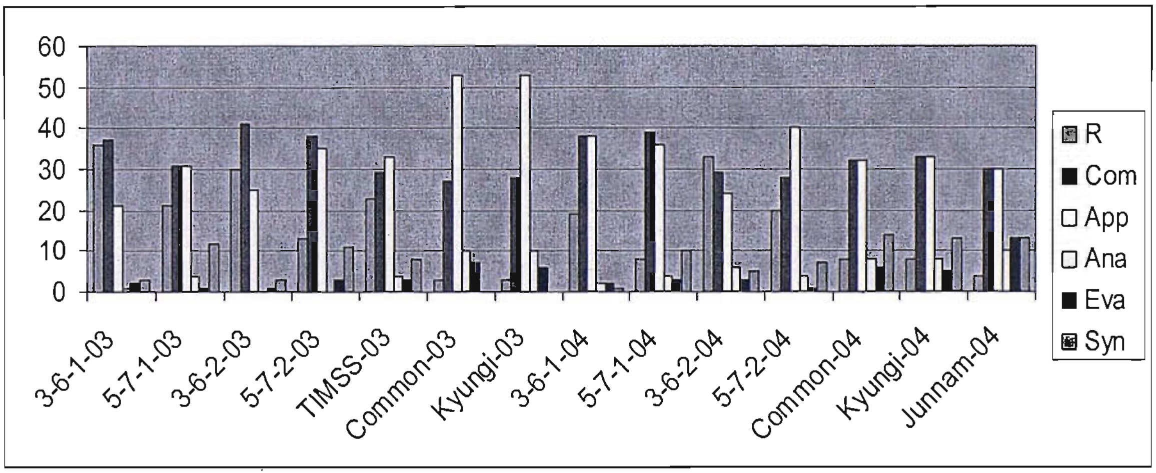
5-3-2 Analysis using Bloom's taxonomy

All items in each test paper are classified according to the following categories. A few questions in the Korean test papers fall into more than one category because they contain more than one cognitive domain. All the data acquired has been turned into percentages so that a comparison can be made more easily. The following Table 24 and figure 11 show the results of analysis by using Bloom's taxonomy.

Table 24 Analysis using Bloom's taxonomy in percentages

Test papers	Recall	Comprehension	Application	Analysis	Evaluation	Synthesis
3-6-1-03	36	37	21	1	2	3
5-7-1-03	21	31	31	4	1	12
3-6-2-03	30	41	25	0	1	3
5-7-2-03	13	38	35	0	3	11
TIMSS-03	23	29	33	4	3	8
Common-03	3	27	53	10	7	0
Kyungi-03	3	28	53	10	6	0
3-6-1-04	19	38	38	2	2	1
5-7-1-04	8	39	36	4	3	10
3-6-2-04	33	29	24	6	3	5
5-7-2-04	20	28	40	4	1	7
Common-04	8	32	32	8	6	14
Kyungi-04	8	33	33	8	5	13
Junnam-04	4	30	30	10	13	13

Figure 11 Distributions of each test paper by using Bloom's taxonomy (%)



As shown in Table 24 and Figure 11, the lower tier in English test papers tends to contain more recall categories than the higher tier test papers. Those lower tier test papers consist of recall and comprehension items. On the other hand, higher tier test papers show more comprehension and application categories. In addition, the table shows a tendency to move toward comprehension and application categories in 2004 test papers.

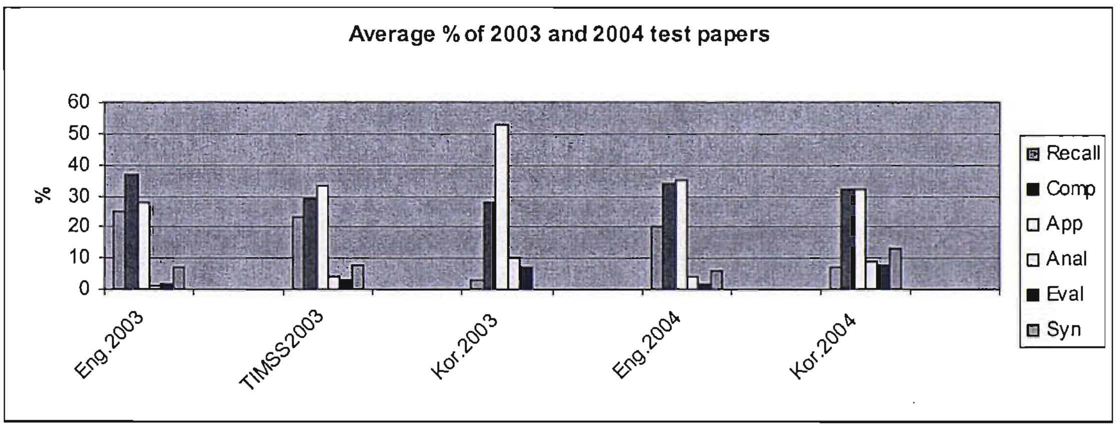
By contrast, Korean test papers contain mainly application and comprehension categories, with a greater proportion of questions in the analysis category than in the English test papers. They also contain fewer recall areas of questions.

Table 25 and Figure 12 show the means and standard deviations in English and Korean test papers in 2003 and 2004 with the later addition of TIMSS 2003. English test papers show a greater standard deviation (SD) with varied distributions in each category and with each test paper. This may refer to either the variety of test items or each test paper containing varied cognitive domain questions in the English test papers.

Table 25 Means of each category in each year with SD (standard deviation)

Test papers	Recall	Comprehension	Application	Analysis	Evaluation	Synthesis
Eng.2003	25 (10.1)	37 (2.0)	28 (0.2)	1 (1.9)	2 (4.0)	7 (0.4)
TIMSS2003	23 (0)	29 (0)	33 (0)	4 (0)	3 (0)	8 (0)
Kor.2003	3 (0)	28 (0.7)	53 (0)	10 (0)	7 (0.7)	0 (0)
Eng.2004	20 (10.2)	34 (5.8)	35 (7.2)	4 (1.6)	2 (1.0)	6 (3.8)
Kor.2004	7 (2.3)	32 (1.5)	32 (1.5)	9 (1.2)	8 (4.3)	13 (0.6)

Figure 12 Average % of 2003 and 2004 test papers



5-3-3 Analysis using Klopfer's Specifications

Klopfer's specifications cover a comprehensive range of science education, comprising *'Knowledge and Comprehension'* (a1-a11), *'Process of Scientific Enquiry'*, *'Application of Scientific Knowledge and Method'* (f1-f2), *'Manual Skills* (g1-g2), *'Attitude and Interest* (h1-h5) and *'Orientation* (i1-i6). The Scientific enquiry area can also be divided into *'Observing and Measuring'* (b1-b5), *'Seeing a Problem and Seeking ways to Solve it* (c1-c4), *'Interpreting Data and Formulating Generalisations* (d1-d6) and *' Building, Testing and Revising a theoretical model* (e1-e6).

However, in this analysis, the area of *'Attitude and Interest'* (h1-h5) has not been included in any test paper. A few questions fall into *'Manual and skills'* categories in English and Korean test papers in 3-6-1-6-b, 2004(appendix 19), and Common-28, 2004(appendix 30) and only 4 questions in English test papers contain *'Orientation'* (i1-i6) in 3-6-2-17,2004 (appendix 31) which relates to the nature of science. Similarly, *'Building, Testing and Revising a theoretical model'* (e1-e6) and *'Application of Scientific Knowledge and Method'* (f1-f2) are not found in any test papers because these categories may belong to the higher knowledge domains and not at this KS3 level of science.

Therefore, the relevant categories have been narrowed down, as shown below in Table 26 and 27. In particular, Korean test papers mostly consist of *'Knowledge and Comprehension'* (a1-a11) and *'Interpreting Data and Formulating Generalisations'* (d1-d6), with only two questions falling into *'Manual Skills'* (g1-g2) and *'Observing and Measuring'* (b1-b5). Whereas, in English and TIMSS-2003 test papers, there are broader ranges of distributions than in Korean test papers.

Tables 26 and 27 show the results of analysis using Klopfer's specifications.
Although the two tables indicate a similar pattern, concentrating on *'Knowledge and Comprehension'* (a1-a11) and *'Interpreting Data and Formulating Generalisations'* (d1-d6) as the area of scientific enquiry, the 2004 English test papers show changes in the diversity of scientific enquiry by having increased the area of *'Observing and Measuring'* (b1-b5) area, and the *'Seeing a Problem and Seeking ways to Solve it'* (c1-c4) area. In addition, the areas of *'Manual Skills'* (g1-g2 and *'Orientation'* (i1-i6) have been added. The Korean test papers, however, show no significant changes from 2003 to 2004.

Table 26 Results of 2003 test papers when analysed according to Klopfer's specifications (numbers of items)

Categories	3-6-1-03	5-7-1-03	3-6-2-03	5-7-2-03	Common-03	Kyungi-03	TIMSS-2003
a1	9	5	25	14	2	3	18
a2	7	3	3	2	2	2	1
a3	22	16	21	12	2	3	15
a4	3	2					
a5			1	1	1	1	4
a6	8	8	3		1	1	5
a7	7		4		2	2	2
a8		1		3	2	2	3
a9		2	2	5	1	1	1
a10	12	23	13	16	7	7	26
a11	2	2	1	1			
b1							
b2							1
b3	1				1	1	
b4	1						1
b5			1	3			2
c1	1	1	2				
c2			1	2			3
c3	1		3	3			1
c4			1	3			3
d1							
d2	2		2	4	1		2
d3	9	8	4	5	5	5	3
d4	1	1			1	2	1
d5	4	3	3	1	1	1	3
d6					1	1	

Table 27 Results of 2004 test papers when analysed according to Klopfer's specifications (numbers of items)

categories	3-6-1-04	5-7-1-04	3-6-2-04	5-7-2-04	Common-04	Kyungi-04	Junnam-04
a1	21	12	13	5	2	2	
a2	6	6	5	4	1	1	1
a3	13	15	18	9	4	5	5
a4					1	1	
a5	8	6	1		5	5	6
a6	1		9	5			1
a7	3		2	2			
a8	3	3	3	3			4
a9		6	4	3	6	6	3
a10	12	10	4	7	10	10	4
a11	1						
b1	1						
b2			1	1			
b3	1	1	1				
b4	1		1				
b5	3		5	2			
c1		1					
c2		1					
c3	2	2	4	4			
c4		1	4	6			
d1	1		2	2			
d2				4			1
d3	10	9	4	6	4	4	1
d4	1		1	5			
d5		1	5	4	5	5	5
d6	1	1				1	
g1					1	1	
g2	1						
i4			1	1			
i5			2	2			

Figure 13 Each category of Klopfer's specifications in 2003 test papers (%)

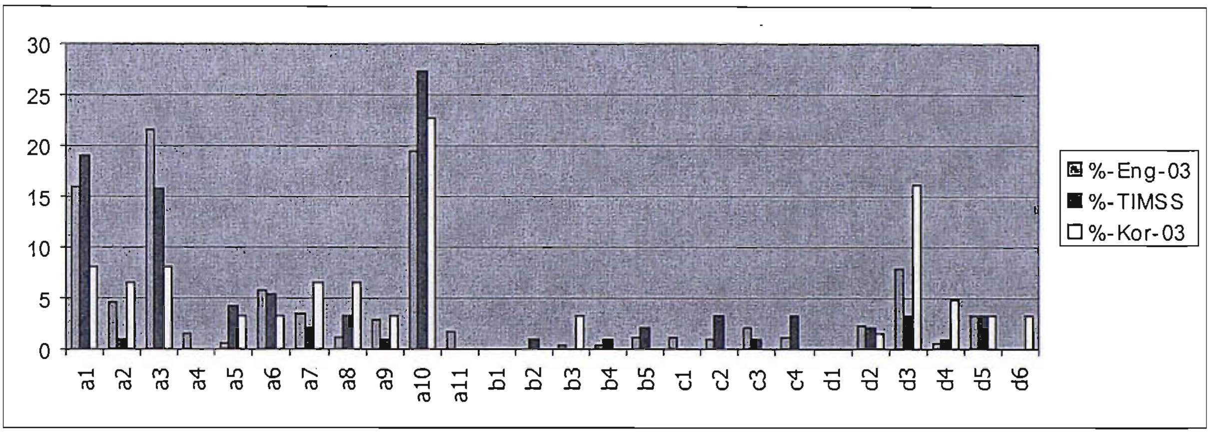
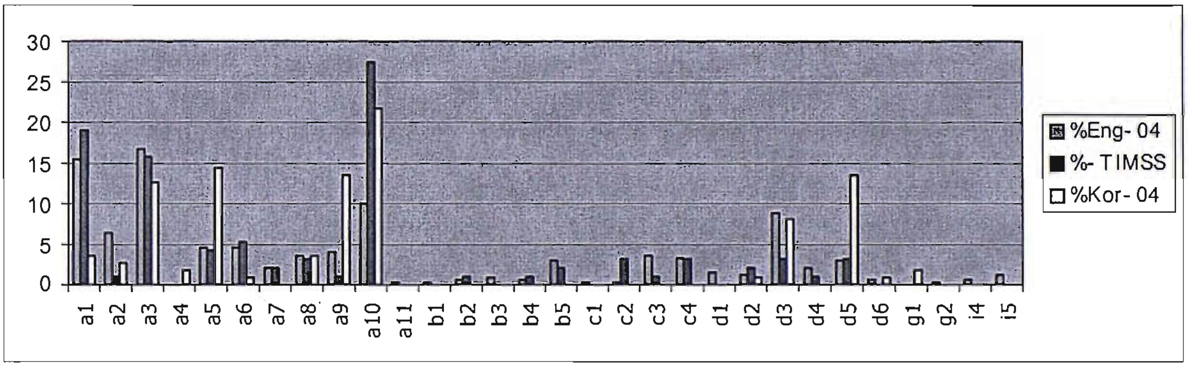


Figure 14 Each category of Klopfer's specifications in 2004 test papers (%)



In order to represent Table 26 and Table 27 graphically, the data have been converted into percentages and are shown as Figures 13 and 14. Generally, English test papers show a wider distribution in 2004 than 2003, whereas Korean test papers show little difference between 2003 and 2004 in this respect. As the above graphs show, Korean test papers generally contain a narrower range of distribution being skewed in the areas of 'a' and 'd' more than English ones

The category of *'Observing and Measuring'* (b1-b5) shows much narrower distributions because it is mainly assessed by performance assessment. In particular, Korean test papers have only two questions in this category, as shown in Common-31, 2003, Kyungi-33, 2003 (appendix 32). The category *'Seeing a Problem and Seeking ways to Solve it' (c1-c4)* mainly covers single scientific investigation questions which are not integrated with other subjects. Therefore, Korean test papers do not fall into this category (c1-c4). In English test papers, Paper 2 for both years has more questions in this category than either of the paper 1 tests. Most scientific enquiry questions fall into *'Interpreting Data and*

Formulating generalisations' (d1-d6) in both English and Korean test papers. In particular, *'Interpretation of experimental data and Observations'* (d3) and *'Evolution of a hypothesis under test in the light of data obtained'* (d5) are major sub-categories.

From the data in tables 26 and 27, a percentage of the sums in each category can be obtained by adding up each sub-category, as shown in tables 28 and 29 and the graph in Figures 15 and 16.

Table 28 Percentage of sums in each category in 2003 test papers

% of sums in each category	3-6-1-2003	5-7-1-2003	3-6-2-2003	5-7-2-2003	Common-2003	Kyungi-2003	TIMSS-2003
a	78	83	81	72	67	69	79
b	2	0	1	4	3	3	4
c	2	1	8	11	0	0	7
d	18	16	10	13	30	28	10

Table 29 Percentage of sums in each category in 2004 test papers

% of sums in each category	3-6-1-2004	5-7-1-2004	3-6-2-2004	5-7-2-2004	Common-2004	Kyungi-2004	Junnam-2004
a	76	77	66	51	74	73	77
b	7	1	9	4	0	0	0
c	2	7	9	13	0	0	0
d	14	15	13	28	26	27	23
g	1	0	0	0	0	0	0
i	0	0	3	4	0	0	0

Figure 15 Percentage of sums in each category in 2003 test papers

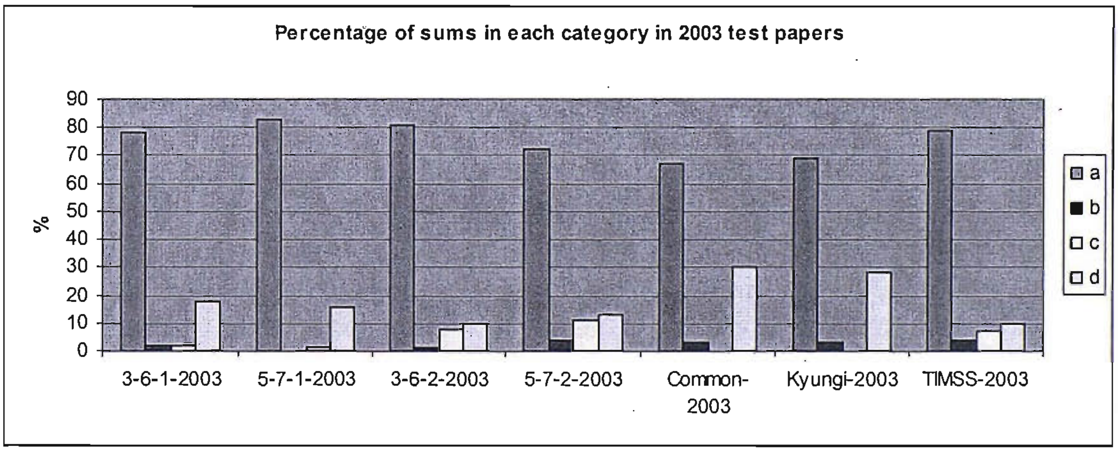
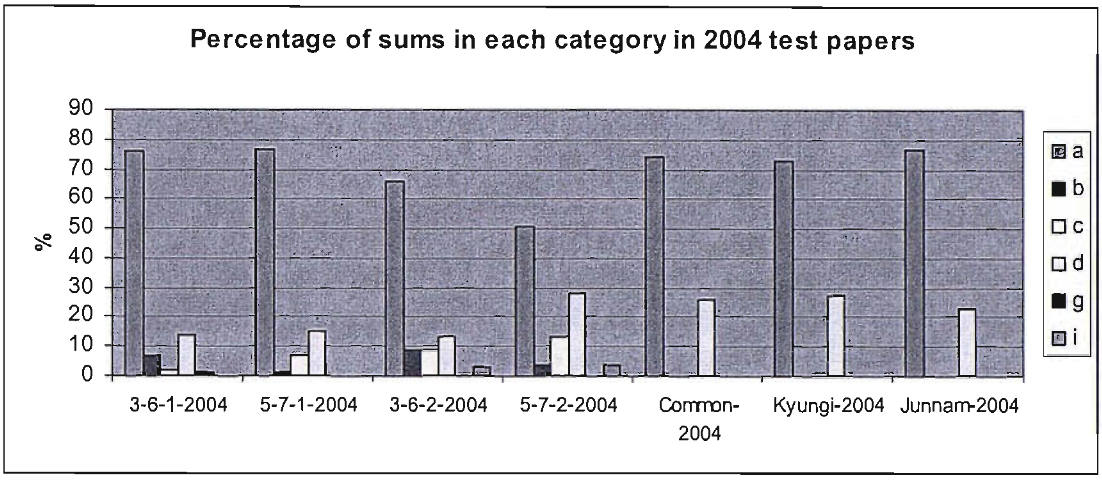


Figure 16 Percentage of sums in each category in 2004 test papers



As shown by the tables and figures, Korean test papers consist of approximately 70% of knowledge comprehension and 30% of data interpretation and show no significant differences between the 2003 and 2004 test papers. By contrast, English test papers show a varied distribution in each category, for example, from 83% to 51% in the *'Knowledge and comprehension'* category. English test papers also show changes in distribution in categories b, c and d indicating an increased proportion of 'c' category questions and more varied distributions amongst sub-categories in 2004 test papers than in 2003. In particular, 5-7-2, 2004 reveals a unique feature in the variety of distribution. It indicates more proportions of 'c' (*Seeing a problem and seeking ways to solve it*) and 'd' (*Interpreting data and formulating generalizations*) and 'i' (*Orientation*) although showing a small proportion. Thus it reflects the increased proportions of discrete investigative questions and data interpretation as well as questions related to the nature of science despite being a tiny proportion. These changes in distribution may reflect changes in scientific enquiry areas in particular. The changes in the distribution of scientific enquiry may refer not only to an increase in the proportion of questions but also to a variation in the nature of the questions.

Finally, in order to compare details of each category, Tables 26 and 27 can be transformed into percentages of each sub-category in each paper, as follows. Although the Korean test papers contain fewer questions, they show a relatively even distribution within the *'Knowledge and comprehension' domain* (a1-a11) whilst English test papers show a tilted distribution towards *'knowledge of specific fact'* (a1) and *'knowledge of concepts of science* (a3) except 5-7-1-2004 which shows a more even distribution than other English test papers within this category.

As mentioned in 4-5, in general, Korean test papers place their emphasis on scientific principles and laws, theories or major conceptual schemes. Consequently, the proportions of a8 and a9 are shown to be higher than in the

English test papers. Thus, Figures 17 and 18 show the proportions of category 'a' (*'Knowledge and comprehension'*).

Figure 17 Percentage distributions of 'a' in test papers in 2003

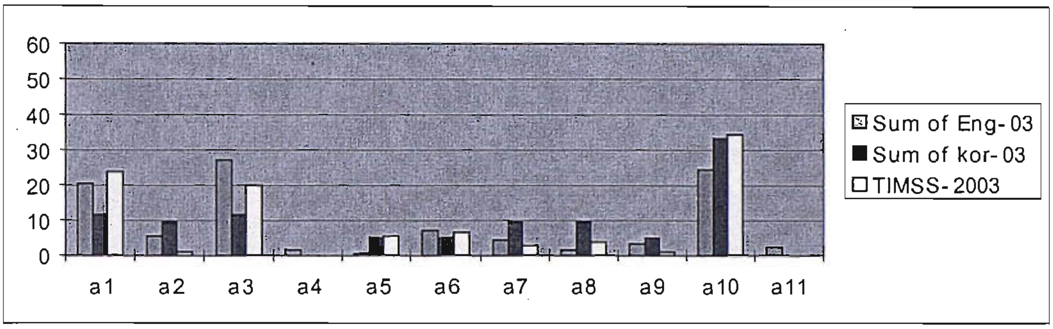
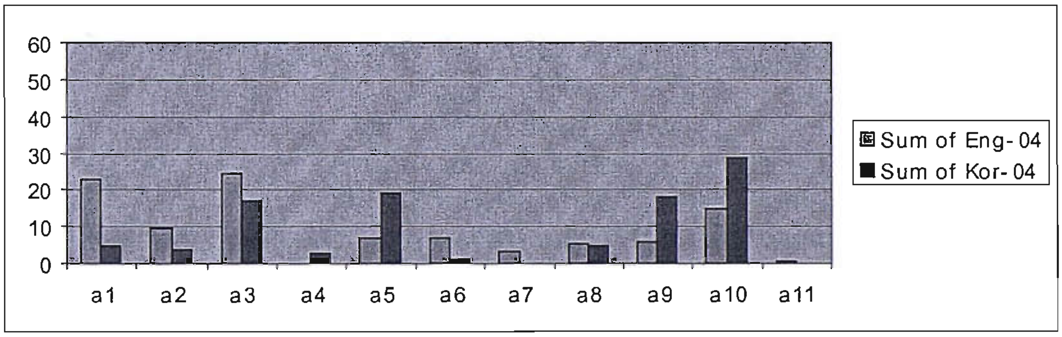


Figure 18 Percentage distributions of 'a' in test papers in 2004



In the area of scientific enquiry, English and TIMSS-2003 test papers show relatively diverse distributions. The following Figures 19 and 20 show the percentage of distribution of 'd' (Interpreting data and formulating generalisations) in each test paper. The figures show that *'interpretation of experimental data and observations'* (d3) and *'evolution of a hypothesis under test in the light of data obtained* (d5) are of major proportions. They also seem to show increased proportions of sums in 'd' as well as a clear change to a bigger proportion from d3 to d5 in Korean test papers in the Korean test papers, whilst showing more diverse distributions from d1 to d6 in the 2004 English test papers.

Figure 19 Percentage distributions of 'd' in test papers in 2003

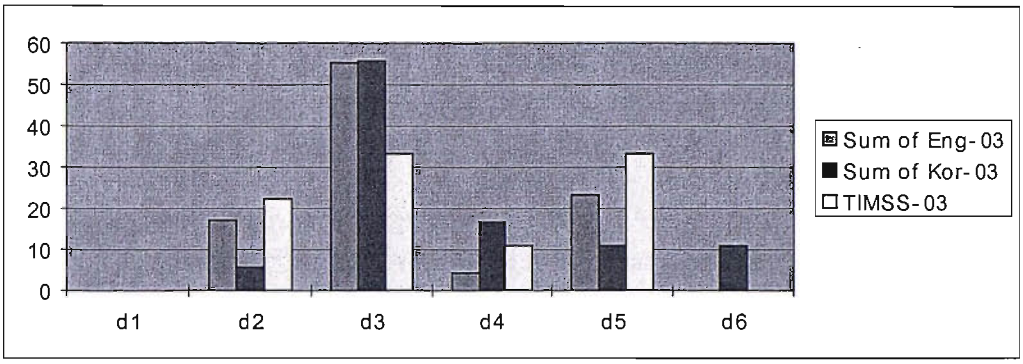
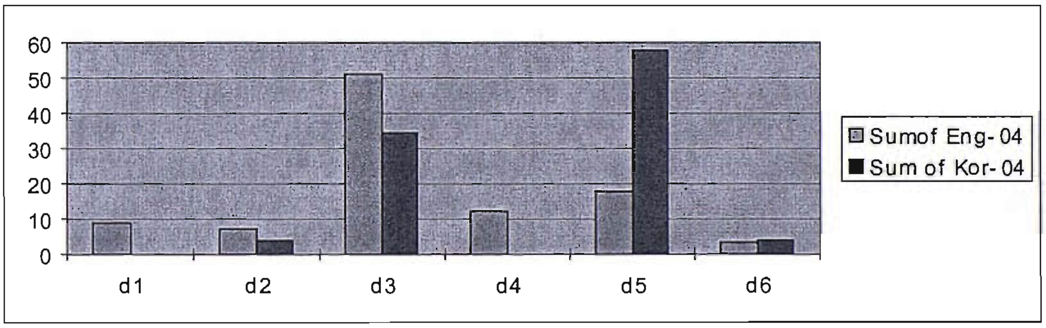


Figure 20 Percentages distributions of 'd' in test papers in 2004



Korean test papers show a narrower range of distribution in scientific enquiry areas, such as 'b' and 'c' and 'g' and 'i', revealing only a few questions found in 'b' and no questions in 'c' 'g' and 'i' as shown in Tables 26 and 27.

In conclusion, by using Klopfer's specification the analysis shows that the distributions of each test paper support the general findings in the section 5-3-1 general findings. There are differences in the areas of Knowledge and Comprehension (a1-a11), showing that Korean test papers emphasize scientific principles and laws, theories and major conceptual understanding as well as revealing a narrower range of scientific enquiry that concentrates on data interpretation.

5-4 Discussion

Throughout this analysis, fair comparisons seem to be difficult because of the differences in the nature of the tests in terms of purpose, type, frequency, number of questions and so on. However, the use of different frameworks has allowed clearer distinction of similarities and differences in triangulation to produce some general findings.

The following section will discuss the similarities and differences between English and Korean test papers considering the dominant effects that standardised examinations have on teaching and the inter-relationship between the aims, content and assessment. The types of questions, the nature of tests and assessment content will be added because these constitute differences between English and Korean test papers.

5-4-1 Scientific enquiry area

The greatest distinction between the two countries' test papers is in the area of scientific enquiry, although examination papers in both countries reflect the importance of scientific inquiry, since they both contain a high proportion of scientific enquiry questions. The examination content also reflects the content of the National Curricula in both countries. There are three areas of difference.

Firstly, there is a significant difference in the level of reflection of the aims and content of the National Curriculum on the assessment. Korean test papers do not include discrete investigative questions and show a narrower distribution of scientific enquiry sub-categories in Klopfer's specifications than the ones in English test papers. In practice, scientific enquiry questions in Korean test papers are only found in four categories of Klopfer's specifications, which are '*Observing and Measuring'* (b1-b5) '*Interpreting Data and Formulating Generalisations* (d1-d6), and '*Manual Skills* (g11-g2). Taking into consideration the fact that the category '*Seeing a Problem and Seeking Ways to Solve it'* (c1-c4) category is included in performance assessment, the contemporary view of science is missing in the '*Orientation*' (i1-i6) category in Klopfer's specifications. By contrast, English test papers show much wider distributions than their Korean counterparts. Those of 2004 also show a wider distribution than those of 2003. Questions in English test papers include diverse question types, various contexts and higher proportions of scientific enquiry, broadening the role of scientific investigations introducing aspects of the nature of science and the ways in which scientists work. There are possible reasons for this. Firstly, the main purpose of Korean tests is to select the more able children by predicting which children have an ability to carry on their learning in high schools, whilst the aim of English KS3 tests are to assess of pupils' academic achievement. Thus, as Sung M W, et al, (2000) points out, the academic achievement tests can be defined as not only measurement-driven instruction but also instruction driven measurement. In other words, assessment can employ content from outside the curriculum content because if the emphasis is on the enquiry process the focus of assessment will be the elements of enquiry rather than the knowledge content. Indeed, English test papers reflect the changes which have been made in broadening the role of scientific investigations and introducing aspects of the nature of science and the ways in which scientists work (Kind, 2003b). In practice, English KS3 test papers in 2004 show a considerable increase in the number of discrete scientific investigative questions and a wider spectrum of distribution in scientific enquiry questions indicating a variety of elements of scientific enquiry ability such as the nature of science. By contrast, the Korean test papers are confined to the content of the current curriculum due to its validity and reliability for the selective purposes of the assessment. Thus, as the purposes are different, the nature of the tests becomes different. It may be quicker to adapt English papers to changing policies because of the nature of the test as a measure of academic achievement, rather than as a means of selection.

Secondly, as has been described in the previous chapter, a different interpretation concerning scientific enquiry seems to affect the content of assessment. The KNSC describes the main aim of scientific enquiry as being the enhancement of understanding basic concepts of scientific knowledge, the reasoning ability of problems and the deducting ability to solve problems (MOE, 2001a). The notion of scientific enquiry is only meant to be a way of helping conceptual understanding of scientific concepts (MOE, 2001b). This seems to reinforce the emphasis on scientific knowledge. Although the HE examination papers have a certain proportion of scientific enquiry questions, they are all integrated with other science subjects.

Finally, Korean schools tend to assess scientific enquiry ability in performance assessment. As was mentioned in the previous chapter, scientific enquiry is difficult to assess, not only in the empirical nature of enquiry but also in conceptual areas. Thus, performance assessment is mostly limited to the skills area. In particular, Korean schools do not place the same amount of weight on practical work compared with English schools. As shown in the previous chapter, although they have a similar amount of time allotted on the timetable, the KNSC has more content knowledge than the ENSC. Consequently, Korean schools seem to have less time to do practical work in the classrooms. Also, practical work tends to be linked directly to performance assessment. Thus, this lack of practical work and the close links it has with the performance assessment may result in difficulty in fostering enough scientific enquiry ability for pupils. Nevertheless, Korean assessment is supposed to assess pupils' enquiry ability by performance assessment and examination papers are to assess content knowledge.

English schools tend to do more practical work than Korean schools as other literature showed (Woolnough, 1991). As was mentioned in the previous chapter, often, scientific investigations are linked directly to performance assessment. Thus, although English science classrooms have more practical work than the Korean counterpart, English classrooms have limitations in fostering pupils' scientific enquiry ability due to the link with performance assessment. As Turner (2000) points out, scientific enquiry in English schools shows a weak connection between scientific enquiry (Sc1) and other subjects (Sc2, Sc3 and Sc4). As a result of this, pupils tend to think of scientific enquiry as a unique element of performance assessment, being separated from and discontinuous with other areas of curriculum content. As the English examination papers contain more discrete investigative questions, the connections between scientific enquiry and other science subjects may be weakened along with carrying out scientific investigations for performance assessment. In practice, English KS3 tests in 2004 show increased proportions of discrete investigative questions so that it means a smaller proportion of scientific knowledge and integrated scientific enquiry questions with other subjects in the assessment. Therefore, it may be necessary to get a better balance between the discrete investigative questions and integrated scientific enquiry questions with other science subjects. Nevertheless, in general the English examination papers reflect more fully the aims of the ENSC in general than do in the Korean counterparts. As mentioned in the aims of the ENSC mentioned, the English examination papers include more contemporary issues and everyday context such as STS (Science-Technology-Society) and everyday applications rather than the theories, principles and laws in the Korean examination papers.

As shown in tables 26 and 27, there are shortcomings between the contemporary views of science and test papers in both countries. Although English KS3 test papers in 2004 have recently employed the elements of the nature of science ('i' category), it seems marginal compared to its emphasis in the curriculum. In addition, there has been no inclusion of the elements of the nature of science and discrete investigative questions ('c' category) in Korean examination papers.

5-4-2 Scientific knowledge areas

Firstly, from the perspective of the scientific knowledge area in test papers, Korean test papers contain higher thinking order questions, demanding difficult conceptual understanding of scientific knowledge. According to the analysis based on Bloom's taxonomy, most questions in Korean test papers tend to fall into application and analysis categories, whilst more questions in English test papers tend to fall into comprehension and recall categories. In addition, even scientific enquiry questions in Korean test papers tend to put the emphasis on reasoning and deducting skills related to scientific principles, theories and laws, rather than on practice or the application in real life contexts. As a result of this, Korean test papers have a relatively higher percentage of mathematical content, demanding inference of science content to mathematical content and a systematic reasoning ability to solve problems. In particular, seven questions (25%) in Junnam-2004 demand mathematical application in solving problems. This also may reflect a Korean tradition to emphasise basic theories and principles, expecting pupils to automatically acquire their applications. This tendency may be why the curriculum content and the tests are deemed to be unnecessarily complicated (Kim S W and Suk H Y, 1993). In addition, English test papers tend to cover less of the content of the National Curriculum than is covered in Korean test papers, despite the greater number of questions in this analysis, whereas the Korean test papers contain compacted questions whereby one question requires more than one cognitive ability, such as those demanding 'comprehension' with 'application' and 'recall' with 'analysis' and so on.

Secondly, the openness of questions in English test papers may reflect the openness of the national curriculum. The openness of a question refers to the fact that a question demands an open answer, in other words, the answers for the question can be varied as far as the explanation for the answer is reasonable and correct. The emphasis on scientific enquiry seems to be moving towards more openness. They also contain more open- ended questions demanding more than one correct answer with explanations of their answers. When the national curriculum specifies a certain topic, such as 'light' or 'sound', the content of assessment can be fairly predictable. However, with questions 5-7-1-14, 2004 (appendix 27) or 5-7-2-6, 2004 (appendix 28) that are 'ideas and evidence' related in the scientific enquiry area, these questions can contain broader contexts. This is because of the nature of the questions which demand pupils' abilities to describe evidence or justify the way the product supports or does not support a conclusion of their own or of others. They also assess pupils' abilities to select and to use suitable strategies, appropriate to different questions, including those in which variables cannot be easily controlled (QCA, 2003b).

Finally, English test papers offer longer explanations about what the questions are asking for, as well as providing more information about the questions and related matters than Korean test papers do. It may take more time to read each question and may need not only scientific knowledge but additional comprehensive ability to understand the given information. In contrast, Korean test papers contain less given information so that some questions cannot be solved without previous knowledge about a certain context.

5-4-3 Types of questions

Firstly, English test papers contain a considerable amount of explanation-seeking, so called 'why- questions' and 'reason-seeking questions' (Zuzovsky & Tamir, 1999). The former are found amongst 'ideas and evidence' related questions mainly and the latter calls for reason in support of a given assertion which is not presupposed mainly in ideas-evidence questions. It is said that through these two forms of questions referring to different contexts, they will, in turn, solicit different types of responses, such as fostering rational arguments (Zuzovsky & Tamir, 1999). Thus, types of questions and an existing repertoire of explanation patterns appear to affect science learning as well as the students' ability to construct an explanation (Zuzovsky & Tamir, 1999). According to Ohlsson, theory articulation is not the same as knowing the abstract theoretical principles but is the ability to 'bridge' between these principles and concrete reality (Zuzovsky & Tamir, 1999). Therefore, in order to foster pupils' ability to build up scientific explanation as an ultimate aim of teaching, the types of questions used in teaching in the classrooms are important (Kim J H & Lee M K, 2003) In this respect, the multiple choice format of Korean test papers has limitations in assessing the students' articulation and pupils' ability to select and organise the appropriate information into logical and coherent responses. In addition, it has limitations in the way it nurtures pupils' ability to explain scientific phenomena and to enhance pupils' creativity, in spite of the major goals of the Korean curriculum being to produce scientific explanations.

Secondly, Korean test papers consist of 100% multiple-choice questions. A multiple-choice format can assess larger amounts of knowledge than any other format in questions (Kim J C, 2004). It is also easier to handle the marking process of a large group when the results will be used as a basis for selection. In addition, the multiple-choice format allows pupils to guess the answers, but if the number of questions is increased, the effect of pure guesswork is considered to be negligible. Thus, it is suggested that the multiple-choice questions have the advantage of improving validity in pre-tests (Taber, 2003). However, multiple-choice question must have limitations even in the planning part of investigations, which may need open-ended answers. English KS3 test papers show reduced proportions of the multiple-choice format but increased proportions of descriptions and explanations.

Finally, English test papers contain a variety of questions emphasising scientific enquiry and the application of scientific knowledge, but these may raise controversial questions concerning the gap between knowledge and its practice. According to Shank's cognitive theory (1986, quoted in Zuzovsky & Tamir, 1999), a new scientific explanation can be constructed as an assimilation of events into already existing patterns of explanations. Thus, if no scientific patterns exist in the students' memory, the process of assimilation and construction of explanation just does not happen (Zuzovsky & Tamir, 1999). Therefore, these may be a mis-match between practical activities and understanding science by having a weak conceptual understanding due to enquiry activities that have not been fully effective.

5-5 Reflections on the analysis of examination papers

Although both sets of test papers reveal differences in the types, aims and contexts of test questions, they may impact on pupils' learning and teachers' teaching because of the nature of their importance.

There are some difficulties in analysing and comparing test papers from both countries and TIMMS-2003 because of the different purposes, question types, numbers of questions and mark schemes in each set of test papers. Those differences seem to lead to other difficulties in analysing questions in cognitive domains by using Bloom's taxonomy, as well as classifying questions by using

Klopfer's specifications. Thus, the analysis focused on the nature of tests in each group rather than pupils' achievements, mark scheme or the levels of feasibility as mentioned in chapter 2 from the view of contemporary science.

However, through this analysis, the general findings could be supported by the results being analysed by assessment frameworks. Thus, findings from both sources give comparisons and evidences for finding similarities and differences between the two samples. Then, the inferences are made for the contemporary view of science. The results are an important reference for developing the teachers' survey questionnaire.

5-6 Summary

It is clear that there are both differences and similarities between the sets of test papers. The greatest difference between the two countries' test papers is in the area of scientific enquiry rather than in scientific knowledge or any of the other components of the test papers. Examination papers in both countries reflect the emphasis on scientific inquiry by having a higher proportion of scientific enquiry questions. The examination content also reflects the content of the National Curricula in both countries.

The English test papers show much wider distributions than their Korean counterparts. In particular, English test papers in 2004 show a wider distribution and higher proportions than in 2003. Korean test papers show a narrower range of distribution in the area of scientific enquiry by retaining a similar proportion of scientific enquiry questions. On the other hand, the Korean test papers include more questions, which demand higher cognitive ability.

In conclusion, the content of the KS3 tests reflect more fully the aims of the ENSC than does the assessment for the KNSC. However, both curricula show their shortcomings in incorporating the contemporary view of science with the curriculum content and assessment.

Chapter 6
Survey of Science Teachers

This chapter explores the sub-question mentioned at 3-1. Thus, the purpose of this chapter is to discuss and to discover the teachers' views about the nature of science, scientific enquiry and opinions about teaching and assessment within the area of scientific enquiry, including how teachers overcome the difficulties inherent within the element of the nature of science and of scientific enquiry as a way of teaching science. This research also includes teachers' opinions of sample questions, which have been selected from the test papers. Then, the research will make comparison between two groups of teachers from England and Korea.

6-1 Background

In the previous documentary analysis, the English and the Korean test papers were analysed to find out what teachers teach and assess about scientific enquiry. This chapter sets out to discover how teachers think they teach scientific enquiry in both England and Korea in order to explore the research question; ***What is the impact of assessment in scientific enquiry on the perception of the teaching of science enquiry at age 14 in a comparison between England Korea?***

The national curricula contain the templates for coverage and methods that are seen as guiding, directing or controlling the routine classroom work of a school or of an entire school system in both countries and may shape teachers' actions. As both national curricula now put emphasis on the nature of science and scientific enquiry, teachers are expected to cover and follow the scheme of work and guideline of the national curricula.

However, teachers own views of the expectations of science curricula may not agree with the national curricula. McComas (1998) has suggested that science teachers must not only include in their teaching the accepted knowledge domain but also explanations about the generation of knowledge comprising why a particular proposition is deemed warranted, why it is worth knowing and how it relates to other propositions both within the discipline and without, both theory and practice being regarded as the nature of science. He also mentioned that teachers' laboratory activities convey much about science processes and the construction of knowledge. Thus, to present the processes of science, classrooms should look like a research laboratory where students participate in science activities as part of a social group by students being given more responsibility for developing experiments to investigate a particular question.

Therefore, the challenge is for teachers to translate an understanding of the knowledge generated and shown in the national curricula into meaningful classroom experiences and appropriate classroom discourse. As McComas (1998) argues, the integration of the nature of science can be related to changes in a teacher's curriculum, pedagogical and subject matter knowledge. In order to integrate the nature of science, teachers need to expand, enrich and elaborate their own knowledge systems so that they are enabled to translate their knowledge and intentions into practice. As research reveals, although teachers acknowledge the importance of teaching scientific enquiry, they reveal difficulties in deciding how they teach it (Millar & Lubben, 1996). As mentioned in chapter 2, implementing scientific enquiry seems to be a complex process: along with teachers' perceptions and intentions about the nature of science and various factors are inter-locking amongst textbooks, the national curriculum, assessment-driven teaching practices. Most of all, assessment-driven school curricula seem to be a great stumbling block to implementing the nature of science and scientific enquiry into the classrooms (Black, 2000). Teachers tend to look to examination questions for a more precise definition of what the intentions of any course are. As a result of this, teachers may place too much emphasis on a limited domain of the curriculum in the limited subset of skills. In addition, such assessment materials are often used for practice in examination questions, for homework and to familiarise the students with the level and demands of the course. Thus, without the assessment content, it is most likely not to be learnt. Therefore, in order to explore this research question, sub questions have been developed as follows.

Sub-questions

1. *What are teachers' perceptions about the nature of science?*
2. *What are teachers' perceptions about scientific enquiry?*
3. *How do they think they teach scientific enquiry?*
4. *How do they think they assess scientific enquiry?*
5. *What do they find difficult about of teaching and assessing scientific enquiry?*
6. *How would they prepare for teaching to enable pupils to answer specific examination questions?*
7. *What strength and weaknesses do they find in the examination questions?*

6-2 Methodology

To explore answers to these questions, qualitative survey methods are used including teachers' perceptions about the nature of science and scientific enquiry, how they think they teach and assess scientific enquiry as well as opinions about the sample questions from TIMSS-2003. This is to be undertaken by means of a questionnaire.

6-2-1 Sampling

The main focus of the research is science teachers who teach year 9 pupils with the national curricula in both countries. Thus, the subjects are science teachers who teach KS3 programme of study in England and the ones who teach middle school science in Korea. The effect of location was minimised by distributions questionnaires to a number of randomly selected schools including Southampton, Bournemouth, Cambridge, Oxford, Sheffield and London in England and Seoul, Kyungi, Junnam, JunBook, Kangwon, Incheon in Korea. Teachers from both countries are mainly from state schools in order to make fair comparison.

6-2-2 Developing the questionnaire

The questionnaire for science teachers was developed in the 4 areas as follows.

The four areas of questionnaire development

The questionnaire consists of 24 questions concerning teachers' personal details, teachers' perceptions about the nature of science and scientific enquiry, how teachers teach and assess scientific enquiry and teachers' opinions about the questions from examination papers (Appendix 33)

A. Teachers' personal details (question1-5)
B. Teachers' perceptions of the nature of science and scientific enquiry (question 6-7)
C. Teachers' perceptions about their teaching and assessing scientific enquiry (question 8-19)
D. Teachers' opinions about the questions from TIMSS-2003, KS3 and High school entrance examination papers (question 20-24)

Teachers' personal details cover age, sex, teaching careers and studying experiences concerning the elements of the nature of science. The objects of this research are teachers who teach year 9, KS3 pupils with the national curricula in both countries. The personal details may be expected to be reference points for comparing the two groups of teachers.

The second and third parts of the questionnaire are to ask questions about teachers' perceptions concerning the nature of science and scientific enquiry as well as how they teach and assess scientific enquiry including difficulties encountered in the implementation of more scientific enquiry in teaching.

The last part consists of three examples of questions from TIMSS-2003 (s10-08), HE examination in Korea (Common-30, 2004) and KS3 test papers in England (5-7-1-14, 2004) (See appendix 33, section D, Question A, B and C). Each question is selected for its typical nature. The question from the end of KS3 is a discrete scientific investigative question, which is not found in Korean test papers. Although English KS 3 tests include other scientific enquiry questions, which are integrated with biology, chemistry or physics, the discrete investigative questions with open-ended answers are regarded as typical because they are found only in KS3 test papers. The Korean question for HE examination illustrates its great emphasis placed on content knowledge with graph interpretations although it is categorized as a scientific enquiry question. The question requires higher level of science knowledge, mathematical skills with using conceptual enquiry. TIMSS-2003 question shows both characteristics: it is looking for scientific investigative skills as well as having a multiple-choice format the same as the Korean question. Questions in part D stem from the results of examination papers analysis. The final version of questionnaire is shown in Appendix 33. Table 30 shows the summary of the area of the questionnaire

Table 30 The Questions

No	Content	Remarks
1	Age	**A. Personal details**
2	Sex	
3	Period of teaching	
4	Background (Subjects)	
5	Background (Knowledge of the nature of science)	
6	Perception of scientific enquiry	**B Perceptions about the nature of science and Scientific enquiry**
7	Perceptions of the nature of science	
8	Aims of teaching science	**C Teaching and Assessing**
9	Teaching methods frequently used in the teaching of science	
10	Aims of practical work	
11	% frequency of doing practical work	
12	The main focuses when teaching scientific enquiry	
13	Teaching methods frequently used in the teaching scientific enquiry	
14	Confidence in teaching scientific enquiry	
15	Openness of investigations	
16	Mismatches between understanding the concept and the process	
17	Obstacles in implementing more scientific enquiry	
18	Scientific enquiry activities affecting pupils' achievements in science	
19	The pressure of examinations affecting the teaching of scientific enquiry	
20	Opinions about how well pupils give the right answer to each question	**D. Opinions about the questions from TIMSS-2003, KS3 and HE (High school Entrance examination)**
21	Opinions about how to prepare pupils to answer each question	
22	Opinions concerning questions which are more likely to change teaching methods	
23	Opinions about question being multiple choice likely to lead to right answers	
24	Opinions concerning the content of assessment	

6-2-3 Rationale in each section

<u>Part A</u>

Teachers' personal details (question 1-5)

This research is designed for science teachers who teach year 9 pupils following the instruction of the National Science Curricula in England and Korea. Teachers may have a different background of subjects as well as having different routes of becoming teachers in both countries. As a result of this, teachers may have different views and experiences about the nature of science. Therefore, it is necessary as a minimum to take into consideration the 5 questions concerning teachers' personal details including age, sex, period of teaching, background and their experience about the nature of science.

These questions can be directly related to questions 6 and 7: teachers' perceptions of the nature of science and scientific enquiry and question 13 and 15 can be linked indirectly in terms of interpreting results of this research: their confidence in teaching and their difficulties in teaching scientific enquiry.

<u>Part B: Perceptions about the nature of science and scientific enquiry</u>

Teachers' perceptions about scientific enquiry (question 6)

Through the review of other research, there may be some misconceptions of the term 'scientific enquiry' among both English and Korean teachers. As Woolnough (1991) has pointed out, most science teachers in England regard scientific enquiry as doing practical work in the classroom. On the other hand, some Korean teachers tend to use scientific enquiry as inquiry based teaching such as 'scientific enquiry' or 'social enquiry'. Thus the term scientific enquiry is used as a way of learning by using reasoning and reflection. Some teachers tend to think of it similarly to English teachers, as doing practical work. In addition, Korean textbooks show their mixed conceptions about scientific enquiry by referring to scientific enquiry as 'observing and thinking,' 'reading and thinking,' 'hands-on activities', 'experimentation' and so on.

Therefore, there may be a gap between the descriptions in the national curriculum and teachers' perception in practice. In particular, the analysis of test papers reveals that the Korean tests do not contain scientific investigation questions and show a narrower range of scientific enquiry questions: mainly they are data interpretation according to Klopfer's classification. The question explores the gap.

Teachers' perceptions about the nature of science (question 7)

There are conflicting accounts amongst educators concerning teachers' perceptions about the nature of science. One argues that teachers' perceptions of the nature of science translate into their pedagogical content knowledge. Thus, teachers' perceptions about the nature of science affect teachers' attitude and understanding and interpretation of science disciplines so that they play an important role in their teaching practice (Khishfe & Abd-El-Khalick, 2002).

Others argue that teachers' perception of the nature of science does not significantly influence their behaviour in the classroom (Osborne, et al, 2003). Research shows that disparity has been found between the perceptions of the nature of science and teaching practice in the classrooms.

However, teachers' views about the nature of science often refer to underlying assumptions or values including the meaning of science, method, consensus making and the characteristics of knowledge produced (Schwartz, et al, 2004). Thus, the views about the nature of science seem to affect matters in indirect ways. As research indicates, there is an ambiguity between their perceptions and their practices (Abd-El-Khalick, 2000)

Nevertheless, Kim H K and Song J W (2004) argue, deficient conceptions about the nature of science in learning and teaching appear to constitute obstacles to the implementation of scientific enquiry. In addition, understanding the nature of science has been a common goal and continues to hold an important place in both Curricula.

Therefore, to explore how teachers think they teach and assess scientific enquiry seems to be important. In this research, question 7 has been developed based on '*your own nature of science profile*' (Nott and Wellington, 1993, p109). Question 7 is to ascertain individual teachers' own philosophy of science. Their original questionnaire consisted of 24 items, including statements concerning instrumentalism and realism. However, question 7 in this survey consists of 14 items. Some statements concerning instrumentalism/realism have been excluded because three out of five statements overlap with the ones in relativism and positivism (RP). As mentioned at section 2-2-5, a speculation has been applied to the tendency in relativism and positivism (RP) that those who show a positivist tendency may be more likely to show a tendency toward Realism. Some of the statements have also been excluded because these are regarded, as it is not directly related to teachers' teaching practice. Finally, the question includes the statements concerning inductivism or deductivism(ID), contextualism or decontextualism (CD) and process content(PC) or relativism and positivism(RP). Finally, the statements become 14 as follows.

Inductivism or Deductivism (ID)

1) Scientists have no idea of the outcome of an experiment before they do it.
2) Science proceeds by drawing conclusions, which later become theories.
3) Scientific theories are as much result of imagination and intuition as inference from experimental results.
4) All scientific experiments and observations are determined by existing theories.

Contextualism or Decontextualism (CD)

5) Science facts are what scientists agree they are.
6) Scientific research is economically and politically determined.
7) Scientific theories have changed overtime simply because experimental techniques have improved.
8) In practice, choices between competing theories are made purely on the basis of experimental results.

Process or Content (PC)

9) Science education should be more about the learning of scientific processes than the learning of scientific facts.
10) The most valuable part of a scientific education is what remains after the facts have been forgotten.
11) Scientific method is transferable from one scientific investigation to another.
12) A good solid ground in basic scientific facts and inherited scientific knowledge is essential before young scientists can go to make discoveries of their own.

Relativism or Positivism (RP)

5) Science facts are what scientists agree they are.
8) In practice, choices between competing theories are made purely on the basis of experimental results.
13) There are certain physical events in the universe which science can never explain.
14) Scientific knowledge is different from other kinds of knowledge in that it has a higher status.

In the original questionnaire, the score was on the scale of 1 to 10, from +5(strongly agree) to –5(strongly disagree) but this seems to be unnecessary in this questionnaire. Thus, a 5point scale is used for convenience. Thus, the responses of teachers are to be scored so that +2 will indicate strong agreement to the statement, -2 strong disagreement and a score of 0 will indicate a balanced view.

Table 31 Scoring methods for each statement

Statement		Score	Statement		Score	Statement		Score	Statement		Score
1	-		5	-		9	-		5	-	
2	-		6	-		10	-		8	+	
3	+		7	+		11	-		13	-	
4	+		8	+		12	+		14	+	
Total			**Total**			**Total**			**Total**		

Then, the score for each question will be put into the appropriate box. Some scores have to have their sign reversed (for example, multiply by –1) before they can be entered into the box. After the numbers add up the sub- totals, then transfer the mark indicating the relevant positions as shown below.

Table 32 The range of the views about the nature of science

Inductivism and Deductivism (1-4)	-8 ------------0---------- +8
Contextualism and Decontextualism(5-8)	-8 ------------0---------- +8
Process and Content (9-12)	-8 ------------0---------- +8
Relativism(5,8,13,14)	-8 ------------0---------- +8

According to the author of the original questionnaire, the interpretation of the results is as follows in Table 33.

Table 33 Interpretation of views (Nott & Wellington,1993, p111)

Positions	Interpretations
Inductivism	By observing many particular instances, one is able to infer from the particular to the general and then determine the underlying laws and theories. According to inductivism, scientists generalise from a set of observations to a universal law 'inductively'. Scientific knowledge is built by induction from a secure set of observation.
Deductivism	You believe that scientists proceed by testing ideas produced by the logical consequences of current theories or of their bold imaginative ideas. According to deductivism, scientific reasoning consists of the forming of hypotheses, which are not established by the empirical data but maybe suggested by them. Science then proceeds by testing the observable consequences of these hypotheses : they are theory-laden.
Contextulaism	You hold the view that the truth of scientific knowledge and processes is interdependent with the culture in which the scientists live and in which it takes place
Decontextualism	You hold the view that scientific knowledge is independent of it cultural location and sociological structure.
Process	You see science as a characteristic set of identifiable method/ processes. The learning of these is the essential part of science education.
Content	You think that science is characterised by the facts and ideas it has and that the essential part of science education is the acquisition and mastery of this 'body of knowledge'.
Relativism	You deny that things are true or false solely based on an independent reality. The 'truth' of a theory will depend on the norms and rationality of the social group considering it as well as the experimental techniques used to test it. Judgements as to the truth of scientific theories will vary from an individual and from one culture to another i.e. Truth is relative not absolute.
Positivism	You believe strongly that scientific knowledge is more 'valid' than other forms of knowledge. The laws and theories generated by experiments are our descriptions of patterns we see in a real, external objective world. To the positivist, science is the primary source of truth. Positivism recognises empirical facts and observable phenomena as the raw material of science. The scientists' job is to establish the objective relationships between the laws governing the facts and observables. Positivism rejects inquiry into underlying causes and ultimate origins.

Part C: Teaching and assessing

Opinions about aims of science in the planning of teaching (question 8)

This section is based on the documentary analysis of the national curricula and the analysis of the test papers. Question 8 teachers consider the focus of their teaching. In particular, items 1 and 2 and 4 in questions 8 explore a typical tendency in the assessment driven teaching method. According to the research, if teachers are focusing on answering all the questions asked by students, they tend to think the content of teaching may be absolute truth not tentative (Kim H K and Song J W, 2004). Question 8 also allows reflection on teachers' opinions about the importance of a learner-centred learning environment in items 3 and 6.

In practice, teachers may not realise whether they teach science or scientific enquiry because science lessons are often involved with scientific enquiry activities with teaching science content. Thus, pupils can get scientific enquiry ability by doing practical work and carrying out scientific investigations rather than scientific enquiry being taught separately. However, some questions in this questionnaire are being asked separately in science and scientific enquiry. Thus, teachers may answer by thinking with different angles in the same science lessons.

Teaching methods frequently used the teaching of science (question 9)

Traditionally, English schools have emphasised doing of practical work in science classrooms whilst science classrooms in Korean schools are not much different from those teaching other subjects. Recently, science lessons in Korea have employed more experimentation and other hands-on activities. Question 9 is to know how two groups of teachers teach science.

Teachers' talking, note taking, teachers' demonstration and *working from work sheets & textbooks* tend to be traditional teaching styles in Korea. In particular, frequent use of working from work sheets & textbooks are to familiarise the children with assessment content. *Whole or group discussion, role play, research by students, experimentation* and *video watching* represent learner-centred activities, helping to reflect content knowledge and its applications.

Aims of practical work (question 10) and frequency of doing practical work in science classrooms (question 11).

Question 10 is to discover teachers' opinions about the purposes of practical work. Each statement comes from the research about teachers' perception of practical work (Wellington, 1998, p6). These numbers can be categorised into three areas: the purpose of practical work is to enhance pupils' motivation, to enhance cognitive understanding and to enhance process skills. This question may also relate to question 6 and 7 concerning teachers' perceptions about the nature of science and scientific enquiry.

The main focus when teaching scientific enquiry (question 12)
Question 12 is about teachers' focus when teaching scientific enquiry. This is similar to purposes for doing practical work such as motivating students; enhancing cognitive understanding and enhancing process skills can be themes in teaching scientific enquiry. In addition, scientific enquiry activities can enhance scientific reasoning, problem solving ability and fostering an understanding the nature of science.

However, recent research reveals that the main aim of scientific investigation is to assess performance assessments for pupils (Robert & Gott, 2004). It may relate to question 6 that is teachers' perception about scientific enquiry. The examples are similar to the aims of practical work in question 10.

Opinions about teaching methods frequently used in teaching scientific enquiry (question 13)
Although some teachers may not distinguish teaching science from teaching scientific enquiry, this question is to ask about the same classroom with different angles emphasising scientific enquiry rather than teaching science to show up any differences between teachers' perceptions of the purpose and nature of teaching the two. Fieldwork and investigation items are added into the items of teaching science in question 9.

Opinions about teachers' confidence in teaching scientific enquiry (question 14)

Although there is a great emphasis on scientific enquiry in both the 7th National Curriculum in Korea and the new policy in England (QCA, 2003a), the area of scientific enquiry seems to be new to both countries. According to the report, pupils showed their weaknesses in answering the scientific enquiry questions at the end of KS3 tests in 2003 (QCA, 2003b). Thus, eight out of eleven booster lessons, which have been provided by QCA, in order for teachers to help students' understanding in the area where pupils have show weaknesses at the KS3 tests, were scientific enquiry questions comprising of analysing and interpreting data, working with variables, evaluating evidence and how scientists work (QCA, 2003b).

Teachers' confidence in teaching scientific enquiry is one of the most important elements in this new stage of implementing more about scientific enquiry area. This question is asking how they describe their self-confidence in teaching scientific enquiry. This question may relate to the obstacles of implementing more scientific enquiry as posed in question 17.

Openness of investigation (question 15)
Scientific investigation is at the centre of scientific enquiry activity along with the elements of the ideas and evidence in the ENSC. Fundamentally, scientific investigation is to foster pupils' curiosity in natural phenomena and to develop explanatory ideas tested against everyday life. According to Jenkins, this curiosity is allied with imagination that lies at the heart of any creative endeavour (Jenkins, 2000). In addition, the KNSC mentioned that science lessons should be taught as part of a scientific enquiry process. Although the outcome of investigation is knowledge, which is not reconstruction of existing knowledge, the knowledge is new in the sense that it provides information about issues that was not hitherto available.

Therefore, it is important to give pupils a sense of ownership of their investigation. The ownership may be more effective for promoting deep understanding of science (Jenkins, 2000). This question 15 is to know which group of science teachers give more freedom to their pupils for performing science investigations. From this question may be drawn a picture of how pupils' experiences in conducting scientific investigation may ultimately contribute to their view of the nature of science (Schwartz, et al, 2004). Ideally, as pupils have more opportunities of ownership in the investigation, they may make sense of the connection that relates theory to supporting data, to conflicting theories, to anomalous data, to equivocal data, what can be taken as data and what is disqualified, what is strong evidence and what is weak evidence (Driver, et al, 1996; Jenkins, 2000).

However, as the main aim of investigative work in practice is for assessment, the school curriculum tends to do coursework, which is used to assess the scientific enquiry element of the performance assessment. Therefore, the assessment can restrict the freedom of open-ended scientific investigations for pupils (Roberts & Gott, 2004).

Opinions about mismatches between understanding related scientific concept and process skills (question 16).
As McComas argues, the form of laboratory activities conveys much about science processes and the construction of knowledge. Unfortunately, these experiences are often cookbook or verification type laboratory activities (McComas, 1998). As a result of this, there are discrepancies between understanding of relevant concepts and the aims of the investigation as well as with the process pupils are engaged in. Kind (2003a) also supports McComas arguing that much investigative work in school science has developed around specific types of task with a focus on scientific process skills.

In particular, the TIMSS-PA (Performance Assessment) in 1995 results revealed Singapore on top in overall but on the science tasks England was equal to Singapore in investigative tasks such as ' *investigate what effect different water temperatures* *have on the speed with which the tablet dissolves*' or '*Find out how your pulse changes when you climb up and down*'. Kind (2003a) argues that TIMSS-PA reveals some of this English schools' tradition of involved considerable amounts of practical work with its emphasis on scientific enquiry. The test format being used in the TIMSS-PA was similar to the guide of APU (Assessment of Performance Unit) in England (Kind, 2003a). Kind (2003b) also suggests that the mismatches in brilliant achievement in the area of scientific enquiry and poor understanding of the nature of science amongst English students might stem from the process-based approaches of school science. Often, this not only damages pupils' motivation, because they already know the results, but also tends to omit the process of why and how the related knowledge is produced being totally divorced from human influence on the scientific knowledge acquired (Roberts & Gott, 2004). Thus, the question 16 asks how much teachers are aware when this mismatch are most likely to happen.

Opinions about obstacles in implementing more scientific enquiry in the science classroom (question 17)

Research has demonstrated the complexity of implementing scientific enquiry into the classrooms (Osborne, et al, 2003; Kim H K and Song J W, 2004). According to the research, the main obstacles pointed out to the implementation of the enquiry by Korean teachers are external factors such as the lack of time and resources to support scientific enquiry (Kim H K and Song J W, 2004). However, the depth of understanding about scientific concepts and the openness of scientific enquiry activities reveal as the most difficult challenge for teachers as well as for students in Korea (Kim H K and Song J W, 2004). The authors also argue that the deficient conception about the nature of science and the nature of scientific enquiry and the lack of confidence in teaching scientific enquiry appear to constitute obstacles to the implementation of scientific enquiry in their teaching.

According to Osborne, et al (2003), another fundamental difficulty is that many science teachers themselves are educated under circumstances, which have largely ignored the epistemic base and nature of its own discipline (Osborne, et al. 2003). Along with this lack of understanding about the nature of science and scientific enquiry and because of curriculum recommendations, teachers tend to transfer most elements of scientific enquiry indirectly and implicitly by doing practical work and scientific investigations (Osborne, et al, 2003).

The items for this question come from Kim and Song's research (Kim H K and Song J W, 2004) and are supported by other research (Osborne, et al, 2003). Items 1-6 are external reasons why it is difficult to implement more scientific enquiry in the classroom. 7-11 are internal reasons for teachers.

Opinions about scientific enquiry activities helping to achieve better performance in science and about the pressures of assessment (question 18, question 19)

As shown in literature review, outcomes of assessment may be one of the most important factors in implementing more scientific enquiry in the classroom. If teachers regard assessment in scientific enquiry as important, it may achieve a higher profile in teachers' agenda. In England, in a study of science teachers' choice of activities in their teaching of the National Curriculum for assessment, the most frequently reported activity by far was given as ' practical work in groups' closely followed by 'scientific investigation' for 'performance assessment' (Donnelly, 2001). The focus of practical work in science is identified mainly with assessment, which narrows the range of strategies and activities to which pupils are exposed. Therefore, the scientific enquiry activities seem to be closely related to summative examinations and performance assessment. This is not much different from Korean schools. The assessment system tends to force teachers and pupils to rehearse for testing, limiting the scope of the curriculum. This question is to explore how teachers regard the activities in enhancing the final science grades for the pupils.

Part D: Different types of questions assessing scientific enquiry

Opinions about the feasibility of questions for their students (question 20)

The three examples of question A, B and C may be new to teachers and students alike because questions introducing scientific investigation and reinforcing scientific enquiry questions are relatively new. Three different sets of questions from the English, Korean and TIMSS-2003 were being given to teachers.

In particular, TIMSS-2003 paper has changed from previous ones that had a higher proportion of multiple-choice format with a conceptual understanding domain to a more open-ended format with an increased proportion of scientific enquiry.

Question 20 is to find out how well teachers think that the year 9 pupils can answer each type of question. This may relate to how familiar they are with the type of question or whether the curriculum content covers the questions.

Opinions about how teachers would prepare pupils to take the three different scientific enquiry questions (question 21)

According to research, the elements of scientific enquiry have been largely ignored by schools in both countries despite the emphasis on the policies and amongst educators. Generally, teachers' regard the elements of scientific enquiry as tacitly acquired by doing practical work or investigative work. Question 21 is being asked to ascertain how teachers would teach for the answering of those questions.

Opinions about which one of three questions, is the most likely to change teachers' teaching practices (question 22)

Question 22 asks how teachers would change their teaching method if the proportions of each type of question were increased by up to 30%.

The question may also relate to question 23 by asking about how they would teach for those types of questions. It may be one of the most important questions to explore the research question: ***What is the impact of assessment in scientific enquiry on the perception of the teaching of science enquiry at age 14 in a comparison between England Korea?***

Opinions about the KS3 in English question (question 23)
This type of scientific investigative question may not be familiar to Korean teachers and students because external tests are mainly in multiple-choice format. Question 23 asks if the question is multiple-choice format, how the students are more likely to answer the question. This question is to know whether the difficulty in answering the question lies in the content or the format of such an investigative question.

Opinions about the content of assessment (question 24)
Scientific investigative questions have been introduced towards the end of KS3 tests since 2003 in order to assess pupils' procedural understanding. Investigative questions can have varied context and content because the purposes of the question may include elements of investigation such as dependent variables, independent variables, controlled factors and so on. If the proportion of this type of question is increased, the content of scientific knowledge area can become narrower than the current content area.

Therefore, question 24 is asking how much teachers are concerned about the content of assessment. In particular, Korean teachers may be used to assessing the content and context within the national curriculum because of its assessment tradition. According to the result of test papers analysis in chapter 5, English test papers tend to cover less of the content of the national curricula.

6-2-4 Pilot research

The research was piloted twice during early January and June 2005 in order to know if the questionnaire was relevant to science teachers in England and Korea. Pilot research has been useful because the questionnaire as a research instrument would be used only once in order to acquire data. The original questionnaires were given to 10 English science teachers and 4 Korean science teachers through the website (**www.eduict.org**). They were asked to record time taken to complete the questionnaire and their opinions concerning the questionnaire design, difficulties in answering the questions, ways to improve quality of the questionnaire. The elements of nature of science and scientific enquiry seemed like a new area for the teachers to comment on that they found it difficult to answer the questions. Interestingly, a Korean science teacher responded to part D so that he listed lots of background science knowledge including the reasons why flowers became withered, principles of genetic mutations and the ways to maintain moisture content from the stems. So, it seemed impossible to have open-ended questions in terms of time taken and the variety of answers. The teachers also indicated that it took 20-40 minutes to complete the questionnaire. In accordance with the results, questionnaire revisions were made in order for teachers to answer the questions easily. Subsequently, the questionnaire tended to give more explanations and to reshape into multiple-choice format. Thus, the pilots increased validity of the research. Finally, the questionnaire were set up and translated into Korean.

6-2-5 Procedures

The main research was conducted from May 2005 to September 2005 among English science teachers and Korean science teachers. The questionnaires were sent to science departments in some schools by post, handed out to some schools by hand and to science teachers during in service training in England. Translated questionnaires were sent to Korean teachers in middle schools whom I had contacted in advance. The translated questionnaires were also sent out to various areas of middle schools in Korea by post and were handed out to teachers during an in service training course in Korea.

Table 34 The questionnaires distributed and collected

Eng	Area	School	Returned
	South East England	Selective girls school	10
		Selective boys school	5
		Girls Comprehensive school	6
		Mixed comprehensive school	5
		Mixed comprehensive school	6
		Mixed comprehensive school	5
		Boys comprehensive school	3
	Sheffield	Girls comprehensive school	7
	London	Urban mixed comprehensive school	5
	Cambridge	Independent boys school	5
	South East England	Various state schools(In service training course)	34
Kor	Seoul	Urban state boys school	8
	Seoul	Urban state girls school	5
	Seoul	Urban state boys school	4
	Kyungi	Suburban state boys school	16
	Kyungi	Suburban state boys school	4
	In Cheon	State girls school	8
	Choong Book	Rural state girls school	12
	Junnam	Suburban state girls school	3
	Junbook	Suburban state boys school	8
	Seoul	Various state schools (In service training course)	32

Overall, 90 questionnaires from English science teachers and 100 questionnaires from Korean science teachers were completed and collected. Although the schools for the survey were chose for convenience there should be no reason to suppose that this sampling is not representative as the teachers were from wide spread locations in both countries and all were from state schools and were teaching science from their national curricula at KS3 level.

6-3 Results and analysis

Collected data were sorted and coded quantitatively or qualitatively depending on the format of questions. Most data was quantified in a way which was considered to be most appropriate.

The information is grouped into 4 sections: A, B, C and D :

Section A: background information including age, sex, teaching experience, background specialty, and experiences of study in particular subjects.
Section B: Teachers' perceptions of scientific enquiry and the nature of science
Section C: the section is divided into three sub-sections:

- C-1) Teachers' perceptions of their teaching and their practice in the classrooms in terms of teaching science, doing practical work, teaching scientific enquiry
- C-2) Teachers' practice in the classrooms,
- C-3) Teachers' opinions about various obstacles in implementing more scientific enquiry, their confidence of teaching scientific enquiry, pressure of attainment targets by schools.

Section D: Teachers' opinions about questions from English KS3 tests, TIMSS 2003 and Korean HE questions

Section A, B and C from the responses in the questionnaires are analysed quantitatively by using spreadsheet. Section D from the responses of the questionnaires.

The data analysis is to be three fold: firstly, the encoded data from the questionnaires are analysed statistically including inferential statistics in both English and Korean teachers. Secondly, the data are analysed with correlations between or within each section. Thirdly, section D is analysed with the same manner of the rest of sections. Finally data analysis is carried out in comparison between two groups of teachers and further finding out commonalities and differences between two groups of teachers.

6-3-1 Data analysis of Section A : Background of information

Section A consists of personal details including age, sex, teaching career, speciality and experience of particular subjects. From the questionnaires, Section A is encoded into numbers and analysed statistically. As Table 35 and Figure 21 show, the majority of the teachers are in their 30s and 40s; 35% and 43% of the English teachers, with 43% and 28% of the Korean teachers respectively. However, the English teachers show fairly even distribution of age from their 20s to 50s whilst the percentage of teachers over 50 represent only 5% of the Korean teachers.

Table 35 Age distributions (%)

Age	21-30 yrs	31-40yrs	41-50yrs	51-60yrs
English teachers	20	35	22	23
Korean teachers	24	43	28	5

Figure 21 Age distribution of the English teachers (%)

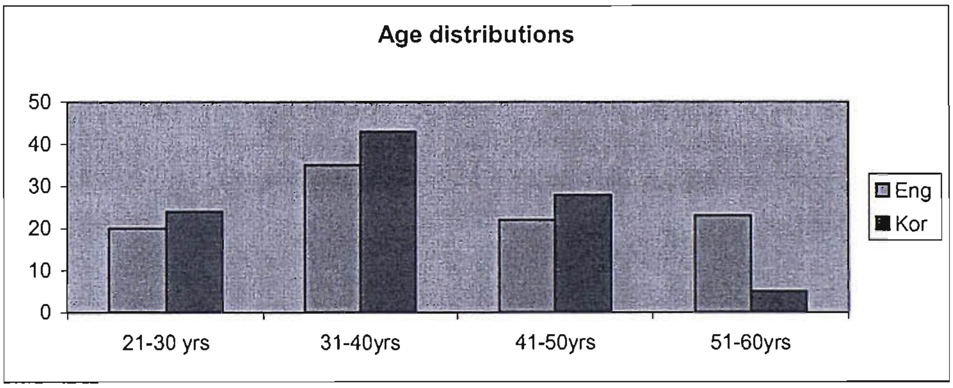


Table 36 shows sex distributions in the two groups of teachers. 59% of the English teachers are female and 41% male whilst 77% of the Korean teachers are female and 23% male.

Table 36 Distribution of sex (%)

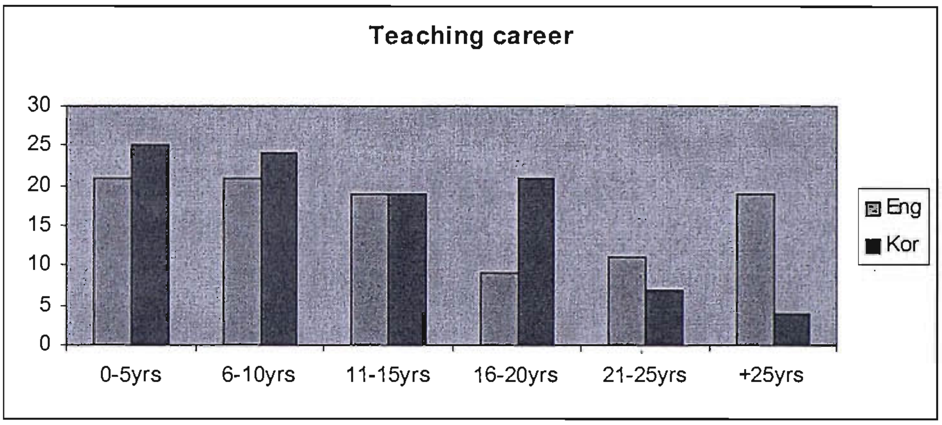
Sex	Male	Female
English teachers	41	59
Korean teachers	23	77

As shown in Table 37 and Figure 22, the distribution of the English teachers indicates a higher proportion of experienced teachers who have more than 20 years teaching experience compared with the one in the Korean teachers, which falls abruptly over 20 years.

Table 37 Distribution of teaching career (%)

Years	0-5	6-10	11-15	16-20	21-25	+25yrs
English teachers	21	21	19	9	11	19
Korean teachers	25	24	19	21	7	4

Figure 22 Distribution of teaching career (%)



In terms of specialty, Korean teachers have integrated science as their major study. As they were qualified as teachers for middle schools, they could choose 'integrated science' as they took the qualification examination. Therefore teachers who have *'Integrated science'* can only teach in middle schools and 'Integrated science' at high school year 1. Table 38 and Figures 23 and 23-1 show the distributions of specialty amongst both groups of teachers.

Table 38 Distribution of specialty (%)

Specialty	Biology	Chemistry	Physics	*Int.Science				Earth Science	Others
				*B+C	*B+C+P	*B+P	*C+P		
English	39	29	18	3	1	1	1		8
Korean	26	14	17	36				6	1

* Int. Science: Integrated Science
* B+C: Biology + Chemistry *B+C+P: Biology + Chemistry + Physics
* B+C: Biology + Chemistry *B+P: Biology + Physics *C+P : Chemistry +Physics

Apart from *'Integrated science'* Biology is the most popular subject in both groups of teachers.

Figure 23-1 Distribution of specialty in the English teachers

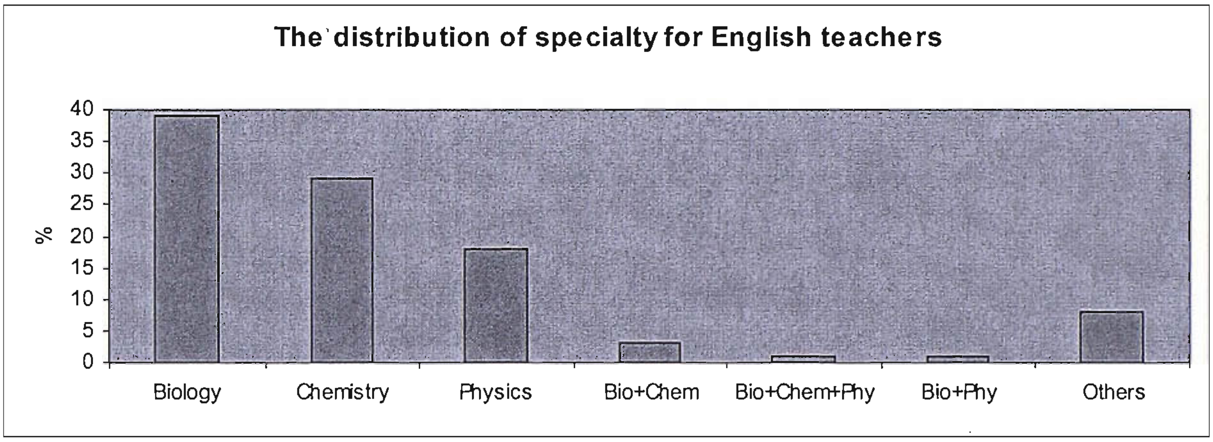
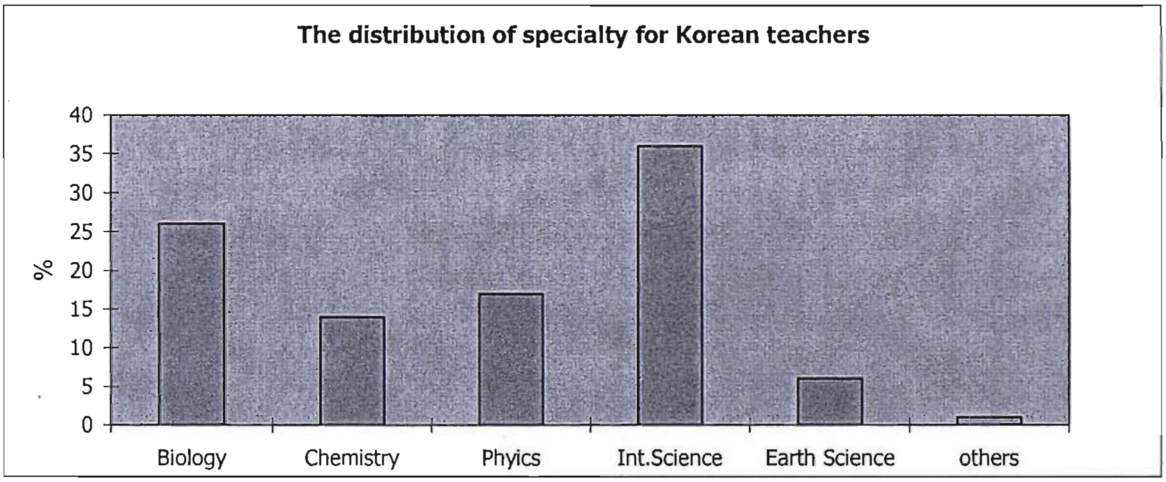


Figure 23-2 Distribution of Specialty in the Korean teachers



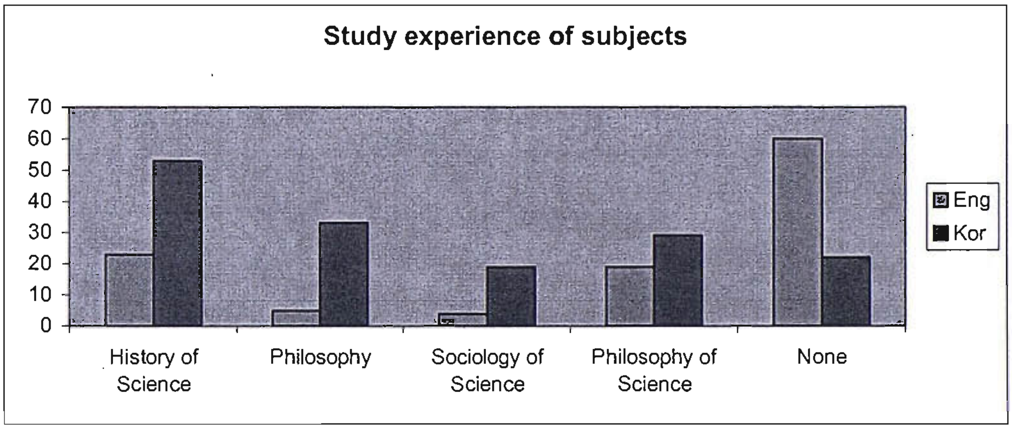
In terms of subject experience, 88 of 100 Korean teachers indicated that they have studied particular subjects, some of them stating more than two subjects. Over half (56%) have studied '*History of science*'. Next are '*Philosophy*' and '*Philosophy of Science*' with 33 and 31 respectively. However, 22 out of 100 teachers stated they have no experience of studying any of those subjects. The lowest proportion is '*Sociology of Science*' with only 15.

According to the English teachers' responses, a considerable proportion of teachers (60 out of 90) indicate they have no experience of any of four subjects. '*Philosophy of Science*' and '*History of Science*' have been studied by 23 and 19. '*Philosophy*' and '*Sociology of science*' are less common with 5 and 4 only. Details are shown in Table 39 and Figures 24.

Table 39 Study experience of subjects (Indicated numbers)

	English teachers	Korean teachers
History of Science	23	53
Philosophy	5	33
Sociology of Science	4	19
Philosophy of Science	19	29
None	60	22

Figure 24 Study experience of subjects (indicated numbers)



Comparing the two groups of teachers, the distributions of age and sex show similar tendencies with the majority female, 30s and 40s. The distribution of the Korean teachers indicates that they have higher proportions of younger teachers and lower proportions of experienced teachers who have more than 20 years experience especially female. In comparison, the group of English teachers shows fairly even distributions of age and teaching experience.

In terms of specialty, both England and Korea have their own teacher training system so that teachers' specialties are varied. A large proportion of the Korean teachers have *'Integrated science'* as their specialty whilst *'Biology'* is a major specialty amongst the English teachers followed by *'Chemistry'* and *'Physics'*. One notable feature in section A is a difference in experience of particular subjects. The majority of English teachers indicates that they have no experience of studying *'History of Science', Philosophy, 'Sociology of Science' or 'Philosophy of Science'*. In contrast, the majority of Korean teachers indicate that they have studied *'History of Science'* or other subjects.

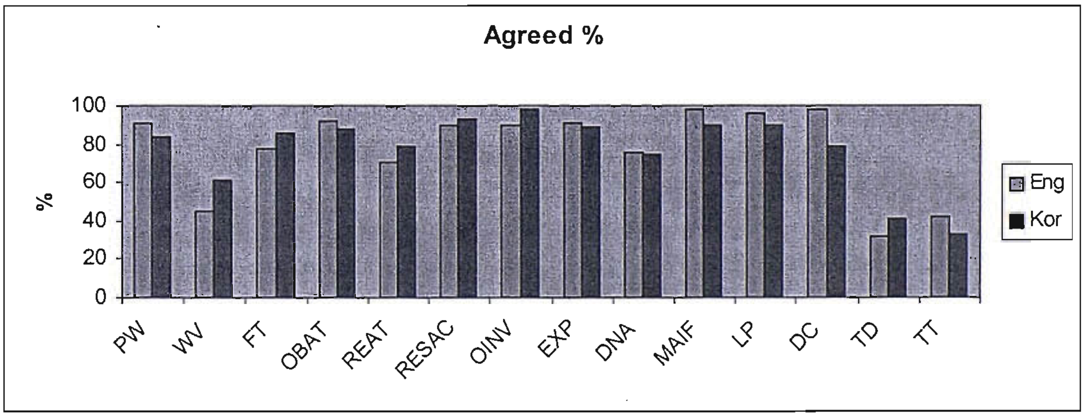
6-3-2 Data analysis of Section B: Teachers' perceptions of scientific enquiry and the views of the nature of science

This section collects data from question 6 and 7 in the questionnaire. Question 6 consists of 14 items, which are regarded as part of learning scientific enquiry.

Table 40 Items being regarded as a part of learning scientific enquiry(%)

Items	English teachers	Korean teachers
Teacher demonstration (TD)	32	41
Teacher talking(TT)	42	33
Watching video (WV)	45	61
Reading and Thinking about Phenomena (REAT)	70	80
Discussion and Argumentation (DNA)	76	75
Field trip(FT)	78	86
Open investigations by pupils (OINV)	90	98
Research information and Collecting data(RESAC)	90	93
Experimentation (EXP)	91	89
Practical work(PW)	91	84
Observation and Thinking about Phenomena (OBAT)	92	88
Looking for patterns in data (LP)	96	90
Making inference from observations or other data(MAIF)	98	90
Drawing conclusions from evidence (DC)	98	79

Figure 25 Items being regarded as a part of learning scientific enquiry (%)



Although there seem to be similar figures amongst items in general, there are differences in teachers' perceptions about parts of learning scientific enquiry. As shown in Table 40 and Figure 25, most teachers in both groups do not regard *'Teachers demonstration,'* and *'Teachers talking'* as part of learning scientific enquiry. Nevertheless, *'Teachers' demonstration'* is less-regarded with 32% than *'Teacher talking'* with 41% by the English teachers whereas *Teachers' talking* is less regarded with 33% than *'Teachers' demonstration'* with 41% by the Korean teachers. There are different percentages for the items *'Watching video'*, *'Reading and Thinking about Phenomena'* and *'Field trip'*. More of Korean teachers regard those items as part of learning scientific enquiry. Interestingly, 80% of Korean teachers indicate *'Reading and Thinking about Phenomena'* as a way to learn scientific enquiry compared with 70% of English teachers. There are similar figures in other items. Almost all Korean respondents indicate *'Open investigations by pupils'* as part of learning scientific enquiry with 98% compared with the proportions of *'Discussion and Argumentation'*, *'Practical work'* and *'Experimentation'*.

To sum up, the Korean responses may reflect that the Korean teachers regard scientific enquiry as the converse of teacher centred learning as mentioned in Chapter 2. Korean teachers do not carry out open investigations, field trips and research frequently; they regard those items as being more learner-centred than those items such as teachers' talking and teachers' demonstrations. Thus, more of the Korean teachers regard 'Watching video', 'Reading and Thinking about Phenomena' and 'Field trip' as part of learning scientific enquiry than English teachers. On the other hand, the English responses may reflect scientific enquiry as an empirical oriented work such as practical work, experimentation, investigation and research showing higher percentages in those items than others such as fieldtrip, watching video, argumentation, thinking and reading about phenomena and so on. These results may show how the national curricula affect teachers' perceptions.

Concerning the teachers' perceptions about the nature of science **(Question 7)**, the result is to show a unique profile of individual teachers' view of science whether a teacher has a view of it as *'Inductivism'* or *'Duductivism'*, *'Contextualism'* or *'Decontexualism'*, *'Relativism'* or *'Positivism'* and whether a teacher views it as *'Process'* oriented or *'Content'* oriented.

Question 7 consists of 14 items modified from the original *'your own nature of science profile'* (Nott and Wellington, 1993; 1998, p310).

Before following the scoring method, responses to each item from both groups of teachers are added up with accordance in the teachers' indications in order to explore the perceptions about each item as shown in the table below.

Table 41 The results of teachers' views about the nature of science

Views	Items	English teachers(%)					Korean teachers (%)				
		SD(-2)	D(-1)	0	A(1)	SA(2)	SD(-2)	D(-1)	0	A(1)	SA(2)
*ID	1	30	60	8	2	0	17	39	33	10	1
	2	2	16	20	52	10	3	16	16	45	20
	3	2	23	19	46	11	7	26	21	36	10
	4	17	43	22	18	0	20	41	16	22	1
*CD	5	10	18	27	38	7	7	13	14	48	18
	6	2	7	19	50	22	5	3	15	51	26
	7	3	38	10	39	10	20	40	22	16	2
	8	8	38	23	27	4	15	39	36	12	1
*PC	9	1	12	28	42	17	0	14	24	32	30
	10	2	11	19	48	20	3	6	35	39	17
	11	0	3	5	44	48	0	3	22	52	23
	12	0	21	12	37	30	0	4	11	47	38
*PR	13	12	23	14	28	23	4	10	23	40	23
	14	24	36	23	14	3	4	17	35	35	9
	5	10	18	27	29	6	7	13	14	48	18
	8	8	38	23	27	4	15	39	36	12	1

*ID: Inductivism/Deductivism
*CD:Contextualism/Decontextualism
*PC: Process/Content
*PR:Positivism/Relativism

SD: Strongly Disagree
D: Disagree
0: Neutral
A: Agree
SA: Strongly Agree

Firstly, the English teachers are more clearly skewed toward *Deductivism* than the Korean teachers. Although more of the Korean teachers show disagreement with item 1 and agreement with item 3, the Korean responses appear more neutral in the item 1:*1.Scientists have no idea of the outcome of an experiment before they do it* and *3.Scientific theories are as much a result of imagination and intuition as inference from experimental results.* Most of the teachers in both groups agree that *Science proceeds by drawing conclusions, which later become theories* but only 18-19% teachers disagree in item 2. In terms of theory-laden nature of science, most of the teachers in both groups disagree 60-61% with item 4: *All science experiments and observations are determined by existing theories,* with only 18-23% agreement respectively. So, the teachers' responses in both groups show inconsistency and odd indication of *Deductivism* view in some items and *Inductivism* view in other items.

Secondly, the Korean teachers show a clearer tendency to the *Contextualism* view whilst the English teachers show indeterminate, mixed and neutral tendency in this *Contextualism* and *Decontextualism* section.

The majority of the Korean teachers agree with item 5 that *Science facts are what scientists agree they are* when the English teachers show mixed and indeterminate tendency with 45% Agree, 27% Neutral and 28% Disagree. Both groups of teachers agree with item 6 that *'Scientific research is economically and politically determined'.* Most of the Korean teachers disagree with item 7 and 8: *'Scientific theories have changed over time simply because experimental techniques have improved* and *In practice, choices between competing theories are made purely on the basis of experimental results.* In particular, the Korean responses to item 8 appear 36% neutral (0).

On the other hand, the English responses to item 7 appear mixed and indeterminate with 41% disagree, 10% neutral and 49% agree. In item 8 English responses also appear indeterminate with 46% disagree, 23% neutral and 31% agree. Except for item 6, the responses from English teachers appear indeterminate and mixed tendencies.

Thirdly, both groups of teachers show similar tendencies to all 4 items in the Process-Content section. In item 9, both groups of the teachers agree that *Science education should be more about the learning of scientific processes than the learning of scientific facts.* The Korean teachers tend to be in stronger agreement with 17% of the English teachers indicating strong agreement and 30% of the Korean teacher. On items 10 and 11, the English teachers indicate stronger agreement with *the most valuable part of a scientific education is what remains after the facts have been forgotten* and *science method is transferable from one scientific investigation to another.* 35% of the Korean teachers opt for the neutral category on item 10 and 22% on item 11. In item 12, the Korean teachers show stronger agreement that *A good solid ground in basic scientific facts and inherited scientific knowledge is essential before young scientists can go on to make discoveries of their own* with 85%, agreeing and only 4% disagreeing. Whilst the English teachers express agreement with 65% agree and 21% disagree.

The fourth section shows the tendency toward Relativisim/Positivism. The English teachers show vague and indeterminate views in most items in this section. The majority of the Korean teachers agree with item 5 that *Science facts are what scientists agree they are* whilst the English teachers show mixed and indeterminate tendency with 45% Agree, 27% Neutral and 28% Disagree. Most of the Korean teachers disagree with item 8 that *In practice, choices between competing theories are made purely on the basis of experimental results* with 36 % neutral (0). On the other hand, on item 8 English responses also appear indeterminate with 46% disagree, 23% neutral and 31% agree. On item 13, the English teachers have vague or mixed views that *there are certain physical events in the universe which science can never explain* 51% agree, 14% neutral and 35% disagree whilst most of the Korean teachers agree with 63% agree, 23% neutral and 14% disagree.

However, on item14, the English responses show a clear disagreement that *'Scientific knowledge is different from other kinds of knowledge in that it has a higher status'* with 60% disagreeing and 17% of agreeing. The Korean responses appear more mixed and indeterminate on the item indicating only 21% disagree, 35% neutral and 44% agree. Apparently, more of the Korean teachers are more likely to think scientific knowledge has a higher status than other kinds of knowledge than English ones.

To sum up, both groups of teachers show naïve idea in terms of the nature of scientific theory and the theory-laden nature of science tending to disagreement at item 4: all scientific experiments and observations are determined by existing theories. In addition, considerable proportions of teachers in both countries believed that science proceeds by drawing conclusions, which later become theories. However, in the *Inductivism/Deductivism* section the English teachers show clearer *Deductivism* views than the Korean ones. More of the English teachers tend to have inconsistent and indeterminate views in the *'Contextualism/Decontextualism'* and *'Relativism/ Positivism'* section including the tentativeness of science. The Korean responses appear to have more of a tendency towards Contextualism and Relativism than the English ones. In particular, the English responses in the six items appear mixed and indeterminate views in all but only two items. On the other hand, the Korean teachers show clearer tendency and more desirable views about the nature of science in the above sections. One notable feature in the results of item 14 is that more of the Korean teachers believe that scientific knowledge has higher status than other kinds of knowledge. By contrast, most of the English teachers indicated disagreement with it.

Both groups of teachers show a process-oriented tendency. The items in the Process/Content oriented section seem to be more closely related to teaching and learning than other sections. Although both groups of the teachers express agreement with the emphasis on scientific process rather than scientific facts, the Korean teachers show a more extreme tendency by selecting strong agreement on item 9:*Science education should be more about the learning of scientific processes than the learning of scientific facts* as well as indicating stronger agreement on item 12:*A good solid ground in scientific facts and inherited scientific knowledge is essential before young scientists can go on to make discoveries of their own.*

This section clearly shows a conflict in teachers' views between the importance of process oriented tendency in item 9 and of the content oriented tendency in item 12. Both groups of the teachers show inconsistency between item 9 and 12 with higher opting for agreeing on the both items.

There follows an analysis based on the original scoring method, which shows the overall picture for each section in Table 42. The responses for each statement have been scored on a scale of +2(Strongly agree) to –2(Strongly disagree) with a score of 0 indicating neutral view. Some items are multiplied by –1 to reflect the direction of the statement. Then, the overall figure is calculated for each sub-section. The total for each sub-section ranges from –8 to +8 as shown in Table 42. Once each individual item has been scored then combined into the 4 sections, it shows a unique profile of each respondent: whether the teacher has views tending toward *'Inductivism' or 'Deductivism', 'Contextualism' or 'Decontextualism', 'Relativism'* or *'Positivism'* and *'Process' or 'Content'* oriented.

Table 42 The original scoring method concerning the views about the nature of science

No	Statements	Indicated number (-2..................2) S.Disagree S.Agree	Calculation	
1	Scientists have no idea of the outcome of an experiment before they do it.		*-1	
2	Science proceeds by drawing conclusions, which later become theories.		*-1	
3	Scientific theories are as much a result of imagination and intuition as inference from experimental results.		* 1	
4	All scientific experiments and observations are determined by existing theories.		* 1	

Subtotal of scores

-8........................0........................8

Indictivism*............................*Deductivism

	Statements	Indicated number (-2..................2) S.Disagree S.Agree	Calculation	
5	Science facts are what scientists agree they are		*-1	
6	Scientific research is economically and politically determined.		*-1	
7	Scientific theories have changed over time simply because experimental techniques have improved.		* 1	
8	In practice, choices between competing theories are made purely on the basis of experimental results.		* 1	

Subtotal of scores

-8.....................0........................8

Contextualism*...................................*Decontexualism

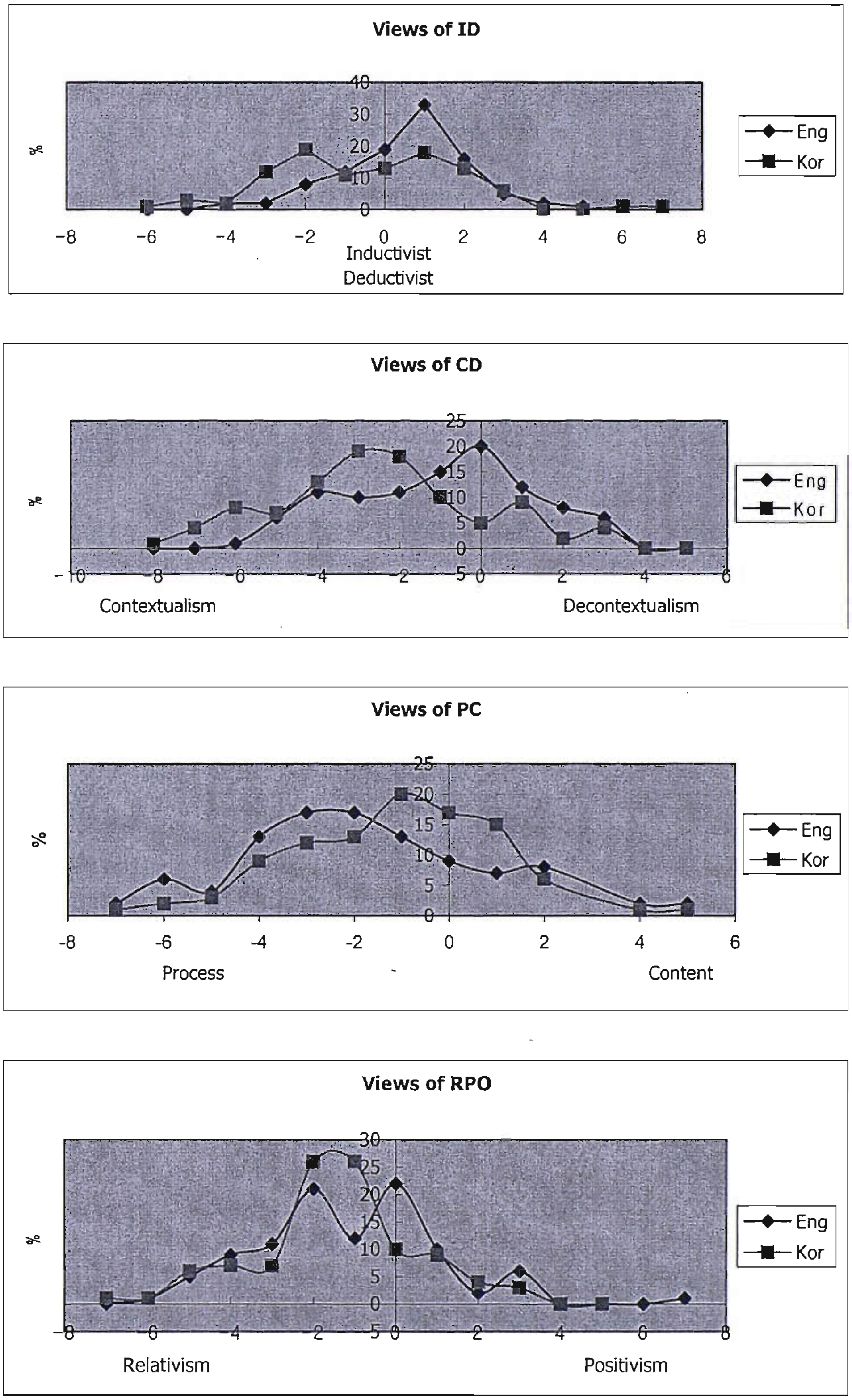
No	Statements	Indicated number (-2.................2) S.Disagree S.Agree	Calculation	
9	Science education should be more about the learning of scientific processes than the learning of scientific facts.		*-1	
10	The most valuable part of a scientific education is what remains after the facts have been forgotten.		*-1	
11	Scientific method is transferable from one scientific investigation to another.		*-1	
12	A good solid ground in basic scientific facts and inherited scientific knowledge is essential before young scientists can go on to make discoveries of their own.		* 1	
Sub-total -8............0..............8 ***Relativism*..................*Positivism***				
	Statements	**Indicated number** (-2.................2) S.Disagree S.Agree	**Calculation**	
5	Science facts are what scientists agree they are		*-1	
8	In practice, choices between competing theories are made purely on the basis of experimental results.		* 1	
13	There are certain physical events in the universe which science can never explain.		*-1	
14	Scientific knowledge is different from other kinds of knowledge in that it has a higher status.		*1	
Sub-total -8............0............8 ***Process*............ *Content***				

Then, the individual profiles are computed to summarise the data and describe the characteristics between the two groups of teachers. **Firstly,** frequencies of each section are shown in Table 43 and figure 26.

Table 43 Frequency about each section between the English and Korean teachers on sub-categories

Range	ID		CD		PC		RPO	
	Eng	Kor	Eng	Kor	Eng	Kor	Eng	Kor
-8	0	0	0	1	0	0	0	0
-7	0	0	0	4	2	1	0	1
-6	0	1	1	8	5	2	1	1
-5	0	3	5	7	4	3	4	6
-4	2	2	10	13	12	9	8	7
-3	2	12	9	19	15	12	10	7
-2	7	19	10	18	15	13	19	26
-1	11	11	14	10	12	20	11	26
0	17	13	18	5	8	17	20	10
1	30	18	11	9	6	15	9	9
2	14	13	7	2	7	6	2	4
3	4	6	5	4	0	0	5	3
4	2	0	0	0	2	1	0	0
5	1	0	0	0	2	1	0	0
6	0	1	0	0	0	0	0	0
7	0	1	0	0	0	0	1	0
8	0	0	0	0	0	0	0	0
Total	90	100	90	100	90	100	90	100

Figure 26 Comparison of frequency about sub-items between the English and Korean teachers



Secondly, means and standard deviations (SD) are shown in Table 44. In order to make inferences about those two populations statistically, a research hypothesis (H1) and a null hypothesis (Ho) are formulated with 95% significance level. In this example, a null hypothesis (Ho) states that there will be no difference in views of the sub-items. Assuming that the distributions of the two groups are normal distributions, a t test is appropriate for this purpose.

Table 44 Mean and SD in the views about the nature of science

Sub-Items	Eng.		Kor.		
(-8..................................+8)	Mean	SD	Mean	SD	t-test
Inductivism /Deductivism	0.49	1.66	-0.39	2.32	0.007
Contextualism/ Decontexualism	-1.02	2.24	-2.42	2.50	0.002
Process/Content	-1.83	2.51	-1.16	2.17	0.050
Relativism/ Positivism	-1.13	2.21	-1.44	1.97	0.097

As shown in Table 44, the null hypothesis is rejected at the 95% level of significance apart from the view of *Relativism/Positivism* because the critical value is more than 0.05.

The results show the same tendency as the previous analysis shown in Table 43 but mask the mixed, indeterminate and inconsistent views on individual items.

According to Table 44, the English responses indicate more *'Dedutivist'* views than the Korean teachers. The English teachers show more *'process oriented'* tendency than the Korean teachers. The Korean teachers have more refined views in the sections in *'Contextualism'/'Decontextualism'* and *Relativism/Positivism* showing more *'Contextualist'* views and *'Relativist'* views. On *'Relativism/Positivism'*, although there is a difference between the mean, showing the Korean teachers have slightly stronger tendency toward Relativism, this is not statistically significant.

Thirdly, Table 45 has been created by considering the scores of each individual response from being calculated by the original method shown in Table 43. As the scores fall into +1 to +8, each respondent is regarded as *'Deductivism', 'Decontextualism', 'Content oriented'* and *'Positivism'* tendency. Whilst as the scores fall into –1 to –8, then each respondent is regarded as *'Inductivism', 'Contextualism', 'Process oriented'* and *'Relativism'* tendency. Thus, the degree of agreeing and disagreeing has been ignored.

More of the English responses appear *'0'* (Neutral) at sub-total of each section by the original scoring method, which reflect teachers' inconsistent responses on some items within a same section. As shown in Table 45, in the sections of *'Contexualism/Decontextualism'* and *'Relativist/Positivist'* more of the English responses are *'0'* (Neutral) with 20% and 22% respectively comparing to 5% and 10% of the Korean responses. By contrast, in the section of *'Process/Content oriented'* section, more of the Korean responses appear *'0'* (Neutral) with 17% compared with 9% of the English responses.

Table 45 Views of the nature of science with '0' (Neutral)

Question 7		Eng(%)	Kor(%)
Deductivism/ Inductivism	Deductivism	57	39
	0(Neutral)	19	13
	InDuctivism	24	48
Contextualism/ Decontexualism	Contextualism	54	80
	0(Neutral)	20	5
	Decontextualism	25	15
Process/ Content oriented	Process oriented	72	60
	0(Neutral)	9	17
	Content oriented	19	23
Relativism/ Positivism	Relativism	59	74
	0(Neutral)	22	10
	Positivism	19	16

Finally, Table 46 shows that there are six different groups of teachers in both countries. Group 1 regards as a developed view of the nature of science which shows Deductivist, Contextualism, Process oriented and Relativist tendency. Groups 2, 3, 4, and 5 are classified only one section about the nature of science being different from group 1.

Majority of teachers in both countries show odd views with 56% English teachers and 42% Korean teachers. Although slightly more of the English teachers indicate developed views, more of them appear to have odd view overall than the Korean teachers. As shown in the table, the main conflict areas about the views of the nature of science among the Korean teachers are revealed in the sections of *'Inductivist/ Deductivist'* and *'Process/Content oriented'*.

Table 46 Grouping of teachers having different tendencies (%)

Groups	View of the nature of science	Eng (%)	Kor(%)	Remarks
1	Deductivist, Contextualism, Process oriented Ralativist	18	14	Developed views
2	**Inductivist** Contextualism, Process oriented Relativist	9	23	
3	Deductivist, **Decontextualism** Process oriented Relativist	5	2	
4	Deductivist Contextualism **Content oriented** Relativist	5	13	
5	Deductivisit Contextualism Process oriented **Positivist**	7	6	
6	Rest	56	42	Mixed views

To sum up, considerable proportions of teachers in both groups show odd or outdated views and are being inconsistent and indeterminate in some items. More of the Korean teachers show clearer views in each section than the English ones except in the *Inductivist/Deductivist* section. The responses of the Korean teachers show conflict in the *Process oriented/ Content oriented* section. This tendency may reflect a confused sense of the stress on the process oriented views or on the content oriented teaching.

6-3-3 Analysis Section C

Section C consists of questions 8 to 19 concerning teachers' emphasis on their teaching in the classroom and opinions in teaching and assessing.

Thus, Section C can be divided into 3 sub-categories:

- **C-1** Teachers' emphasis on their teaching: Questions **8, 10, 12**
- **C-2** Teachers' practice: Questions **9, 11, 13, 15**
- **C-3** Teachers' opinions: Questions **14, 16, 17, 18, 19**

Section C is a threefold analysis: First, each item of each question is to be computed and mean and standard deviation (SD) calculated. Second, in order to make comparison between the two groups of teachers, employing a t test uses inferential statistics. Third, correlations are explored between the sub-categories mainly between teachers' views (Section B) and their emphasis (C-1) and between their emphasis (C-1) and their practice (C-2).

C-1 Teachers' emphasis in their teaching: Questions 8, 10, 12

These three questions explore teachers' perceptions concerning the aims of teaching science in Question 8, the aims of doing practical work in Question 16 and focuses on teaching scientific enquiry in Question 12.

Firstly, Question 8 is to explore how teachers regard the aims of teaching science. Reponses on each item are encoded from 1, *'very important'* to 5 *'not important'.*

Table 47 Aims of teaching science (Question 8)

Items	Eng		Kor		t-test
	Mean	SD	Mean	SD	
To summarise and interpret the programme of study	2.14	0.94	2.36	0.99	0.126
To familiarise students with the type of assessments they will get	2.22	0.9	2.72	0.79	<0.000
To stimulate scientific curiosity	1.33	0.54	1.79	1.09	0.0003
To answer all the questions asked by students	2.1	0.93	2.1	0.93	0.934
To demonstrate how to justify scientific claims based on evidence	2.0	0.7	2.29	0.82	0.009
To guide and organise pupils' study	2.16	0.76	2.22	0.89	0.592
To provide good understanding of scientific concepts	1.57	0.69	1.94	1.07	0.004
To enhance students' career prospects	2.52	0.96	2.65	0.89	0.345

* Statistical significance at 95% confidence level

As Table 47 shows, both groups of teachers regard the most important factors in planning their teaching as *to stimulate scientific curiosity* and *to provide good understanding of scientific concepts.*

However, the English teachers rate those items as more important than the Koreans which is statistically significant at the 95% confidence level. The table also shows that both groups of teachers regard the least important factors in planning their teaching as *to familiarise students with the type of assessments they will get* and *to enhance students' career prospects.* Korean teachers regard the former item as less important than English ones, which is significant at the 95% confidence level.

Other items show no significant difference on the t-test. Apart from *'To demonstrate how to justify scientific claims based on evidence'*
which the English teachers rate as a more important factor.

Secondly, Question 10 explores teachers' perceptions about the aims of practical work. As the t-test in Table 48 shows, most items have no significant difference statistically when comparing the means of the two groups.

Table 48 Aims of doing practical work (question 10)

Items	Eng		Kor		t-test
	Mean	SD	Mean	SD	
To make phenomena more real through experience	1.72	0.62	1.90	0.87	0.103
To practise seeing problems and seeking ways to solve them	1.90	0.70	1.87	0.95	0.803
To promote a logical and reasoning method of thought	1.84	0.73	1.95	0.88	0.368
To encourage accurate observation and description	1.57	0.62	2.1	0.89	0.000
To find facts and arrive at new principles	2.48	1.02	2.22	0.82	0.058
To demonstrate theoretical work as an aid to comprehension	2.04	0.92	2.21	0.82	0.194
To arose and maintain interest	1.49	0.64	1.72	0.92	0.044
To develop manipulative skills	1.84	0.85	2.13	0.90	0.025
To develop verifying facts and principles already taught	2.36	0.98	2.31	0.85	0.732
To satisfy National Curriculum requirement	3.10	0.99	2.64	0.91	0.062

The English teachers regard *'To motivate pupils' and 'To encourage accurate observation and description'* as more important aims of practical work than any other item. The English teachers also say that *'To promote a logical and reasoning method of thought'* as well as *'To develop manipulate skills'* are important.

The Korean teachers regard *'To motivate pupils'* as the most important aim of practical work. They also indicate *'To practise seeing problems and seeking ways to solve them'* and *'To promote a logical and reasoning method of thought'* as more important aims of practical work than other items.

Both groups of teachers indicate the least important factor as *'To satisfy National Curriculum requirement'.* On the item *'To develop manipulative skills',* there is a significant difference statistically, the English teachers regarding it as more important than the Korean teachers.

Thirdly, Question 12 concerning teaching scientific enquiry is scored from 1-5(high focus to low focus) and computed as shown on Table 49.

Table 49 Focus on teaching scientific enquiry (Question 12)

Items	Eng		Kor		ttest
	Mean	SD	Mean	SD	
Fostering explorative or research skills	2.41	0.89	2.61	0.86	0.119
Preparing students to get practical skills for their investigations	2.07	0.7	2.61	0.86	0.000
Fostering an understanding of the nature of science	2.43	0.89	2.1	0.94	0.011
Encouraging students to solve problems	2.12	0.88	2.0	0.93	0.355
Encouraging reasoning and critical thinking	1.88	0.73	2.36	0.92	0.000
Preparing students for performance assessments	2.68	1.05	3.05	0.99	0.012
Helping students understand content of topic	2.06	0.89	1.90	0.78	0.205
Motivating students	1.82	0.73	1.84	0.77	0.870

The English teachers show greatest focus on *'Motivating students'* and *'Encouraging reasoning and critical thinking'* whilst the Korean teachers focus most on *'Motivating* *students'* and *'Helping students understand content of topic'* as they teach scientific enquiry.

'Helping students understand content of topic' and *'Preparing students to get practical skills for their investigations'* are indicated as fairly important items by the English teachers. On the other hand, the Korean teachers regard *'Encouraging students to solve problems'* and *'Fostering an understanding of the nature of science'* as fairly important factors.

Both groups of teachers indicate *'Preparing students for performance assessments'* as the item they focus on least. There are several items that show a significant difference between the two groups of teachers. The English teachers rate *'Encouraging reasoning and critical thinking'* as a much higher focus than the Korean teachers do 1.88 and 2.36 respectively. The English teachers also rate *'Preparing students to get practical skills for their investigations'* as a more important item when teaching scientific enquiry than the Korean teachers do. The English teachers rate *'Preparing students for performance assessments'* as a slightly more important item than the Korean teachers. However, the Korean teachers indicate *'Fostering an understanding of the nature of science'* as a slightly more important item than English teachers do.
Table 50 shows a summary of this section C-1 selecting the most frequently chosen items from questions 8, 10 and 12.

Table 50 Summary of teachers' perceptions about teaching science, doing practical work and teaching scientific enquiry

Aims of	Eng	Kor
Teaching science	-To stimulate scientific curiosity -To provide good understanding of scientific concepts	-To stimulate scientific curiosity -To provide good understanding scientific concepts
Doing practical work	-To arouse interest and maintain interest -To encourage accurate observation and description -To promote logical thinking and reasoning method of thought -To develop manipulative skills	-To arouse interest and maintain interest -To practise seeing problems and seeking ways to solve problems -To promote a logical and reasoning method of thought
Teaching scientific enquiry	-Motivating students -Encouraging reasoning and critical thinking -Helping students understand content of topic -Preparing students to get practical skills for their investigations	-Motivating students -Helping students understand content of topic -Encouraging students to solve problems -Fostering an understanding of the nature of science

There is a similar tendency between the two groups of teachers concerning the aims of teaching science. Both groups of teachers regard stimulating scientific curiosity and providing good understanding of scientific concepts as the most important items. They also regard familiarising students with the type of assessment and enhancing students' career prospects as the least important items.

Concerning the aims of practical work, both groups of teachers indicate motivating students as the most important consideration and the national curriculum requirement as the least important. However, there is a different tendency in that the English teachers regard encouraging more accurate observation and developing manipulate skills as important factors as well as indicating that to promote a logical, reasoning method of thought is an important item. By contrast, the Korean teachers regard *to practise seeing problems and seeking ways to solve them and to promote a logical, reasoning method of thought* as important items indicating *the development of manipulative skills* as less important.

In respect of the focus on scientific enquiry, both groups of teachers indicate motivating students as the most important item and preparing students for performance assessments as the least important. Whilst the English teachers indicate encouraging reasoning and critical thinking with similar importance for motivating students, the Korean teachers rate helping students understand content as an important item with a similar level of importance to the item of motivating students. The English teachers regard preparing students to get practical skills for their investigations as an important item with a similar level of importance to helping students understand content. By contrast, the Korean teachers indicate fostering an understanding of the nature of science and encouraging problem solving as important items but fostering explorative skills or research skills and practical skills for students' investigations are less important items.

Therefore, there seems a strong similarity between the two groups of teachers. One notable difference is that English teachers are more concerned about the empirical nature of science such as manipulative skills, observation or investigative skills than the Korean ones who are more concerned about problem solving and logical thinking. One interesting feature may be that the English teachers relate scientific enquiry as a way to encourage students' reasoning and critical thinking whereas practical work is a way to improve observation and manipulative skills and method of reasoning. On the other hand, the Korean teachers relate understanding the nature of science to scientific enquiry concerning problem solving.

C-2 Teachers' practice: Questions 9, 11, 13, 15

This section analyses how teachers think they teach in the classroom in practice. **Question 9** concerns main teaching methods. The data is encoded into 1-5 from very often to seldom and never.

Table 51 Frequency of using teaching methods

Items	Eng		Kor		t-test
	Means	SD	Mean	SD	
Teacher talking and explaining	1.43	0.56	1.49	0.63	0.512
Note taking	2.5	0.9	2.8	0.98	0.029
Whole group Discussion/ argumentation	2.29	0.8	3.62	0.78	<0.000
Role play	3.68	0.73	4.14	0.87	<0.000
Research information and collecting data to solve problems	2.61	0.84	3.33	0.71	<0.000
Teacher demonstration	2.16	0.65	2.56	0.82	0.0002
Experimentation	1.69	0.63	2.73	0.8	<0.000
Open-ended investigation	3.06	0.78	3.7	0.75	<0.000
Working from worksheets/textbooks	2.38	0.77	2.33	0.89	0.692
Video watching	3.12	0.7	3.18	0.73	0.578
Field trip	4.01	0.66	4.38	0.63	*0.0007

* Statistical significance at 95% confidence level

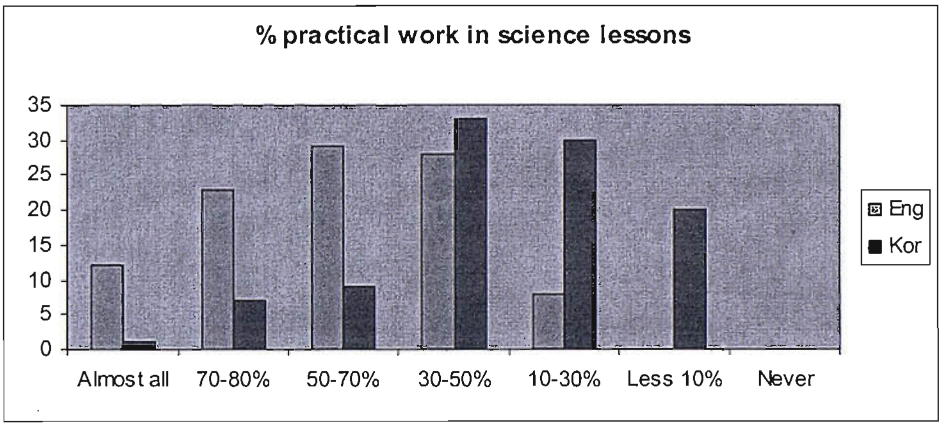
There are no significant differences statistically in these items *'Teacher talking and explaining'*, *'Working from worksheets/textbooks'* and *'Video watching'* between both groups of teachers. However, there are differences in those items *'Whole group discussion/ argumentation'*, *'Role play'*, *'Research information and collecting data to solve problems'*, *'Experimentation'*, *'Open-ended investigation'* and *'Field trip'*. The English teachers tend to do more the above items, which can be learner centred activities. By contrast, the Korean teachers tend to use worksheet, note taking and teacher demonstration that can be more teacher-directed and they put more emphasis on problem solving and conceptual understanding.

In terms of frequent teaching methods, the English teachers use *'Teacher talking and explaining'* and *'Experimentation'* most frequently. *'Teacher demonstration'* and *'Whole group discussion/ argumentation'* come next. The Korean teachers use

'Teacher talking and explaining' and *'Working from worksheets/textbooks'* most often. *'Teacher demonstration'* and *'Experimentation'* follow. So, apart from *'teacher talking'* as dominant in both groups of teachers, there are lots of differences in teaching methods.

In terms of frequency of practical work **(Question11),** the majority of English teachers (64%) indicate that they do practical work in more than half of their lessons shown in Figure 27. On the other hand, the majority of Korean teachers indicate that they do practical work in 10-50% of their lessons.

Figure 27 The percentage of practical work in science lessons



Question 13 asks about teaching methods when teachers teach scientific enquiry The data is encoded into 1-5 from very often to never.

Table 52 Frequent teaching methods in teaching scientific enquiry

Items	Eng		Kor		t-test
	Means	SD	Means	SD	
Giving pupils opportunities to describe patterns and relationship in data from pupils own or other's investigations and asking them to explain and justify pupils' description	2.11	0.76	2.78	0.92	<0.000
Making prediction of additional readings from pupils' own or other's investigations	2.37	0.92	2.67	0.95	0.063
Teaching explicitly about how to collect evidence in situations where variables cannot be readily collected from their own investigation	2.92	1.05	2.85	0.87	0.608
Presenting pupils with graphs of different kinds and asking them to draw conclusions and to state clearly the evidence on which they base their conclusions	2.46	0.91	2.6	1.01	0.303
Presenting pupils with conclusions others have drawn from evidence and asking them to decide whether these are justified	2.96	0.97	2.83	0.91	0.360
Providing opportunities for practical work that requires pupils to solve problems	2.38	0.88	2.62	1.07	0.089
Being explicit about how evidence from either historical or contemporary data can be used to draw conclusions and to develop scientific ideas	2.89	0.83	3.08	0.88	0.204

As shown in Table 52, the responses show fairly even distributions with no significant differences between the two groups statistically except the item, '*Giving pupils opportunities to describe patterns and relationship in data from pupils own or other's investigations and asking them to explain and justify pupils' description*'. The English teachers indicate the item as more frequently used. The items '*Making predictions of additional readings from pupils' own or other's investigations*' and '*Providing opportunities for practical work that requires pupils to solve problems*' come next.

The Korean Teachers indicate '*Present pupils with graphs and ask them to draw conclusions as the way to teach scientific enquiry*' is slightly more frequently used than other items. '*Providing opportunities for practical work that requires pupils to solve problems*' comes close behind.

Question 15 concerns the level of ownership in open-investigation. The responses are encoded into 1 *always teachers*, 2 *usually teacher infrequently students*, 3 *usually students rarely teachers* and 4 with *always students*.

Table 53 Level of pupil's freedom in investigations

Items	Eng		Kor		t-test
	Mean	SD	Mean	SD	
Type of investigation	1.49	0.52	1.66	0.64	0.044
Variables	2.36	0.57	1.8	0.65	0.000
Apparatus	2.18	0.63	1.69	0.71	0.000
Planning	2.68	0.68	1.65	0.64	0.000
Collecting data	3.0	0.73	2.52	0.87	0.000
Conclusion/ Analysis	3.1	0.61	2.65	0.80	0.000
Evaluation	3.3	0.64	1.58	0.57	0.000

As shown in Table 53, the English teachers give more freedom to pupils when pupils are carrying out open-investigations. The responses from the English teachers reflect that *'Types of investigation'* tend to be given by teachers and *'Variables'*, *'Apparatus'* and *'Planning'* tend to be decided usually by teachers but infrequently students and *'Conclusion'*, *'Analysis'* and *'Evaluation'* by usually students rarely teachers.

In contrast, The Korean teachers tend to direct *'Evaluation'*, *'Apparatus'*, *'Variables' and 'Planning'* whilst with *'Collecting data' and 'Conclusion/ Analysis'*, a little more freedom is to be given to students.

There are significant differences statistically in items between the two groups of teachers at the 95% confidence level. Thus, both groups of teachers tend to decide 'type of investigation'. Yet, Korean teachers tend to direct *'Evaluation'* whilst English teachers rarely do.

Summary of C-2

There are important similarities as well as differences in teaching science in practice. Table 54 shows a summary of this section C-2 reflecting the most frequently selected items from questions 9, 11, 13 and 15.

Table 54 Summary of teachers' practice

	Eng	Kor
Most frequently used items in classrooms	Teachers talking Experimentation Teacher demonstration Whole group discussion	Teachers talking Working from worksheet Teacher demonstration Experimentation
Practical work	More practical work	Less practical work
Teaching scientific enquiry	Giving pupils opportunities to describe patterns and relationship in data from pupils own or other's investigations and asking them to explain and justify pupils' description	Presenting pupils with graphs of different kinds and asking them to draw conclusions and to state clearly the evidence on which they base their conclusions
Openness of investigation	More freedom to pupils	Less freedom to pupils

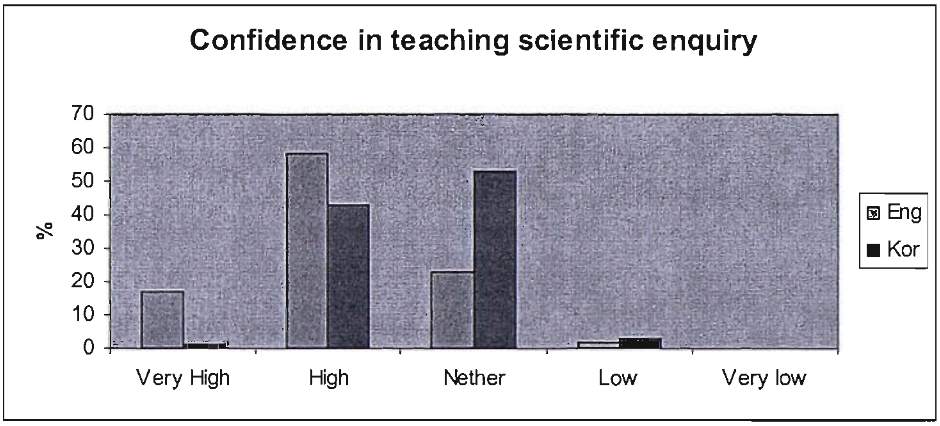
Although both national curricula put emphasis on scientific enquiry, teachers from both countries do not take the teaching methods which are known to enhance pupils' scientific enquiry ability such as scientific investigation, whole group discussions and so on. In addition, there is a little difference statistically amongst the statements in question 13 as shown in table 52. This may a reflection of the fact that teachers are not very concerned about those teaching methods.

Compared with the Korean teachers' responses, English teachers do more practical work and are more concerned about practical skills. English teachers tend to do more learner centred teaching methods than Korean teachers. In terms of the level of pupils' freedom in the investigations, the English teachers tend to give more freedom to their pupils than the Korean teachers do. On the other hand, the Korean responses indicate Korean teachers tend to take up more teacher dominated teaching methods and concern more of conceptual understanding. Interestingly, more Korean responses identify the *'Field trip'* as a scientific enquiry activity in section B (Question 6) but the Korean responses show less use of field trips than the English. However, both groups of teachers seldom use *'Role play'* or *'Field trips'.*

C-3 Teachers' opinions: Questions 14, 16, 17, 18, 19

Question 14 concerns teachers' confidence in teaching scientific enquiry as shown in Figure 28.

Figure 28 The teachers' confidence in teaching scientific enquiry (%)



The English teachers indicate they have more confidence than Korean teachers in teaching scientific enquiry. The figures show that 75% of English respondents express their confidence in teaching scientific enquiry as *'High'* or *'Very high'* whilst 53% of the Korean teachers express their confidence as *'Neither high nor low'* and only 43% of teachers indicate that they are *'Confident'* in teaching scientific enquiry.

In terms of opinion about possible causes of mismatch between ideas in an investigation and pupils' activities more English teachers indicate the items *'When the investigation was carried out within a limited time and space'* and *'When the process was complicated and students did not have enough skills'.* **(Question 16)** On the other hand, 68 % of the Korean teachers indicate that *'When the process was complicated and students did not have enough skills'* pupils were most likely to a have mismatch between doing investigation and understanding what they had done. Half of the Korean teachers also consider the causes, *'When the investigation was carried out within a limited time and space'* and *'When the scientific concepts and the investigation were not related'* the latter being least likely to be chosen by the English teachers, with only 28%. Details are shown in Table 55.

Table 55 Possible causes of mismatches in pupils' investigations

Items	Eng (%)	Kor (%)
When the teacher's explanation concerning the related concepts was not sufficient	47	42
When students were not given ownership of the investigation	28	44
When the process was complicated and students did not have enough skills	72	68
When the investigation was carried out within a limited time and space	78	50
When the scientific concepts and the investigation were not related	28	50

In the opinions about obstacles to implementing more scientific enquiry **(Question 17)** the teachers' responses are shown in Table 56 ranging from large obstacle with 1 to no obstacle with 5.

Table 56 Opinions about obstacles in implementing more scientific enquiry

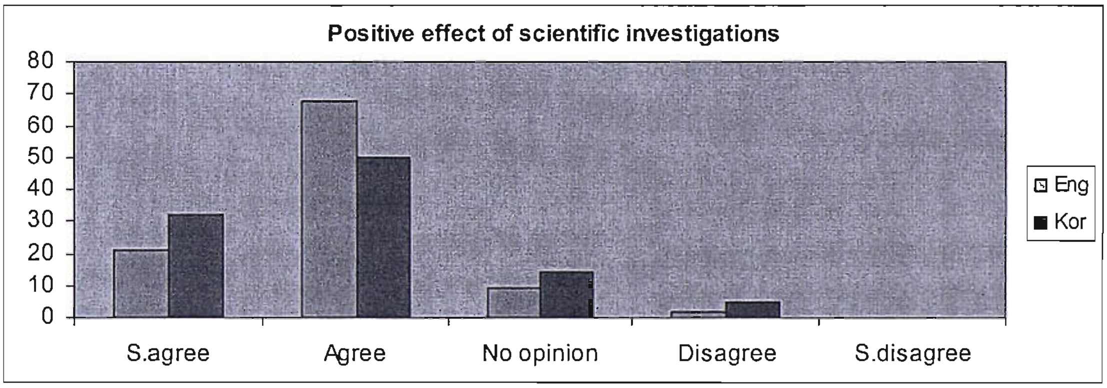
Items	Eng		Kor		t-test
	Mean	SD	Mean	SD	
Inflexible time table	2.44	1.17	1.74	0.91	<0.00
The organisation required for open investigations or project	2.36	1	2.05	0.91	0.030
Large classes	2.08	1.11	1.57	0.87	0.0006
Lack of laboratory facilities	2.72	1.26	2.09	1	0.0002
Lack of appropriate resources	2.66	1.24	2.69	0.9	0.8279
The pressure of examinations	1.99	0.9	2.24	1.06	0.0272
Lack of teachers confidence in process skills	3.49	1.25	3.14	0.91	0.0305
Lack of confidence in integrating practical work into a concept	3.57	1.25	3.11	1	0.0032
Lack of teachers confidence in assessing scientific enquiry	3.6	1.26	3.23	0.98	0.0539
Lack of teachers own interest	3.54	1.32	3.38	1.08	0.3511
Lack of teachers' understanding about scientific enquiry	3.53	1.44	3.28	1.12	0.1953

As shown in Table 56, apart from the three items; *'Lack of appropriate resources', 'Lack of teachers' own interest', 'Lack of teachers' understanding about scientific enquiry' and 'Lack of teachers confidence in assessing scientific enquiry',* there are statistically no significant differences between the two groups of teachers at the 95% confidence level.

Both groups of teachers generally state that teacher related factors are smaller obstacles than other items. However, the Korean teachers' indicate *'Lack of confidence in integrating practical work into a concept'* and *'Lack of teachers confidence in process skills'* as larger obstacles than the English teachers do.

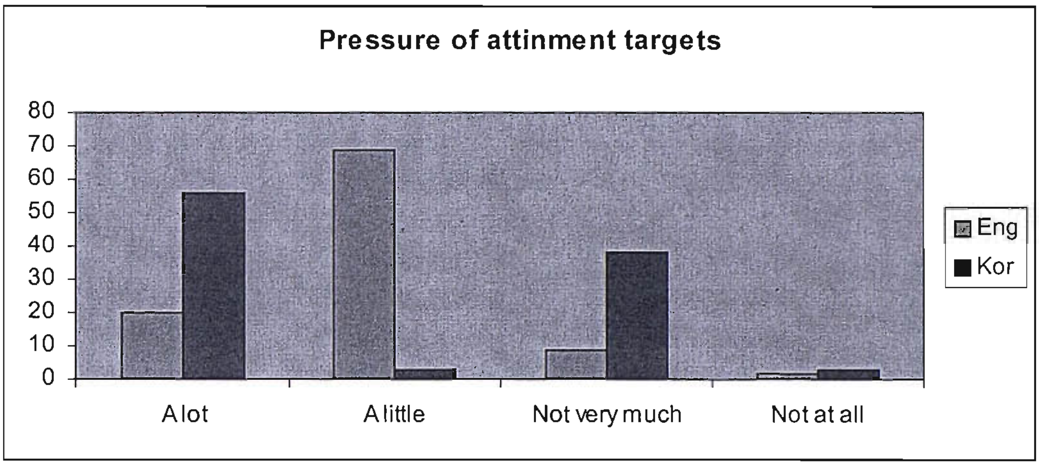
The English teachers indicate *'The pressure of examinations'* as the largest obstacle whilst the Korean teachers indicate *'Inflexible time table'* and *'large classes'* as large obstacles. In contrast, *'The organization required for open investigations'* and *'Lack of laboratory facilities'* are big obstacles than *'The pressure of examination'* for the Korean teachers.
When asked their opinion about the positive effect of scientific investigation on pupils' performance (**Question 18**) both groups of teachers agree that scientific investigations and scientific enquiry activities help students perform better in science overall as shown in Figures 29. 32% of Korean teachers are more likely to agree strongly compared with 21 % of the English teachers.

Figure 29 Positive effects of scientific investigations (%)



Finally, asked about the pressure the teachers (Question 19) experience reach the attainment targets, 69% of the English teachers say *'A little'* and 20% *'A lot'* compared with 56% of the Korean teachers saying *'A lot'* and 38% *'A little'* as shown in Figure 30.

Figure 30 Pressure of meeting the attainment targets (%)



Summary of C-3

Table 57 shows a summary of this section C-3 reflecting the most frequently selected items from questions 14,16, 17, 18 and 19.

Table 57 Summary of teachers' opinions

Teachers' opinions	Eng	Kor
Confidence in teaching scientific enquiry	High or Very high (75%)	High(43%), Neither(53%)
Causes of mismatches	-When the investigation was carried out within a limited time and space (78%) - When the process was complicated and students did mot have enough skills (72%)	-When the process was complicated and students did mot have enough skills (68%) - When the investigation was carried out within a limited time and space (50%) - When the scientific concepts and the investigation were not related (50%)
Positive effect on investigations	Agree	Agree
Pressure of attainment targets	A little	A lot
Obstacles toward more scientific enquiry	-The pressure of examinations - Large classes	-Large classes -Inflexible time table

More than 80% of teachers in both countries agree that scientific investigations and scientific enquiry activities help students perform better in science overall. A higher proportion of the Korean teachers strongly agree with that. Both groups of teachers do not regard teacher-oriented items such as lack of teachers' confidence in process skills and lack of teachers' confidence in integrating practical work into a concept as obstacles to implementing more scientific enquiry in the classroom. Both groups of teachers indicate a large class is a bigger obstacle. The pressure of examinations is the largest obstacle to implementing more scientific enquiry according to the English teachers whereas large classes and inflexible timetables are the largest obstacles for the Korean teachers. This pattern seems to be contradictory to the responses of section C-1, which show that for both groups of teachers assessment and the national curriculum requirements are less important. In addition, more or less 90% of teachers in both groups indicate that they feel pressure to reach the attainment targets. In Question 19, 56% of the Korean teachers indicate a lot of pressure compared with 20% of the English teachers.

However, More of Korean teachers are concerned about pupils' understanding about science concepts as well as their lack of confidence in integrating practical work into a concept and their practical skills than English teachers as shown the results from questions 16 and 17. Likewise, concerning possible causes of mismatches in pupils' investigations, 78% of the English teachers pick up the item *'When the investigation was carried out within a limited time and space'* whilst 68 % of the Korean teachers, 'when the process was complicated and students did not have enough skills'. The English teachers are least likely to choose *'when the scientific concepts and the investigation were not related'* 28% versus 50% for the Korean teachers. Although the Korean teachers give less-emphasis to practical skills both in their perceptions and in practice as shown in sections C-1 and C-2, the Korean responses to Question 16 show that the Korean teachers are aware of their pupils' need to have practical skills in order to avoid mismatches between the ideas in investigation and what pupils actually do. Finally, 75% of the English teachers state they are confident in teaching scientific enquiry whilst only 43% of the Korean teachers are confident.

6-3-4 Analysis part D:
In part D, teachers were asked for their opinions about three different types of questions assessing scientific enquiry from English KS3 test papers, Korean HE examinations and TIMSS-2003.

There are 5 questions in this part D concerning how well pupils would answer each question (**Question 20**), how teachers would prepare pupils in answering each set of questions (**Question 21**), how those types of questions would affect teachers' current teaching method (**Question 22**), how pupils' answers would be affected if the English KS3 question changes to multiple choice format (**Question23**) and finally teachers' opinions concerning the assessment content being confined within the National Curriculum content (**Question 24**)

Firstly, the responses to **Question 20** are to analyse teachers' opinions concerning how well year 9 pupils would answer each set of questions. All the data is encoded into from *'very well'*(1), *'Well'*(2), *'Satisfactorily'*(3), *'Not very well'*(4) and *'Not at all'*(5).

Table 58 Teachers' opinions concerning how well year 9 pupils would answer

Questions	Eng		Kor		t-test
	Mean	SD	Mean	SD	
A (TIMSS-2003)	1.69	0.77	2.62	0,92	<0.000
B (Korean question)	3.31	1.02	2.69	0.90	<0.000
C (English question)	2.80	0.96	3.88	0.75	<0.000

As shown in Table 58, the English teachers indicate that their Year 9 pupils would answer *'Very well'* in TIMSS-2003 questions and answer *'Well'* in English KS3 question but *'Not very well'* in the Korean High School entrance question. By contrast, the Korean teachers indicate that their year 9 pupils would answer TIMSS-2003 and the Korean High School entrance question *'Well'* but English KS3 question would *'Not answer at all'.*

Secondly, Question 21 concerns how teachers would prepare pupils to answer each set of question given plausible teaching methods as items. The responses are computed by adding up the ticked numbers in each set of questions.

As shown in Table 59, both groups of teachers indicate similar opinions about how they would prepare pupils to answer those questions.

Most of the teachers in both groups indicate *'More practice concerning identification of variables'* as a way they would prepare pupils to answer the most common answer TIMSS-2003 question. The second many indication in the English teachers, is *'More explanations about appropriate methods and fair tests'* whereas in the Korean teachers *'More open investigative works for pupils'* being followed the item *'More explanations about appropriate methods and fair tests'*

The majority of the teachers in both groups indicate *'More practice to familiarise pupils with these new types of questions by work sheet or previous exam papers'* and *'More explanations about the science concepts being tested'* in order to prepare their pupils to answer the Korean HE examination.

More of the English teachers indicate *'More practice concerning identification of variables'* 68% and *'More open investigative works'* 57% whilst more of the Korean teachers indicate *'More explicit teaching of individual elements of scientific enquiry'* 77% and *'More practice concerning identification of variables'* 70% as a way to prepare for pupils to answer the English KS3 question. The item *'More open investigative works'* ranks the third highest the Korean teachers with 55%

Table 59 Teachers' opinions concerning how they would prepare to answer the questions

Items	Eng (Marked numbers)			Kor (Marked numbers)		
	A*	B*	C*	A*	B*	C*
Allocated more time to do scientific investigation	32	21	43	38	9	46
More practice to familiarise pupils with these new types of questions by work sheet or previous exam papers	36	70	37	14	72	18
More learner centred teaching techniques	13	17	16	26	19	48
More open investigative works for pupils	24	16	52	52	18	55
More practical works	36	23	25	39	14	43
More explanations about appropriate methods and fair tests	57	18	47	37	27	41
More explanations about the science concepts being tested	15	61	17	26	45	30
More practice concerning identification of variables	60	23	62	52	14	70
More explicit teaching of individual elements of scientific enquiry	25	27	40	38	18	77

A* TIMSS-2003 question
B* Korean High School Entrance examination question
C* English KS3 question

Thirdly, **Question 22** concerns teachers' opinions whether the English KS3 question would affect their current teaching method. The responses are computed 1-4: *'A lot'* (1), *'A little'* (2), *'Not very much'* (3), *'Not at all'* (4). Table 60 shows means, standard deviation (SD) t-test at the 95% confident level.

Table 60 Opinions concerning how those questions would affect teachers' current teaching method

	Eng		Kor		t-test
	Mean	SD	Mean	SD	
A (TIMSS-2003)	2.5	0.851	2.35	0.8	0.225
B (Korean question)	2.12	0.818	3.16	0.9	<0.000
C (English question)	2.11	0.84	1.53	0.8	<0.000

According to the English teachers' responses, their current teaching method would change *'A little'* if the Korean HE examination question and the English KS3 question occupied up to 30% of exam questions referring with no significant difference between them in 95% confident level. The English teachers also indicate TIMSS-

2003 question as having little effect question on their current teaching method, most saying between *'A little or not very much'.*

On the other hand, the Korean teachers indicate that the English KS3 question would change their teaching method *'A lot'* if the question occupied up to 30% of exam questions followed by TIMSS-2003 question. The Korean teachers indicate that the Korean High School Entrance examination question would not make their teaching method change if the question occupied up to 30%.

Fourthly **Question 23** is to explore whether the English KS3 questions was turned into a multiple-choice format, pupils would answer correctly. The responses are computed 1-5, Very likely (1), Agree (2), No difference (3), Disagree (4) and Very unlikely (5). As shown in Table 61, the responses from the English teachers indicate in between *'No difference'* or *'Disagree'* whilst the responses from the Korean teachers indicate more positively referring *'Very likely'* or *'Agree'.*

Table 61 Opinions about multiple-choice format on the KS3 questions

Eng		Kor		t-test
Mean	SD	Mean	SD	
2.55	1.06	1.85	0.60	<0.000

Finally Question 24 explores teachers' opinions concerning the assessment being confined within the national curriculum content where pupils have learnt during their schooling. The responses are computed 1-5, Strongly agree (1), Agree (2), No opinion (3), Disagree (4) and Strongly disagree (5). As shown in Table 62, there is a significant difference at the 95% confident level.

Table 62 Opinions concerning assessment content

	Mean	SD	t-test
Eng	2.91	1.176	0.01
Kor	2.53	0.958	

The Korean teachers show more agreement that the assessment content and context should be within the national curriculum.

Summary of section D

Table 63 shows a summary of this section D reflecting the most frequently selected items from questions 20, 21, 22, 23, 24.

Table 63 Summary of teachers' opinions about three sets of questions

Items	Eng	Kor
How well Year 9 pupils would answer each question	TIMSS: Very well HE: Not very well KS3; Well	TIMSS : Well HE:Well KS3:Not answer at all
How would teachers prepare for pupils to answer each question	**TIMSS:** -More practice concerning identification variables -More explanations about appropriate methods and fair tests	**TIMSS** -More practice concerning identification variables -More open investigative work -More explanations about appropriate methods and fair tests
	HE -More practice to familiarize pupils with these new types of questions of questions by work sheet or previous exam papers -More explanations about the science concepts being tested	**HE** -More practice to familiarize pupils with these now types of questions of questions by work sheet or previous exam papers -More explanations about the science concepts being tested
	KS3 -More practice concerning identification of variables -More open investigative work	**KS3** -More explicit teaching of individual elements of scientific enquiry -More practice concerning identification of variables -More open investigative work
Those questions would affect teachers' current teaching practice	Korean HE and English KS3 questions would affect a little but TIMSS would a little or not very much	English KS3 would affect a lot being followed by TIMSS. Korean HE would not.
Opinions about multiple Choice format	Multiple choice format questions would be easier but not much	Multiple choice format questions would be much easier

* Korean teachers indicate a stronger agreement that the assessment content and context should be within the national curriculum than English teachers.

Both groups of teachers indicate that their year 9 would answer the TIMSS-2003 questions very well or well. There are similar responses concerning how teachers would prepare for pupils to answer the questions, there are similar responses. The results indicate that both groups of teachers would prepare pupils by giving them more practice concerning identification of variables and more open investigative works in answering TIMSS-2003 and the English KS3 question. Both groups of teachers also would prepare pupils by more practice to familiarize pupils with new types of questions by work sheet or previous test papers and more explanations about the science concepts being tested. However, the Korean teachers indicate more explicit teaching of individual elements of scientific enquiry as a way to prepare to answer the English KS3 questions.

On the other hand, when asked about adopting a multiple-choice format for the English KS3 question, the Korean teachers felt that their pupils would answer more correctly. The English teachers indicate that their year 9 pupils would answer not very well in the Korean HE examination questions whilst the Korean teachers, not answer at all in the English KS3 questions. Korean teachers have strong opinions concerning the assessment content indicating assessment content and context should be within the national curriculum. These results may show that Korean teachers are familiar with multiple choice format questions with rigid structure of the national curriculum.

6-4 Discussions

The teachers' survey reflects the different educational systems such as teachers' training courses, background specialities and experiences of study in particular subjects. In this section, commonalities, differences and correlations between questions are discussed based on the findings from the results of documentary analysis and other research papers.

6-4-1 Background information

Both groups of teachers show similar distributions by age and sex being dominated by 30-40s and females. Both groups of teachers show differences, which reflect the different educational systems. The majority of Korean science teachers indicate their speciality as integrated science whilst more English teachers indicate their speciality as Biology. Most of the Korean teachers indicate that they have studied History of science, Philosophy of science or Philosophy. Whilst considerable proportions of English teachers indicate they have no experience of any of these four subjects. This may result in poorer views of the nature of science in the question 7. However, there are no significant correlation between each question from question 1 to 5 and the view about the nature of science in question 7. In other words, there are no correlations amongst age, sex, career, speciality and study experience as well as no significant correlation between those factors and the view of the nature of science shown in Table 29 in appendix 34.

6-4-2 Teachers' views about the nature of science

There is a difference in the views about scientific enquiry between the two groups of teachers. Korean teachers regard scientific enquiry as enquiry based learning which can be a way opposite to teachers' centred learning. As mentioned in 2-4, this teaching methodology can comprise not only laboratory activities but also questions and discussions in order to acquire scientific knowledge (Sung M W, 1994; Sung M W, et al, 2000). Compared to the responses from the English teachers, more of the

Korean teachers rank *'watching video', 'Field trip', 'Reading and thinking about phenomena',* highly than the English ones. This may because those activities are regarded as learner centred activities contrasting to *'Teachers' talking'* or *'Teachers' demonstration'.*

The national curriculum description seems also to influence teachers' perceptions about the term of 'scientific enquiry'. The ENSC mentions *'Drawing conclusions from evidence'* or *'Making inference from observations'* or *'Seeking for pattern'* along with other elements in the section of ideas and evidence (DfES, 2002). So, the English teachers indicate these elements as scientific enquiry activities in a higher proportion than the Korean responses. The KNSC describe *'Field trip'* as part of learning scientific enquiry compared to only 78% of the English teachers, yet Korean teachers do not seem to employ field trips as much as English teachers do.

In the views about the nature of science, significant proportions of the teachers in both countries have naive views about the nature of science. In particular, the teachers from both countries show misconceptions and indeterminate views about theory-laden, scientific theory or the tentativeness of science.

Although more of the English teachers are inclined toward deductivism and show a stronger tendency to be process oriented than the Korean teachers, more of the English teachers in general reveal unsophisticated and indeterminate views of the nature of science. On the other hand, more Korean teachers hold an inductivist views with a higher proportion than English teachers, indicating fairly desirable views in the contextualism/decontextualism and relativism/positivism sections reflecting their own learning. Overall, the Korean teachers show slightly better views about the nature of science. The responses of Korean teachers show a clearer tendency towards certain views and more consistency in answering sub-items.

This result seems to be contradictory to the result of research by Swain et al (1999), which revealed that Korean teacher show a Positivistic attitude compared to English teachers in their comparative study. By contrast, in this research, more of the Korean teachers show Relativist views than the English teachers. This research also seems to be contradictory to other research findings (Lederman, et al, 2002, et al; Batholomew, et al, 2003). English teachers show relatively poor and outdated views about the nature of science but majority of English teachers indicate in question 14 that they are confident in teaching scientific enquiry.

There is a notable feature concerning the Korean teachers about the nature of science in question 6. They show that they are being torn between being process oriented in item 9 and the stress on being content based in item 12. Although they acknowledge that teaching the process of science is important, they also put their emphasis on following up the content. They show inconsistency between items 9 and 12 by the results having a higher proportion of neutral (0).

More Korean teachers show inductivist and content oriented tendency in their perceptions of teaching and teaching in the classroom than their views about the nature of science. In their view of the nature of science, slightly more Korean teachers indicate indeterminate and inductivist view of science but in section C (Questions 8,10,12 and 9), they indicate clearly inductivist and content oriented. For example, if a teacher has inductivisit views, he will regard theories as truths uncovered through rigid experimentation and his intention is to include precise procedures to acquire the right answer. In consequence, the assessment of students' performances will put the emphasis on results and the scientific processes will be neglected (Millar & Lubben, 1996). Thus, this may reflect teachers' pedagogy prior to views about the nature of science as other literature revealed (Osborne, et al, 2003).

In terms of correlation, there are no significant correlations between the teachers' views about the nature of science and teachers' personal status such as age, sex, career and so on. There is also no significant correlation between the items within the view about the nature of science. The Korean responses show higher correlations between contextualism/decontextualism and relativist/positivist sections being at 0.58 for the Korean response and at 0.48 for the English ones as shown in appendix 34.

In addition, there is no significant correlation between the items in Question 7 concerning about the nature of science (Question 7) and other perceptions concerning teaching science (Question8), doing practical work (Question 10) and teaching scientific enquiry (Question12) as show in appendix 34. Exceptionally, Korean responses show significant numbers (Correlation co efficiency) between Process/Content oriented tendency and the items of the aims of teaching science (Question 8) *'To answer all the questions'* is 0.30 and between Process/Content and *'To demonstrate how to justify scientific claims based on evidence'* is 0.31.

6-4-3 Teachers' perceptions

This section includes teachers' perceptions about the aims of teaching science, doing practical work and teaching scientific enquiry (Question 8, 10, 12). The teachers in both countries indicate similar aims in the teaching of science, which are *'To stimulate scientific curiosity'* and *'To provide good understanding scientific concepts'*.

However, in the perceptions about the aims of doing practical work and teaching scientific enquiry, there are differences. The English teachers tend to emphasise the empirical nature of science by placing more emphasis on practical skills, manipulative skills, investigative skills, observation and so on. By contrast, the Korean teachers are less concerned about the empirical nature of science but more concerned about conceptual enquiry such as problem solving and logical thinking.

Apparently, the Korean teachers do less practical work than the English teachers as indicated by question 9. In addition, the perceptions about the aims of teaching scientific enquiry also seem to support this different tendency. More of the English teachers indicate the aims of teaching scientific enquiry as *'To Encourage reasoning and critical thinking'* and *'To prepare students to get practical skills for their investigation'.* On the other hand, more of the Korean teachers indicate the aims of teaching scientific enquiry as *'To encourage students to solve problems'* and *'To foster an understanding of the nature of science'.*

General findings for both groups show correlations between the items within questions 8, 10 and 12 but little correlation with question 7 concerning the nature of science as shown in appendix 34.

However, the Korean responses show higher numbers of correlation co efficiency for both of the items between the questions (Questions 8, 10 and 12) and within items in each question as shown in appendix 34 (tables 1-8). This may reflect that Korean teachers indicate they have a clearer perception and more consistency in answering the questions about the aims of teaching science and the aims of doing practical work and the aims of teaching scientific enquiry. Comparing the correlations between teachers' views about the nature of science, the higher correlations reflect that teachers' perceptions are more consistent when answering how they teach in practice.

Examples of the Korean responses showing much higher correlations within items which may reflects greater consistency in their perceptions are to stimulate scientific curiosity and to provide good understanding scientific concepts (STCU/ PUSC) with coefficient 0.79, To stimulate scientific curiosity and To answer all the questions asked by pupils (STCU/ AAQ), with 0.66 and 0.65. By contrast, the English responses show little correlations between those items concerning teachers' perceptions about teaching science, doing practical work and teaching scientific enquiry. For example, *To stimulate scientific curiosity and To provide good understanding scientific concepts* (STCU/PUSC) with coefficient 0.18, *To stimulate scientific curiosity and To guide and organize pupils' study* (STCU/GO), *To stimulate scientific curiosity and To answer all the questions asked by pupils*(STCU/AAQ), with 0.03 and 0.20.

To sum up, the Korean responses show much higher correlations within the items of teachers' perceptions about the aims in teaching science, doing practical work and teaching scientific enquiry which reflects clearer tendency in their perceptions. The Korean teachers indicate more consistency in responses representing higher correlations within items and between items in each question (Question 7, 9, 10 and 12)

6-4-4 Teachers' practice (Questions, 9, 11, 13, 15)

Although both groups of teachers agree on the importance of scientific enquiry, the majority of science teachers indicate *'Teachers talking'* is the most frequent teaching method followed by experimentation amongst English teachers and working from worksheet in Korean teachers. Thus, by their own admission teachers are not engaging in teaching methods, which they acknowledge help in scientific enquiry in Question 12. Nevertheless, English teachers tend to take more learner-centred teaching methods by having scientific investigations, whole group discussions, role-play and doing research. In addition, the English teachers tend to give more freedom for pupils to carry out investigations than the Korean teachers. Compared with the English teachers' responses, Korean teachers tend to take up teacher-dominated teaching methods and concern more of pupils' conceptual understanding. Interestingly, more Korean responses identify the *'Field trip'* as a scientific enquiry activity in section B (Question 6) but the Korean responses show less use of field trips than the English. This may reflect a gap between what they do and what they believe they ought to do. However, both groups of teachers seldom use *'Role play'* or *'Field trips'.*

In terms of teaching scientific enquiry in question 13, there is little difference in either between items and two groups of teachers. This may reflect that both groups of teachers are not concerned much about teaching scientific enquiry in practice. As the most frequent way to teach scientific enquiry, the English teachers indicate giving pupils opportunity to describe patterns and relationship in data whilst the Korean teachers indicate presenting pupils with graphs and asking them to draw conclusions. In practice, the area of data interpretation in Klopfer's specification has formed the largest proportion in the result of examination papers from both countries. So teachers are tending to focus on activities, which reflect assessment items. In terms of correlation of frequent teaching methods (Question 9) in science and in scientific enquiry (Question 13) both groups reveal low correlation under 0.4 as shown in appendix 34. For example, *'Experiment'* and *'Investigation'* in question 9 and *'Providing opportunities for practical work that requires pupils to solve problems'* in question 13 indicate 0.337 and 0.361 respectively. *'Research information and collecting data to solve problems'* in question 9 and *'Teaching explicitly about how to collect evidence in situations where variables cannot be readily collected where a suitable control'* is not obvious in question 13 indicate 0.334. The English responses show lower correlations than the Korean ones.

To sum up, there are similarities in teachers' perceptions concerning the aims of teaching science. Yet, English teachers tend to give more weight to the empirical nature of science such as skills and Korean teachers stress teaching science knowledge.

6-4-5 Teachers' opinions (Questions, 14, 16, 17, 18, 19)

In this section includes teachers' confidence, causes of mismatches between pupils' doing practical work and their understanding of science, the obstacles to implementing more scientific enquiry, pressure from the attainment target.

Both groups of teachers agree scientific investigations and scientific enquiry activities help students perform better in science overall although they are not engaging in teaching methods which they acknowledge help in scientific enquiry. Both groups of teachers indicate that causes of mismatches between pupils' doing practical work and their understanding of science are due to limited time and space and to the lack of skills possessed by their pupils.

However, half of the Korean teachers consider the cause *'When the scientific concepts and the investigation were not related'* which is the least likely to be chosen by the English teachers, with only 28%. Korean teachers tend to be concerned more with their confidence in integrating practical work into a scientific concept, process skills and assessing scientific enquiry although both groups of teachers do not choose teacher related obstacles in implementing more scientific enquiry in question 17. Thus, Korean teachers seem to be more concerned about pupils' understanding of scientific concepts as well as teachers' confidence in teaching scientific enquiry. Nevertheless, the English teachers show their confidence in teaching scientific enquiry and express less pressure to reach attainment targets whilst more Korean teachers indicate that they are less confident in teaching scientific enquiry. More of the Korean teachers feel pressure from the attainment targets set by schools.

However, there seems to be a discrepancy in answering questions 17 and 19. The majority of the English teachers concerning obstacles to implementing more scientific enquiry suggest *'the pressure of examination'* and *'large classes'* as cause whilst the majority of the Korean teachers give 'large classes' and 'inflexible time table' as their reasons. This may reflect that both groups of teachers are under assessment driven school curricula although the level of pressure is different. This may stem from scientific enquiry activities or scientific investigations being mainly connected to performance assessment. In this case, the term 'large' may be interpreted differently due to different school environments between two countries.

6-4-6 Opinions concerning three different types of questions

In this section, three different types of questions assessing scientific enquiry from TIMSS-2003, HE examinations and English KS3 test papers.

Teachers' confidence in teaching scientific enquiry seems to affect their answering of these questions. Although Korean pupils' performed better in the international comparative study such as TIMSS-2003 than English counterparts, the Korean responses reveal a little lack of confidence. Both groups of teachers indicate that their pupils would do 'well' in the question fromTIMSS-2003. The English teachers' responses to the Korean HE question thought their pupils would perform 'not very well' whilst the Korean teachers,' 'not answer at all' for the English KS3 questions.

Both groups of teachers answer that they would prepare pupils in a similar way. For example, they would do more open investigation and more practice concerning identification of variables for English KS3 questions. TIMSS-2003 questions are favoured by both groups of teachers. Thus, if the same examination questions are given to teachers in both countries both conform to assessment pressure and adapt their teaching.

6-5 Conclusions

The majority of Korean teachers indicate that they have studied at least one of four subjects: History of science, Philosophy, Philosophy of science or Sociology of science. Generally teachers in both countries have naïve views about the nature of science. However, the Korean teachers show slightly better views in Contexualism / Decontextualism, Relativism / Positivism and Process / Content oriented although more of the Korean teachers indicate Inductivist tendency. The views about the nature of science are not strongly related to teachers' perceptions of aims about teaching science, doing practical work and teaching scientific enquiry. The correlations between items about the views about the nature of science and the perceptions concerning the aims of teaching science are lower than the correlations of items between all the other perceptions. Thus, teachers' views on aspects of the nature of science tend to be isolated from their perceptions on teaching. The responses of Korean teachers show a clearer tendency towards certain views and more consistency in answering the sub-items.

Teachers in both countries show similarities in the aims of teaching science. They focus on motivating pupils and helping pupils to understand science concepts. However, the English teachers put more emphasis on the empirical nature of science than the Korean teachers. Thus, English teachers tend to do more practical work and emphasise on improving pupils' skills.

In terms of teachers' opinions, more English teachers are confident in teaching scientific enquiry and have less pressure to reach attainment targets set by schools.

Teachers in both countries agree that scientific enquiry activities and scientific investigation help pupils to improve in science overall.

Finally, in terms of teachers' opinions, teachers indicate commonalities in the way that they would prepare pupils to answer three different questions such as TIMSS-2003, Korean HE questions and English KS3 questions. Thus, they would teach in a similar manner if they get the same questions. The questions from TIMSS-2003 are favoured by both groups.

6-6 Reflections on the survey research

The questionnaire has been useful to collect data concerning teachers' views, perceptions and opinions.

Although there has been a great emphasis on teaching the nature of science and scientific enquiry, those have not been implemented properly into the national curriculum as far as it has been stressed on. This research also shows the discrepancies between their views about the nature of science, scientific enquiry and teachers' perceptions about the aims of teaching science, doing practical work and teaching scientific enquiry.

However, this research may not show the reasons why discrepancies occurred such as English teachers indicating they do not feel pressure concerning the target attainment set by individual schools. At the same time, more English teachers answer the pressure of examinations to the question when asked the obstacles to employing scientific enquiry than the Korean counterpart. It has not been easy to analyse quantitatively because of its complexity in the nature of some questions.

In addition, due to the difficulties in teaching and assessing scientific enquiry as well as the elements of nature of science or scientific enquiry are relatively new to teachers in both countries, the questionnaires have been revised a bit longer with multiple-choice format. Nevertheless, some teachers still expressed it was difficult to answer questions. In particular, the section of part D asking teachers' opinions about three different sets of scientific enquiry questions Thus, the focus group interview has been employed in the following chapter.

Chapter 7 Focus Group Discussions for Science Teachers

This chapter is a further investigation of the sub-question; How teachers perceive teaching scientific enquiry and their perceptions about the nature of science and of scientific enquiry mentioned in 3-1 by employing a different survey method. Continuing from the previous chapter, the purpose of this chapter is to explore teachers' opinions about the teaching and assessment of science and scientific enquiry. In particular, this focus group discussion is to collect information in depth supporting the data from part D in the questionnaire (appendix 33). Thus, the questions have been developed as follows, based on part D of the questionnaire. This research is to collect robust data, which can support and be able to give explanations to the findings from the questionnaire.

Questions:

1. *What do you think these questions are testing?*
2. *How well would your year 9 pupils answer each set of questions?*
3. *What do you see as the differences between the sets of questions?*
4. *If pupils had difficulty in answering a particular set of questions, which set would they find most difficult? What would be the reason?*
5. *How are you teaching scientific enquiry at present?*
6. *How would you prepare to answer each set of questions?*
7. *Compared with your current teaching practice, if these three types of questions comprised more than 30% of the whole test paper, which of these 3 sets of questions would cause you to change your teaching practice? How would your teaching practice change?*
8. *In order to enhance the scientific enquiry ability of your pupils, which set of questions would you prefer to have more of in the test?*

7-1 Procedure

During July 2005 and October 2005, there were 7 focus group interviews for this research as shown below. Four focus group interviews were with English teachers and three focus group interviews with Korean teachers as shown in Table 64. Each focus group interview was made up of 3-7 participants discussing the above 8 questions. The following three sets of questions as shown in Table 61 were given before the focus groups interviews proceeded.

Table 64 Samples for the focus group interviews

	Place	Numbers participated	Date
Eng	SLC (In service training course)	6	04/07/2005
	SLC (In service training course)	4	12/10/2005
	A school (Comprehensive school)	6	21/10/2005
	SLC (In service training course)	3	31/10/2005
Kor	B school (Middle school for girls)	7	16/07/2005
	S school (Middle school for girls)	4	19/07/2005
	Teachers community (In-service training)	4	13/08/2005

The Focus group discussions in Korea were arranged in advance by Emailing. On two occasions, they were carried out at schools and once during an in service training course. On the other hand, the focus group discussions in England took place during in service training courses except for one occasion at a school. Time taken was 30-90 minutes.

Three different sets of questions were given to the participants as shown in Table 65. These questions are considered as typical scientific enquiry questions from English, Korean and TIMSS test papers. Some of these questions were also used in the questionnaire part D (5-7-1-14, 2004, Common-30, 2004 and SO 22154, as shown in appendix 33) plus two more questions each from English and Korean test papers. Then, the discussions were based on the above 8 questions.

Table 65 Three sets of questions

	Questions
English KS3 tests	5-7-1-14, 2004 (appendix 14), 3-6-2-13, 2003 (appendix 35)
Korean HE examinations	Common-30, 2004 (appendix 12), Junnman-50, 2004 (appendix 26)
TIMSS-2003	SO22154 (appendix 33 part D),

All the discussions were recorded and transcribed. Then the transcripts were analysed using the qualitative data software package NUD*ISTNvivo to assist in coding and to allow exploration of emerging themes based on the above 8 questions. The following are the answers to each question.

7-2 Findings

Although each question was given to the participants in turn, some of the answers were repeated. For example, there was much in common in the responses for the questions '*What do you think these questions are testing?' and 'What do you see as the differences between the sets of questions?'* as well as for the questions '*How are you teaching scientific enquiry at present?'* and *'How would you prepare to answer each set of questions?'.* Nevertheless, the responses seem to support and complement each other.

7-2-1 What do you think these questions are testing?

Questions from English KS3 tests

Most English teachers regard the questions from English KS3 tests as a process of science or scientific investigation questions. Some suggested they were application based. For example, as the English teachers said in appendix 36, Eng-1.

The English teachers considered that with their pupil's lack of familiarity, there was work to be done in helping pupils interpret the question. Apparently, most of the English teachers responded that these English KS3 questions are relatively new to them but that they are good for moving toward more application based questions in order to encourage more scientific enquiry (appendix 36, Eng-2). An English teacher says;

We have never had this at KS3, so, a lot of kids are struggling because many teachers won't really be sure what sort of questions are going to be asked. As we see more and more of this type of question, we will be better prepared for the kids. As we are teaching and changing the methods, then kids will get better and better. (070405, B)

However, there seem to be variations, some teachers answered that they are happier to teach content based questions like the graph questions because they have not been teaching the application based questions (appendix 36, Eng-3). For example, an English teacher notes as follows;

I would be quite happy to teach TIMSS and to teach graphs (Korean ones). I would have thought pupils in higher level could work out and be OK with graph (Korean ones) I go with you... That application one, I have not been teaching these questions my self. (070405, C)

Participants bring out another point that pupils' ability to read and understand the text is critical in the English KS3 tests. In particular, low ability pupils would be worried about given information when it seems irrelevant or has an unfamiliar content (appendix 36, Eng-4).

Most of the Korean teachers describe the questions from English KS3 tests as a process of science, scientific enquiry or scientific investigation questions, which is similar to the responses of the English teachers. For example, see what a Korean teacher said in appendix 36, Kor-1.

They conclude that these questions are unfamiliar to them but not totally alien because these types of questions have been used in the special programme for able pupils and are being used in 'reasoning' classes or open investigative projects in classes in primary schools at a slightly lower level than the English KS3 questions. They also recognise that these types of questions are going to be dealt with at high school year 10 in the programme of study of integrated science (appendix 36, Kor-2). For example, a couple of Korean teachers respond as follow.

The questions from English KS3 tests look like 'reasoning' or 'open-investigative projects done at primary school although it is here at a higher level. If we train primary pupils do this type of questions, they would soon be able to solve them. I don't understand why we have this content- based curriculum at middle school level... Definitely I think, our curriculum is inconsistent in this sense. (130805, K and A)

Nevertheless, the Korean teachers recognise that these questions demand more practical work and more time to think and more integrated ability of literacy, common sense, critical thinking and creativity because these questions are asking for planning in investigations rather than simply giving an interpretation of final results, as they are open-ended questions (appendix 36, Kor-2).

The Korean teachers indicate that their pupils do not carry out much scientific investigation by themselves so that they are not familiar with planning, carrying out, and drawing conclusions from scientific investigations by themselves. Although their pupils would do investigations they would have difficulty coping with the process of problem solving and the process of enquiry because they are so used to getting questions asked within the context of science textbooks. Most Korean teachers agree that even though their pupils understand the terms of control variables, they would not be competent in planning investigations or solving these English questions because Korean pupils are used to multiple-choice format and right or wrong answers (appendix 36, Kor-3).
For example, the Korean teachers say;

Although pupils understand the terms such as variables, they would experience difficulty in the process of problem solving and the process of enquiry because *pupils do not do much investigative work. Pupils would have difficulty in planning, carrying out and drawing conclusions by themselves. (130805, K)*

Korean teachers themselves show their apprehension about the openness of the questions mentioning that it would be difficult to assess open-ended questions because answers can be varied (appendix 36, Kor-4). As a teacher mentions as below;

I think, if a new type of question is given, such as the English questions, then teachers would take some time to work them out before they integrate them in teaching and assessing... I think teachers would feel it difficult to assess open-ended questions...(130805, M).

Questions from Korean HE questions

As **the English participants** look at the Korean HE questions, they think those questions are much shorter, less reading and more straightforward by being able to know what you expect the answer to be than the questions from English KS3 tests (appendix 36, Eng-5).

However, some English teachers recognise that those questions are not actually straightforward. Apart from unfamiliarity, a question contains lots of information within 5 different answers. The question is assuming that pupils already know the content. Most English teachers do not think their year 9 pupils could work them out because the cognitive level is too high. The English teachers agree that the Korean questions look like year 11 modular examination and KS4 syllabus (appendix 36, Eng-6). For example, an English teacher notes;

When you look at this graph, there is too much information. Only the very very bright pupil will be able to pick up anything from that. They don't know where to look. You could train them. ..lots of details. There is a lot to explain to them step by step. (121005, A)

I think you have to assume that they have seen the family tree type diagrams before (Junnam-49-2004). If it is in their cognition level, can they work it out? Can they interpret the diagram? (311005, C)

The English teachers do not think the Korean HE questions are scientific enquiry questions although they agree that the questions are about interpreting data or graphical analysis. Some of the English teachers regard HE questions as mathematics questions, or pure knowledge based questions (appendix 36, Eg-7). The following is an English teacher's quote;

The thing with this, as with the other one, if you train people to extract information from graphs, it is not really about science, It's literally a maths thing *isn't it? Its not really about science it's just whether they can extract information from a table. It's an interpretation of scientific knowledge- that one's maths. That's pure knowledge. (121005, C)*

Many of the English teachers pick out difficulties in language. For example, some teachers point out the sentence in a question (Common-30-2004, appendix 12), which asks pupils to choose the incorrect answer. The teachers mention that their pupils would find this kind of language difficult and confusing (appendix 36, Eng-8).

One science teacher makes a point about the multiple-choice format in the Korean HE questions. He believes that this format would have a limitation in assessing pupils' scientific enquiry ability. An English teacher points out (appendix 36, Eng-9);

... If you are using multiple choice in a right way, maybe you want to try to show if you looking for proving what you want to prove in the content is design to do is right.... Open questions with multiple-choice.. I think, it would never gonna work out because 20 kids would have 20 different answers... Multiple-choice in scientific investigative science... it would never gona work. (040705, J)

Almost all the Korean teachers indicate that the Korean HE questions demand a higher cognitive ability including scientific enquiry ability, problem solving ability and mathematical ability. Without these required abilities, pupils would not get the right answer. In order to do this, pupils need to keep practising the process of solving problems (appendix 36, Kor-5). For example, a Korean teacher's comment;

Pupils cannot get right answers unless they have known all of the content in a question including answers 1-5. Kids have to have enquiry ability, problems solving ability and mathematical ability. Then they keep practising the problem solving process in order to familiarise themselves with how to answer those questions. (160705, B).

The Korean teachers indicate that the HE questions have not been changed ever since their schooling. Pupils and teachers alike are used to these types of questions (appendix 36, Kor-6)

Questions from TIMSS-2003

Both groups of teachers agree in their opinions about the TIMSS-2003. The questions from TIMSS-2003 are favoured by both groups of teachers because they are short, pictorial and easy to apply to their teaching. Both groups of teachers also recognise that the TIMSS-2003 questions are familiar to them mentioning them as primary school science. Both groups of teachers indicate that the questions from TIMSS-2003 are somewhere in between the questions from English KS3 tests and the Korean HE examinations (appendix 36, Eng-10 and Kor-7). Examples are as follows;

A is primary school science. When a pupil is in primary school, they would do this kind of simple, puzzle like questions. (From the English responses: 121005, A)

TIMSS-2003 question is familiar to pupils because of the multiple-choice for them, and these are being taught in primary science. Thus, it would not be difficult to solve them. (From the Korean responses: 190705, C)

Interestingly, some teachers from both groups suggest that for this reason it would be a good idea to start with the questions from TIMSS-2003. As Korean pupils do not use the process of scientific enquiry enough, they would find difficulty in working out the English KS3 questions (appendix 36, Eng-11, appendix 36 Kor-8). Examples are as follows.

I think, if Korean pupils learn KS3 scientific enquiry questions straightway, then they can use the TIMSS questions as a bridge because it would be hard to jump from content based to application based. (From the English responses: 211005,P)

I think, it would be good idea to start with TIMSS-2003 questions if we have to teach this type of question (English ones) they are easy to apply in the classroom. If the questions are too difficult, it would take too much time to work out for teachers themselves....(From the Korean responses:130805, K)

The English teachers think that they are a combination of content and investigative skills. All the English teachers agree that the questions from TIMSS-2003 are simple science or scientific enquiry questions. Some of the teachers recognise that they are about fair test, variables, and investigation questions (appendix 36, Eng-12).

The Korean teachers favour the questions from TIMSS-2003 because they are easy and simple but include a core of scientific enquiry elements. They also think such questions could well be adopted into the 7th national curriculum which is putting great emphasis on scientific enquiry (appendix 36, Kor-9).

7-2-2 How well would your year 9 pupils answer each set of questions?

Questions concerning English KS3 tests

The English teachers think their top groups would get the questions from English KS3 tests right but that the majority would be struggling. The reason for this is that these types of questions are new to them so that many teachers will not really be sure what kind of questions are going to be asked (appendix 36, Eng-13). Some of the teachers also point out that the questions require a high level of English. Thus, pupils with lower ability literacy would find it difficult to understand the questions (appendix 36, Eng-13).

Nevertheless, most of the English teachers respond to the questions from KS3 test papers positively. They think the questions are more valid in scientific terms. Then, they would change their teaching methods in order for pupils to be able to solve the questions (appendix 36, Eng-13).

The new KS3 is heading for application based ones. Actually these application-based questions are more valid in scientific terms. (040705,J) As we see more and more of these types of questions, we would be better prepared for pupils. As we are teaching and changing the methods, then pupils will be better. (040705, J)

We used to teach like this (Korean HE questions). But we have now changed our mode of work toward this (English KS3 questions). Now, we teach more of this type (211005, A) Yes, we used to teach science knowledge but now we do more process and enquiry. (211005, H)

Most of the Korean teachers think the majority of their year 9 pupils would not be able to answer the questions from English KS3 tests because they are unfamiliar with them. Some of the Korean teachers suggest that only bright pupils would even try to solve the questions but the majority would not know how to start to solve them (appendix 36, Kor-10).

Most Korean teachers agree that their pupils are accustomed to a multiple-choice format and pick out the right answer within familiar curriculum content. However, their pupils are not used to working out questions as presented in English KS3 tests, which have no right or wrong answers within an unfamiliar context. In addition, the Korean teachers express the fact that pupils do not have many opportunities to plan and carry out their own investigations as mentioned above (appendix 36, Kor-11). The Korean teachers also express that their pupils are not used to reasoning and thinking by being asked 'how' and 'why' as well as having to 'explain' and to 'suggest' with a long reading (appendix 36, Kor-11).

Pupils are used to doing multiple-choice format choosing one out of 4 or 5 examples. Although they understand science knowledge with the multiple-choice format, they may not do well in the question, which demands explanations with the same science knowledge... My pupils would not even try these type of questions 'suggest' or 'explain' or 'why'. (130805, M)

However, most of the Korean teachers believe that they could train pupils to be able to answer the type of KS3 questions easily. They argue that the English KS3 questions are relatively easier and less work would be needed to teach them. This is because English KS3 questions require science process skills in which their pupils can be trained more easily whilst the Korean HE questions require a higher level of conceptual understanding of science knowledge. A teacher has pointed out that if the 7th national curriculum (KNSC) was implemented properly, it would be possible for pupils to answer all three questions. With conventional ways of teaching, pupils would be able to answer the HE questions and with the new curriculum recommendations, pupils should be able to answer the English KS3 questions (appendix 36, Kor-12). Following are what some the Korean teachers think.

I think, pupils can work out those questions by training them up easily. Although kids have not enough experience in open investigative works, they could work out easily... if pupils can solve the Korean questions, they won't have difficulty in solving the English KS3 questions. (160705, A; 190705, C; 130805, K)

I think it will take 1 month to train them up to get the right answers. (130805, K)

The majority of Korean teachers are concerned about assessing the open-ended questions, pointing out their unfamiliarity as well as the difficulties of assessing questions which can have various answers as mentioned at 7-2-1 (appendix 36, Kor-13).

Assessment would be a crucial matter.. if we teach the KS3 type of questions
As the answers would be varied and in a descriptive form, assessment becomes a real matter to teachers. (130805, M)

Questions concerning Korean HE questions

There are varied opinions. Some **English teachers** think their top group would be able to get the questions from Korean HE examinations right. On the other hand some of the English teachers think even their top groups would not get the right answers for Korean HE questions because the content is not introduced until the KS4 syllabus so that would block their access to these questions (appendix 36, Eng-14).

By contrast, **some of the English teachers** think pupils would do better at the Korean HE questions than in their own English KS3 questions because pupils and teachers alike would be comfortable to have content-based questions rather than application based (appendix 36, Eng-15).

On the other hand, **most of the Korean teachers** agree that around 30-40% of their pupils would manage the questions from Korean HE tests (appendix 36, Kor-14).

Questions from TIMSS-2003

All English teachers agree that their year 9 pupils would answer the questions from TIMSS-2003 well. However, some teachers think, their pupils would do better at English KS3 tests than TIMSS-2003. However, the majority of English teachers responded that their pupils would answer better in TIMSS-2003, than in English KS3 questions and Korean HE questions respectively (appendix 36, Eng-16).

An English teacher suggests that around 60-70% of pupils would get right answers to the TIMSS-2003 questions (appendix 36 Eng-16).

All of the Korean teachers are sure that their pupils would do better in TIMSS-2003, than in Korean HE questions but they do not know how well pupils would do in KS3 or they think their pupils would not do very well in questions from English KS3 tests (appendix 36, Kor-14). One teacher estimates that around 60% of pupils would get right answers to TIMSS-2003, while 30-40% of pupils would do well in the Korean HE questions. By contrast, pupils would not get right answers for the English KS3 questions (appendix 36, Kor-14). A couple of Korean teachers suggest the following;

Questions from TIMSS-2003 and Korean HE are assessed within what kids have already been taught. Thus, 60% of the pupils would get the right answer 60% in TIMSS-2003 and 30-40% in questions from Korean HE. By contrast, questions from English KS3 seem easy but they are not from within the curriculum content. Pupils would not get the right answer. (160705, A)

Most pupils would be able to do in TIMSS-2003. 10-15 out of a class of 40 would get the right answers to the Korean HE questions. But I do not know how kids would manage with KS3 questions without any experience. Kids don't like reading and thinking...(130805, K)

Thus, teachers from both countries indicate that around 60% of their pupils would get the right answers in TIMSS-2003 questions.

7-2-3 What do you see as the differences between the sets of questions?

Both groups of teachers agree that the main differences are unfamiliarity, open-endedness of the questions and whether they are content based or application based, the cognitive level, the mathematical content and the multiple-choice format.

7-2-4 If pupils had difficulty in answering a particular set of questions, which set would they find most difficult? What would be the reason?

<u>**Questions from English KS3 tests**</u>

The English teachers agree that the difficulties would be two-fold in answering the English KS 3 questions. One is the demand for a higher level of English literacy ability and because this type of investigation question is new to both teachers and pupils (appendix 36, Eng-17).

Most of the Korean teachers indicate the difficulties would be the unfamiliarity of the questions and assessment of open-ended questions. They regard the English questions as dealing with the process of science. The teachers suggest that assessment related issues would be a great stumbling block in the way of doing more process of science. This raises three main points.

Firstly, although the 7th national curriculum (KNSC) guides teachers to give more emphasis to the process of science rather than to the teaching of content knowledge, the external standardised examinations such as the HE examinations are assessed within the area of pupils' understanding of content knowledge. As a result of this, teachers tend to focus on teaching the content knowledge in order to prepare their pupils for the examinations (appendix 36, Kor-15). For example, a teacher mentions as follows;

As teachers, we cannot separate science lessons in the classroom from assessment. We have typical Korean style questions as we know. We are under pressure to train pupils up to familiarise themselves with the questions. Even though the English questions seems good to enhance scientific enquiry ability and to be consistent with primary science, we cannot teach this way because the examinations demand content knowledge rather than the process or method of science such as control variables...(130805, M)

Secondly, there are various textbooks reflecting the 7th national curriculum. These textbooks include the content knowledge as well as related scientific enquiry activities. As teachers teach in accordance with these textbooks, they would do practical work like following a cookbook and would confirm the results of what they have learnt with the content knowledge. Some of the textbooks organise content knowledge with the process of science loosely whilst others organise it tightly. According to a Korean teacher, teachers would prefer to have loosely structured textbooks so that they would be able to choose more appropriate methods for teaching the content. However, the assessment has driven them to choose more tightly structured textbooks because they are apprehensive concerning the assessment content (appendix 36, Kor-16). Following are examples;

I think it is nonsense because the new curriculum recommends us to teach scientific enquiry with more or less similar content in which we were taught in our schooling. The worst thing is the assessment. The examinations are assessed on content knowledge not on the process or the scientific enquiry. (130805, A)

Although we all acknowledge that school science should give children various experiences, under assessment driven school curriculum, the focus becomes changed. (130805, K)

Thirdly, pupils and parents are very sensitive about the results of assessment. If there are open-investigative questions demanding open answers in examinations, those questions could result in a great dispute in terms of particular questions' validity. A Korean teacher describes this as follows (appendix 36, Kor-17);

A teacher who is not good at teaching may be acceptable but the teacher who fails to assess kids properly such as making a mistake in marking is not acceptable amongst Korean parents and pupils. If I assess the work of scientific investigation and I give 10 marks to one child and only 9 marks to another child because he missed one thing out in the process, then the 9 marks child with 9 marks complains about it and I have to explain all about the assessment process. Some of the pupils and parents will not accept what I did. So, I would rather avoid those disputes. To be truthful, we are so used to assessing the knowledge in science because right and wrong answers are without any dispute. (130805, M).

Most Korean teachers tend to think of doing open-investigation as an extra-workload and consider that they have too heavy a workload to do open-investigations. Although the Korean teachers admit the importance of scientific enquiry, they would be apprehensive about doing more investigations due to the time constraint for covering the national curriculum content (appendix 36, Kor-18). A teacher expresses this as follows;

We have to give lessons, guide pupils' extra-curricula activities, do other paper work and do counselling ... so many things to do ...this kind of question demands doing more open-investigations... We may have to do feedback after the investigation... it is all a question of time. (160705, K)

Summing up, the Korean teachers agree concerning the importance of scientific enquiry and the need for a variety of learning experiences but the priority changes when they confront the needs of assessment. They believe that if they taught the national curriculum by different teaching methods such as enquiry based or with discussion, it would be harder to prepare pupils to get the right answers to the Korean HE questions. Some of the Korean teachers recognise that pupils would acquire the elements of scientific enquiry by consistently doing practical work because this would include tacit knowledge.

Questions from Korean HE examinations

The Majority of the English teachers express the fact that the HE questions are not acceptable for their pupils. The English teachers recognise that pupils would struggle with the mathematics and phraseology along with conceptual understanding if they were given the Korean questions. Pupils would struggle to break down the given information into what is needed and relevant. In the graph question, a lower ability group tends to use a bar chart and a one-line graph at the level 4 or 5 (appendix 36, Eng-18). Following are some examples.

In this country, if you look at the syllabus, for example get a graph with something that is pushing the limit of what is reasonable for a year 9 pupils and it has got sodium nitrate, potassium nitrate... The staff tend to go back to the syllabus and say ' hang on', ' it doesn't say anything about comparative solubility between this, this and this. ' Why are we asked a question like this?' Pushing your luck a little bit with children... That's what you've got to do. That's the content. ...you are asked for kids to recall. (040705, J)

I think they really would not know how to handle the Korean questions. The government wants level 5 in KS3. Drawing graphs is level 6. Interpreting a graph is not a strong point for most pupils. It is a kind of maths. (121005, B)

Some of the Korean teachers describe how they find difficulty in teaching the higher abstract forms of scientific knowledge. As they teach terms and concepts such as solubility, amount of crystallising or saturated solution, they find difficulty because pupils have hardly ever seen the real solutions such as KCl, NaNO3 or KNO3 (appendix 36, Kor-19). A Korean teacher makes the following comment.

I find difficulty in teaching terms and concepts in science. For example, pupils find it difficult to grasp the meaning of the terms solubility, amount of crystallising, saturated solution and unsaturated solution because pupils have never seen those solutions such as KCl, NaNO3 or KNO3. If I tell them NaCl is Salt, pupils would be surprised. I think the ways we teach lacks real sense. (160705, C).

7-2-5 How are you teaching scientific enquiry at present?
The following are examples of how **the English teachers** teach scientific enquiry. Although these English KS3 questions are fairly new to them, most of the English teachers responded positively to the scientific investigative questions mentioning that they are heading toward more scientific enquiry.

The English teachers all agree that they can train their pupils to become familiarised with these types of questions. In addition, they believe that pupils are getting used to scientific investigation questions because they have done lots of practical work since year 7(appendix 36, Eng-22). Following are examples from the English teachers.

Pupils are getting familiar with this type of question because they have been continually taught this way. During lessons, they gradually grasp the meaning of terms. While, they were doing investigations, they were told about the "mark scheme." (211005, P)

I think we have to teach Sc1. Especially since year 7 gets the pupils prepared to put their own ideas forward for prediction and to be prepared to write about strange situations and about things, which they may never have heard of. That is a way of encouraging pupils to do that sort of thing. We have to take a step away from traditional experiments and take something that may be a bit odd like the 'rose'. It is not something... pupils would never have done before. (040705, A)

Most of the English teachers agree that they have begun to start to teach the elements of scientific enquiry with skills from year 7 using various materials such as plates, sheets or pictures. The material is the same but just using different ways of introducing the concepts such as fair test, dependent variables or independent variables (appendix 35, Eng-23). An English teacher explains as follows.

We can use pictorial things. Dictate them. Put them up on the board..... contributing ideas, sharing ideas. Build up from yr7 really, doing any type of investigation. Talking through things, sorting out what we are trying to find out, what we are changing, gradually building up... process starting at yr 7, as a routine. What are we going to change? And keep the same? You keep doing this all the time until you come to respect the nature so that by the time you get to GCSE practical assessments, they just do it automatically. (121005, C)

Teachers also recognise that pupils would gradually build up the ability to carry out scientific investigations and ability to understand the elements of scientific enquiry as one thing develops from the other (appendix 36, Eng-24) For example, a teacher suggests that he would prepare content-based scientific knowledge by pushing the elements of scientific enquiry along with doing investigations for two years and one year of preparation for application-based questions. Then, pupils would be able to answer the questions at the end of year 9. Here are his comments:

... In year 7, 8, 9 nearly all of our lessons have some sort of scientific enquiry content every year towards what 's a fair test, How do you plan properly? How do you consider all the criteria in sc1 or just pushing it again to the whole of year 7, 8 and 9 all the way through. Actually what we are doing is putting into year 9 two years of content based preparation one year of application based preparation, the subsequent year they should, if we are doing our job properly, do better and better. (040705, J)

Interestingly, some of English teachers also suggest doing repetitive explanations and reviewing past examination papers in order to familiarise the pupils with the new type of questions (appendix 36, Eng-25). For example, an English teacher makes the following suggestion.

I found this question on a previous paper and this year, I gave it to my current year 9 to do for the first part of the lesson then at the latter part of the lesson, I did the experiment. It worked well. Then we discussed the work, considering the key points and what the questions were asking for. (040705, E)

Some of the English teachers suggest how to teach scientific enquiry in a slightly different way from the above statements. Yet, their statements do not seem to be much different from other teachers' opinions as shown below (appendix 36, Eng-26).

Because it's (our teaching) driven by SATs (Standard Attainment Tests) we tend to teach POAE (Predication, Observation, Analysis, Evaluation) type at the moment because we need to know our facts except that a few weeks prior to the exam we teach terminology and investigation through cases using the case terminology and we do POAE type of thing for GCSE. So we teach planning, obtaining evidence, analysing and evaluating but we only really pick up on this type of question on POAE but not very well and we pick out this in the revision programme and in practice questions before SATs in April. (311005, B)

To sum up, it is clear that the English teachers regard doing practical work as a main teaching method in the classroom. They also regard carrying out investigations as a way of teaching scientific enquiry. They all agree that pupils could be trained in patterns, methods and processes. A teacher supports this by mentioning that the questions from English KS3 tests are easier for pupils to answer because the nature of the questions is from practical science. This coincides with the Korean teachers' opinions (appendix 36, Kor-12).

On the other hand, almost all **Korean teachers** say that they do not do enough experimentation or investigation. They mainly do experimentation in order to confirm what they have taught from the textbook. Then, they demonstrate how to solve problems and make pupils practice in order to familiarise themselves with the content. Pupils would also practise similar types of questions through using past examination papers. The Korean teachers say that they also do open investigations only once a term (there are two terms in Korea). Some of the Korean teachers mention that they only do investigations or experimentations for performance assessment (appendix 35, Kor-24). For example, a Korean teacher mentions as follows:

I think, these ones need lots of practical work or investigations. But we don't do much practical work... Mostly, pupils do experimentations to confirm what they have learnt rather than planning or carrying out investigations to find something new. We normally do open investigation once a year for a performance assessment. (160704, K)

Most of the Korean teachers explain that they become anxious to keep the same conditions and to use the same apparatus as in the textbooks while they are carrying out experimentations, in order to demonstrate the same results as in the textbooks. Teachers and pupils expect to confirm the content knowledge with the same results given in the textbook, which leads to teachers putting off doing more practical work (appendix 35, Kor-25). Due to this textbook centred school curriculum there may not be enough time to try other activities in the classroom. This is described by a Korean teacher as follows:

I explain to pupils the aims, processes and results of an experiment because we don't have enough time .... So, pupils expect what would happen as a result. If the result is not the same as in the textbook, pupils would be confused.... Thus, I am cautious about the conditions for doing experimentation in order that the result from the experiment conforms to the result in the textbook. Although I tell pupils not to worry about different results from those in the textbook, they are sticking to the results in the textbooks. (160705, K)

Apparently, there are negative opinions concerning doing more practical work apart from the above causes such as a textbook centred school curriculum or assessment related constraints. These include large class sizes and lack of laboratory facilities (appendix 36, Kor-26). Some of the Korean teachers also mention that they believe direct teaching is more effective for imparting knowledge than teaching with practical work. The teachers said they rather avoid doing practical work because it seems to require much time and is ineffective in enhancing pupils' understanding of content knowledge. A teacher points out that pupils are not interested in the aims of practical work but in the process itself. So, while they are doing practical work, they keep asking what the next step is.

A teacher mentions that only 25-30% of pupils in the class seem to understand what they are doing. Another teacher supports this and mentions that she finds no point in doing practical work when she has to explain over again after doing such work. In addition, a teacher expresses his idea concerning scientific enquiry as ' enquiry based teaching' by saying that he does not believe scientific enquiry should always involve doing practical work. It can be scientific enquiry as long as teachers can encourage pupils to think (appendix 36, Kor-27). Following are examples from the Korean teachers.

Pupils are not interested in the aims of practical work. They tend to look at the process and keep asking what the next step is. Only about 25-30% pupils pay attention to know what they are doing. (160705, M)

I encourage pupils to think as a way to apply enquiry-based teaching in the classroom. I tell them about the bibliography of famous scientists, interesting apparatus and history of science. (130805, M)

Scientific enquiry does not mean doing practical work. We can encourage pupils to think and stimulate discussions. I also do not think scientific enquiry is everything in science education (130805, M)

Often I feel I have wasted my lesson. I teach one thing with practical work with one lesson expecting pupils would understand better. However, I find I have to explain again and again after practical work. Kids tend to remember more as I explain after doing practical work. (160705,A).

In order to teach Korean questions, teachers need to focus on pupils' understanding of science concepts and principles, a so called ' academic basis'. If children don't understand one of the questions, then they cannot get secure their marks. I think, this would be an advantage to foster pupils to be able to apply what they have learnt to other things (190705, B).

Instead of doing much practical work, the Korean teachers describe ways in which to prepare pupils to answer the Korean HE questions. They would explain every single term such as solubility, saturated solution, unsaturated solutions and so on. Then, they would explain all the answers 1-5. Then, they would demonstrate the process of solving a problem including how to calculate mathematically to get the right answers. Then, they would repeat it over again (appendix 35, Kor-29)

I would explain the terms such as solubility, mixture, saturated solution and so on. Then, I would explain all the details. Then I demonstrate how to solve problems and show the process of solving problems including mathematical *processes if necessary. Then, pupils would become familiarized with what they have learnt through example questions. (160705, A)*

They agree that pupils do not understand hard questions but they are getting used to the process of understanding how to solve problems and ways of thinking in order to get the right answers through much repetitive practice. Later on, they would understand more and more about the content (appendix 36, Kor-29). For example, the Korean teachers mention as follows.

I don't think pupils would understand fully some of the assessment content. As we understood certain content with limited comprehension when we were in middle schools, pupils would understand partially and practice the ways in which the problems can be solved. As they move on to high school, they could understand more about it. (160705, C)

I believe that 30% of able pupils can understand the Korean questions. Even if teachers do repetitive training for the context, it would be difficult to get over 50% of pupils with right answers. In particular, the amount of crystallized solution would be the most difficult one. (160705, K; 160705, B)

All of the Korean teachers recognise that the implementation of the 7th national curriculum (KNSC) has enhanced the opportunity for doing more practical work by being reduced in content. Yet, they think that the national curriculum content is still huge so that they feel they have not enough time to do experimentations or to give time for discussions (appendix 36, Kor-26).

Ironically, some of teachers are concerned about the reduced content of the 7th national curriculum, which has eliminated relatively difficult topics. They believe that this may result in their pupils' achievement being degraded because they do not see that their pupils' achievements can get better with a reduced and easier content (appendix 36, Kor-22). A Korean teacher says:

I don't agree that the national curriculum content should be reduced with an easier content mode. In the 7th national curriculum, some difficult content has gone in the examination papers and the content was reduced considerably. I see the national curricular content is limited within natural phenomena. Nevertheless, I don't think pupils' achievement has improved. As the curriculum content level is lowered, pupils' achievements become lowered accordingly. I prefer the previous national curriculum because kids were working harder because kids had to work out the higher level content. (160705, K)

Some of the Korean teachers criticise the fact that the reduction in curricula content has led to a more fragmented curriculum structure with each strand becoming less coherent (appendix 36, Kor-28). A couple of Korean teachers comment:

I think we have a problem with the national curriculum content because the content is the same as we used to be taught while we were in secondary school. Now, the curriculum requires learning scientific enquiry rather than science knowledge. I really don't think it is going to work out. (130805, A)

Another problem in the national curriculum is that the content reduction brings fragmented and disintegrated textbook structure. Simple curriculum reduction makes school science bits and pieces. (130805, A)

To sum up, the Korean teachers agree that the Korean examination papers assess only limited areas of pupils' abilities, assessed such as mainly in the area of data interpretation (appendix 36, Kor-3). They also agree that examination papers should assess a wider range of pupils' ability. In this respect, they believe that English questions have the advantage of giving more variety. However, although they agree that the questions from English KS3 tests can enhance pupils' scientific enquiry ability; they do not agree that the questions from Korean HE should be changed or that the level of understanding should be lowered. They still believe that pupils need to understand content knowledge and should build up a sufficient base of knowledge so that they can apply this in various different contexts.

7-2-6 How would you prepare for pupils to answer each set of questions?

In this section, the participants were asked to respond to each counterpart's questions. For example, the English participants were asked how they would prepare pupils to answer the Korean questions. The Korean participants were asked how they would prepare pupils to answer the English questions. Then both groups of teachers were asked about the TIMSS-2003 questions.

<u>Korean HE examination</u>

Most of the English teachers recognise that the Korean questions would require them to teach knowledge mostly by explanation. All of the English teachers agree that those questions demand lots of work in their lessons because the questions include a considerable amount of content knowledge. Most of the English teachers think they could teach the Korean questions but it would be much harder work. In practice, they would use practice papers or past examination papers in order to get the pupils familiar with the type of questions. Some teachers mention that they would train pupils to use a process of elimination for the multiple-choice format. A teacher points out that the Korean questions are too hard for KS3 pupils so that pupils may be asked to recall science concepts (appendix 38, Eng-18, Eng-27). Following are examples of what the English teachers said;

I think you have to teach technique...you can incorporate that in your science teaching... so they pick up the skills when necessary. I do some practice questions from past papers. I think to build up over the previous papers. For this type of question, I would make pupils do lots of practice. So they can see the format used and answer the multiple-choice. (040705, B)

Probably, I will try to teach my pupils the process of elimination. Trying to figure out which ones don't make sense because I think a lot of these will throw pupils off really quickly... apart from the very very top set. (040705, E)

It has to be built up because with my year 8s, they can do OK with two lines on a graph but it could mean anything. There has to be training because you have to get analysis with graph work.... So we put lots of work into teaching them how to read graphs, especially, as they do incredibly well on the graph questions but then something else has been lost. There's got to be a balance. (121005, A)

...you can put that on to that. You can break this down into that and gradually develop it through. So you can use that idea with the brighter pupils and that for the bottom end. (311005, D)

When you look at this graph, there is too much information. Only the very very bright pupil will be able to pick up anything from that. They don't know where to look. You could train them. Lots of details.... There is a lot to explain to them step by step. (211005, C),

As I said, we used to teach this type. We taught knowledge and explain everything and make them get it right in the multiple-choice or simple answer format. We can teach B (Korean questions). It is not impossible, but it is going to be a hard job. (211005, A)

Questions from TIMSS-2003

The English teachers agree that they would easily teach TIMSS-2003 questions. T**he Korean teachers** also indicate that there would be difference in the way in which they would prepare pupils to answer the English KS3 questions. Responses from both groups of teachers are as follows: (appendix 36, Eng-28, Kor-30).

(An English response)
It looks like primary science. Puzzle stuff... It will be a similar way to teach KS3 questions. (311005, P)

(A Korean response)
...the questions from the English KS3 tests and TIMSS-2003 look similar types of questions because they demand knowing control variables....although TIMSS-2003 questions are of a lower level ... (190705, C)

Questions from English KS3 tests

Most of the Korean teachers say that they would explain the terms and do experiments and give pupils time for planning and thinking. Then, they would make pupils practice with a similar pattern of examination papers. Most of the Korean teachers agree that these questions would be easier to make pupils familiar with because the amount of teaching content is relatively less than for Korean questions (appendix 36, Kor-31). Following are examples from the Korean teachers.

I think pupils can work out those questions by training them easily. Although kids have not enough experience in open investigative works, they could work them out easily as they can solve the Korean questions. I would explain terms such as variables and related science concepts, then, I would give pupils time to carry out investigation... Then, get them practice papers to familiarise them with the pattern. (160705, A; 190705, C; 130805, K)

There would be two ways to prepare pupils to get answers to these questions. If I have enough time, I would explain terms and principles. Then make pupils do open investigation doing hypothesising, planning, carrying out experiments and analysis of the results. When pupils get the experiment wrong, I would make them do it again until they are happy about the results. It would be a good way to foster pupils' scientific enquiry ability. If I don't have enough time, I would explain the terms: independent variables and dependent variables. Then I would demonstrate examples and make them more familiar with similar patterns of questions of investigations. (160705, C)

Some of the Korean teachers do not think pupils would be trained easily or quickly but that pupils could be familiarised with these patterns through repetitive long- term work in investigations. They also think these questions demand higher- level literacy skills in order to understand what the questions demand and to be able to breakdown the information and construct the right answers (appendix 35, Kor-32). For example, a Korean teacher mentions as follows;

I think, English questions demands high literacy skills, which take time to understand them and time to plan which would not easily be built up but could be built up by carrying out investigations. (130805, M)

To sum up, both groups of teachers agree that they would find it easier to prepare their pupils for the English questions rather than for the Korean questions.

7-2-7 Compared with your current teaching practice, if these three types of questions comprised more than 30% of the whole test paper, which of these 3 sets of questions would cause you to change your teaching practice? How would your teaching practice change?

There are two different directions in answering the above question amongst the English teachers. The majority of the English teachers think they are moving in the direction of having more scientific investigations so that they would teach more of the scientific enquiry elements. On the other hand, some teachers think they are already teaching in the way necessary to prepare their pupils to answer questions for English KS3 tests, having already left the way in which they used to teach knowledge based or content based science. Thus, they indicate that the Korean HE questions would change their current teaching practice (appendix 36, Eng-19).

On the other hand, **all the Korean teachers** indicate that it would be the questions from English KS3 tests which would cause them to change their present teaching practice (appendix 35, Kor-20).

7-2-8 In order for pupils to enhance scientific enquiry ability, which set of questions would you prefer to have more of in the test?

Most of the English teachers say that they like the questions from English KS3 tests because they are more relevant to application in everyday life. They also mention that those questions make pupils think critically and make pupils have adopt a more investigative approach as well as being preparation for GCSE course work and science jobs after school (appendix 35, Eng-20).

Some of the English teachers indicate that they like the questions from TIMSS-2003 because those are easy to apply to their daily teaching. They agree that they would be suitable for bottom set pupils because the context is familiar and there is a less amount of reading (appendix 36, Eng-21). No English teacher favoured the Korean HE questions.

However, **the majority of the Korean teachers** say that the questions from English KS3 tests would be good to enhance empirical enquiry, but they do not want to discard the questions from Korean HE examinations because they think it is a necessary way to learn science by keeping up the practice of the process of understanding the content and the process of problem solving (appendix 36, Kor-22 and Kor-27). Although only 20-30% pupils are able to understand fully and to get the right answers, they think the questions from Korean HE tests are still worth teaching as the way, pupils have been trained in and they expected their pupils would understand more and more later on as they go to high schools or colleges (appendix 36, Kor-29). They believe that pupils need a strong foundation of knowledge to enable them to move on to further dimensions such as application-based questions (Section 7-2-5).

Therefore, both groups of teachers agree that the English KS3 questions would be good for enhancing pupils' scientific enquiry ability. Both groups of teachers favour TIMSS-2003 questions which teachers from both countries regard as science for primary schools. The English teachers show their preference for having more discrete investigation question in the KS3 tests whilst the Korean teachers show their resistance to the English questions.

7-3 Discussion and conclusion

The findings from the focus group interviews are not only consistent with the result from the questionnaire part D in the previous chapter but they also reveal detailed data in depth to add strength to the findings from the questionnaires.

This section sums up the findings from the above 8 questions and accordingly describes similarities and differences. It also includes discussions concerning the issues from the comparisons. Table 66 shows a summary from the above 8 questions.

Table 66 Summary of findings from the focus group interviews

	Questions	Eng		Kor	TIMSS-2003
1	What do you think these questions are testing?	**English responses**	- science process - scientific investigation - application based (English responses)	- scientific enquiry - not science, but maths - content based	- science process - scientific enquiry - primary science
		Korean responses	- scientific enquiry - scientific investigation - common-sense - critical thinking (Korean responses)	- scientific enquiry - problem solving ability - maths ability - high cognitive ability	- science process - scientific enquiry - primary science
2	How well would your year 9 pupils answer each set of questions?	Their pupils would be better: 1. TIMSS-2003 questions 2. English KS3 questions 3. Korean HE questions		1TIMSS-2003 questions 2.Korean HE questions 3. English KS3 questions	
3	What do you see as the differences between the sets of questions?	- unfamiliarity - openness of question - application based - content based - cognitive level - mathematical content		- unfamiliarity - openness of question - application based - content based - cognitive level - mathematical content	- somewhere in between the two: - questions between Eng : Kor

	Questions	Eng		Kor	TIMSS-2003
4	If pupils had difficulty in answering a particular set of questions, which set would they find most difficult? What would be the reason?	**Eng responses**	- unfamiliarity - demanding higher level of English literacy	- pupils' maths ability - KS4 syllabus - demanding too much work to teach(repetitive explanations)	- no particular difficulty
		Kor responses	- **assessment-related problems** * not incorporated with the aim of the curriculum and assessment * demanding questions with clear-cut answers not open questions * textbook centred school curriculum - **barriers not to do practical work** * time table * too much content * traditional curriculum content * lack of facilities and large class size *teachers' strong belief in knowledge-based teaching.	- demanding too much work to teach (repetitive explanations)	- demanding more experiments and investigations
5	How are you teaching scientific enquiry at present?	*Teachers respond positively toward more scientific enquiry: they are happy to teach KS3 questions although they're new to them *They would train pupils by practical work: pupils would build up the ability to carry out investigations, ability to understand the elements of scientific enquiry. *To familiarise with the type of questions by past exam papers or worksheets		*Teachers explain the scientific terms, principles and process. Then, they demonstrate process. * Experiments are carried out mainly in order to prove what they have learnt *Teachers demonstrate how to solve problems including mathematical tasks. * As far as possible, pupils are familiarised with the pattern of solving the problem, teachers give repetitive explanations. * Work sheet or past examination papers	
6	How would you prepare to answer each set of questions?	* Do more investigations * Do more practical work * Give time to think * Familiarise by using practice papers and past examination papers **(From Korean teachers)**		* Breakdown information *Explain every single things *Familiarise by using practice papers and examination papers **(From English teachers)**	* Do more investigations

Questions		Eng	Kor	TIMSS-2003
7	Compared with your current teaching practice, if these three types of questions comprised more than 30% of the whole test paper, which of these 3 sets of questions would cause you to change your teaching practice? How would your teaching practice change?	*Most teachers indicate KS3 questions *Some teachers respond Korean questions because they have already moved on toward the new direction in preparing for the English questions	* KS3 questions	
8	In order to enhance the scientific enquiry ability of your pupils, which set of questions would you prefer to have more of in the test?	* They agree that the KS3 questions are good to enhance scientific enquiry ability. * They agree with increasing the English KS3 type of questions * They favour TIMSS-2003 questions	*They agree that KS3 questions are good to enhance scientific enquiry ability *Yet they do not agree to employing more of KS3 questions. *They favour TIMSS-2003 questions	

As shown in table 65, there are many similarities in the findings from the focus group interviews. The following are similarities.

Firstly, both groups of teachers assess the three different sets of questions in similar ways. They indicate that the English questions and TIMSS-2003 questions deal with the 'process of science', 'scientific investigation' and that they are 'application based'. They also consider that TIMSS-2003 contains elements of 'primary science'. On the other hand, they regard the Korean questions as 'scientific enquiry', 'content based' and of 'a higher cognitive level. Concerning the differences between the three sets of questions both groups of teachers answer similarly indicating 'unfamiliarity', 'openness of questions', 'knowledge based', 'cognitive level' and ' mathematical content'.

Secondly, both groups of teachers are familiar with TIMSS-2003 questions. In particular, Korean teachers mention that primary science questions tend to be open-ended like the questions from TIMSS-2003 and the English KS3 tests (appendix 36, Kor-7). They agree that their pupils would do well in the TIMSS-2003 test as well favouring the questions by saying this type of question is good for enhancing pupils' scientific enquiry ability. Some teachers from both countries suggest that Korean examination papers could apply this type of question as a bridge to move toward implementing investigation questions such as those in English KS3 tests (appendix 36, Kor-8)

Thirdly, both groups of teachers indicate that they would teach in similar ways in order for their pupils to be able to answer each set of questions, which may reflect that if they were given the same questions, they would teach in the same way. They generally agree that the English questions would change their current teaching practice, the Korean teachers showing strong agreement on this issue. Both groups of teachers recognise that much harder work is needed as they prepare pupils to answer the Korean questions because each question includes a considerable amount of science knowledge. Both groups of teachers acknowledge that the English questions tend to be learnt by doing practical work and scientific investigation whereas the Korean questions require repetitive explanations (appendix 36, Eng-22-29 and Kor-11, 20-29). Then, both groups of teachers agree that pupils can be trained to answer each set of questions. They also agree that the English type of questions would be easier to familiarise their pupils with because these are practical science questions (appendix 36, Eng-28, Kor-31). Interestingly, both groups of teachers suggest using practice papers and past examination papers as a way of familiarising pupils with a new type of question (appendix 36, Eng-25 and Kor-31). Familiarisation with both types of questions can be achieved by practising similar questions from past examination papers.

The following are differences, which may stem from the different teaching methods of the two countries.

Firstly, according to both groups of teachers, the English questions tend to be learnt by doing practical work and scientific investigations whereas the Korean questions by doing repetitive explanations (appendix 36, Eng-22-29 and Kor-11, 20-29). Evidently, the English teachers show their satisfaction concerning their current teaching practice as a way of teaching scientific enquiry although the type of English question is relatively new to them. The English teachers agree that the English questions are good for enhancing pupils' scientific enquiry ability. A few English teachers show their confidence as mentioned in appendix 36, Eng-25 and 27. They used to teach science knowledge and explain every detail in a way similar to prepare pupils to answer the Korean questions but they have changed; now teaching in a way to prepare pupils for the English type questions.

However, the English teachers do not seem to be concerned about the mismatches between doing practical work and understanding related science concepts whilst some Korean teachers recognise that pupils tend to look at the process and only 25-30% of pupils pay attention what they are doing (appendix 36, Kor-21). As Kind (2003b) argues, this mismatch may cause pupils' to have a poor understanding of science knowledge and may reflect that the teaching method develops certain skills rather than that meaningful learning takes place. Similarly, most of the English teachers do not seem to pay as much attention to enhancing pupils' conceptual enquiry as the Korean teachers do.

Secondly, the majority of the Korean teachers agree that the English questions would be good to enhance scientific enquiry, but they do not agree with employing more of the English questions in their own examination papers. In this respect, Korean teachers may have more constraints in 'theory and practice' triangulation (Grenfell, 1998); for example, there seems to be a conflict between what they think is the way to teach scientific enquiry and the way they teach in practice as well as what they think is the best way to teach science and what the national curriculum is recommending.

According to the findings from the Korean teachers, there is a three-fold resistance to employing more of the English type questions. **First,** the Korean teachers indicate that the assessment related difficulties are a great stumbling block against implementing more scientific enquiry. They suggest that the examination papers do not fully reflect the aims of the curriculum (appendix 36, Kor-16). The examinations include mainly content knowledge, not the process of science or scientific enquiry. This is consistent with the findings from the documentary analysis. The Korean teachers are apprehensive to assess open-ended questions although most of the Korean teachers have understanding about the tentativeness of science knowledge as shown in chapter 6-3-2 by revealing their tendency toward relativism. As shown in appendix 36, Kor-21, the Korean teachers are apprehensive about getting into disputes with their pupils about marking if the answer to a question can be varied when the examinations involve high stakes. **In addition,** the textbook centred school curriculum is a barrier. The Korean teachers tend to do experimentations in order to confirm what they taught from the textbook because they are under pressure to familiarise pupils with the questions and the experimentation context. Thus, as a Korean teacher has mentioned, carrying out investigations and doing experimentations are closely related to either the performance assessment or the examination questions (appendix 36, Kor-24).

Thirdly, it is clear that the Korean teachers have difficulties in doing more practical work in the classroom. As the Korean teachers point out, they have lack of facilities, large class-sizes and time constraints, which is consistent with the findings from the questionnaire (6-3-3). For example, most science lessons are carried out not in the laboratory but in the classroom with 45 minutes lesson time. Then, doing practical work seems to them to be impractical. The Korean teachers also indicate that the KNSC still contains too much curriculum content and remains the traditional content and context. Thus, they believe the curriculum content does not fit into scientific enquiry teaching (appendix 36, Kor-16).

Lastly, there is a difference between the two groups of teachers in their beliefs concerning science knowledge and in conceptual enquiry. The English teachers do not see any merit in the Korean questions in terms of enhancing scientific enquiry in contrast the Korean teachers believe that the Korean questions are still worth teaching. According to the Korean teachers, they think a necessary way of learning science is by way of keep practising the process of understanding the content and the process of problem solving (appendix 36, Kor-29).

Although only 20-30% pupils are able to understand the science concept fully and to get the right answers in the examinations, the Korean teachers are still confident in teaching this way and they expect their pupils will understand more and more later on as they go to high school or college (appendix 36, Kor-10). Some Korean teachers express their concern about the reduced content of the 7th national curriculum, which has eliminated some relatively difficult topics. They believe that this may result in their pupils' achievements being degraded because they do not see that their pupils' achievements have got better with the easier reduced content (appendix 36, Kor-22). Some of the Korean teachers criticise this curricular content reduction as they think it results in a less integrated and more fragmented curriculum structure (appendix 36, Kor-28). Some of the Korean teachers suggest that pupils can solve the English type questions when the 7th national curriculum is fully implemented and the Korean questions can still be learnt by the conventional teaching method (appendix 36, Kor-12). As such, the Korean teachers recognise their pupils need to learn more about skills, yet they would place more weight on conceptual enquiry rather than empirical enquiry which is consistent with the findings from the questionnaire (6-3-3).

While the Korean teachers exercise this teaching method, they explain every detail and demonstrate the process of problem solving concerning the science content over and over again. This process may lead Korean teachers to be more reflective on their teaching and learning in the classrooms and to commit themselves to pupils' learning process. As shown in appendix 36, Kor-10, Kor-14, Kor-21, the Korean teachers can indicate approximate proportions of pupils who could get the right answers in each set of examinations. This may be controversial to the learner centred teaching. The Korean questions are also criticised for demanding a high cognitive ability to understand the science concepts (Kim J H & Lee M K, 2003). Nevertheless, the Korean teaching method could be valued on the basis of Korean culture.

The above tendency may be linked with the Korean teachers' emphasis on science knowledge derived from an academic orientated curriculum (KICE, 2001). Although both groups of teachers agree that an important aim of teaching science is to provide good understanding of science concepts, the Korean teachers show their strong attachment to science knowledge. They tend to believe that pupils need a strong foundation of knowledge to enable them to move on to further dimensions such as application-based questions (Kim J H & Lee M K, 2003).

In general, from the findings through the focus group interviews, both groups of teachers reveal shortcomings in their teaching by not integrating the nature of science and scientific enquiry into the curriculum content as recommended by the national curricula. The English teachers tend to teach science by doing practical work and carrying out investigations, whilst the Korean teachers teach with repetitive explanations and demonstrations over and over again, yet neither group of teachers tend to teach science content and related enquiry activities in an integrated manner.

7-4 Summary

Both groups of teachers favour TIMSS-2003 questions, which are known as questions, which integrate investigative skills and content knowledge. Teachers in both countries respond in similar ways to each set of questions in terms of their preference and ways of preparation for their pupils to answer them, which may reflect that if they were given the same questions, they would teach in the same way.

Through the results of the focus group interviews, the English teachers show their satisfaction with the type of English questions although these are relatively new to them. They would be willing to change and to follow a new scheme of work in order to implement the new policy. On the other hand, the Korean teachers show their discontent with the KNSC in terms of it being traditional with too much fragmented content. Both groups of teachers agree that the English questions would enhance more scientific enquiry. However, the Korean teachers do not want to employ more of the English questions.

There are various reasons: the Korean teachers indicate that the assessment driven school curriculum is a great stumbling block to implementing more scientific enquiry into the classroom. Thus, unless the elements of scientific enquiry are integrated into the assessment content, teachers would not teach scientific enquiry. In addition, the Korean teachers show resistance to employing more scientific enquiry and express their strong belief in the importance of conceptual enquiry and an emphasis on science knowledge

Both groups of teachers recognise the importance of scientific enquiry. Yet they both show their shortcomings in teaching science knowledge and scientific enquiry activities in an integrated manner according to the national curriculum recommendations.

7-5 Reflections on these focus group interviews

The results from the focus group interviews are not only consistent with the result from the questionnaire part D in the previous chapter but they also reveal detailed data in depth to add strength to the conclusions drawn. Thus, the data from the focus group interviews support the results from the questionnaires as well as providing detailed information concerning the discrepancy and resistance between teachers' perceptions and their practice.

Most findings from these focus group interviews are consistent with the findings from the questionnaires in chapter 6 and the findings from the documentary analysis in chapters 4 and 5. Although a few findings show differences, these may not refer to controversial issues but show discrepancy and resistance between teachers' perceptions and their practice. Thus, the findings may need to be interpreted in context. There is an example showing the different responses with the same question.

According to the responses from the questionnaires, the majority of the English teachers indicate that their pupils would do ' very well' in TIMSS-2003 questions, 'well' in the English KS3 questions but 'not very well' in the Korean HE questions. Whilst the majority of the Korean teachers indicate that their pupils would do ' well' in TIMSS-2003 questions, 'well' in the Korean HE questions but 'not answer at all' in the English KS3 questions.

However, in the focus group discussions, teachers express this in slightly different ways: As the English teachers had more time to look at the questions from Korean HE examinations, they tended to realise that even their pupils in the able groups would not be able to answer the questions on the Korean HE test paters. On the other hand, the Korean teachers expressed their views that the English KS3 questions are easier to teach.

This is a slightly different result from that in section 6-3-4, in which the English teachers respond to the Korean questions more confidently than the Korean teachers to the English questions. The English teachers recognise that the Korean questions are up to KS 4 syllabus level demanding higher cognitive and mathematical ability.

In addition, although both groups of teachers agree that the English KS3 questions are good for enhancing scientific enquiry ability, the Korean teachers show considerable resistance concerning the idea they should have more questions in the style of English KS3 tests. Yet, the findings from the questionnaire could not show the teachers' resistance or the discrepancy between their perceptions and the teaching in the classroom.

Therefore, the focus group discussion is useful to substantiate data from the questionnaire results. However, during the focus group discussions, one or two participants tended to dominate conversations so that each occasion shows slightly different points being made, for example, on the 130805 occasion, the dominant conversation was about assessment driven school curricula whilst the 210805 occasion was dominated by a teacher whose concerns were teaching and learning with a new scheme of work.

Chapter 8 Discussions and Conclusions

The research question *'**What is the impact of assessment in scientific enquiry on the perception of teaching of science at age 14 in a comparison between England Korea?'*** has led to exploration of the following sub-questions as mentioned at the beginning of this study:

- What is taught and assessed in scientific enquiry in the national curricula in England and Korea?
- How do teachers perceive their teaching of scientific enquiry and what are their perceptions about the nature of science and of scientific enquiry?

The first sub-question explored the national curricula and assessment areas by documentary analysis described in chapters 4 and 5. The second has been explored by survey research using the questionnaires and focus group discussions described in chapters 6 and 7. These chapters include similarities and differences between England and Korea of the national curricula and teachers' perceptions

This chapter will synthesise the findings from previous chapters and emerging issues throughout the study will be discussed in order to draw conclusions. Thus, this chapter includes:

-Summary of similarities and differences of the national curricula and examination papers from the documentary analysis
-Summary of similarities and differences in teachers' perceptions and opinions from the survey research
-Discussions and implications of the issues concerning curriculum, examinations and teachers' perceptions from the perspective of improving the quality of education
-Implications from the educational comparisons
-Reflections on this study including limitations, confidence in the findings
-Drawing conclusions

8-1 Summary of the findings

Making comparisons assists in discovering that which is common, and that which is unique to each education system. Prior to discussing emerging issues, a summary concerning the commonalities and differences from the findings of the documentary analysis and survey research are shown in tables 67-1, 67-2, 67-3, 67-4 and 67-5.

Table-67 –1 Summary of documentary analysis (the national curricula)

Curriculum	Similarities	Differences	
Content	***similar aims** ***similar content (traditional content)**		***Different cultural historical backgrounds** ***Different curriculum structure** ('Spiral structure' in England: 'Staircase structure' in Korea) ***Different level of incorporation of scientific enquiry and other subjects**
		Eng	*** Sc1 is prominent in the ENSC** - scientific enquiry as a contemporary view of science - a separate strand of curriculum content - as a way of teaching science
		Kor	*** Scientific enquiry** -as the way to teach science -described as enquiry based teaching -less incorporation of scientific enquiry with knowledge ***The KNSC is more extensive and more in depth** - Equivalent to KS4 syllabus - More mathematical content ***Earth science is prominent in the KNSC**
Teaching & Learning	***similar time tables for science**		
		Eng	***more practical work,** - lessons in laboratories
		Kor	*** less practical work** - more lessons in classrooms - teachers move classrooms each lesson
Assessment	*** assessments involving high stakes** ***around 65-70% of common content in 2003**		*** different assessment regime** -to maintain quality of education in Eng -to select able pupils in Kor -criterion referenced yet adding to the elements of norm in Eng -norm referenced, yet adding to criterion reference in Kor -more examinations in Kor *** different types of examination papers** - 2 sets of test papers which have different feasibilities in Eng - one feasibility in Kor *** different types of questions** - various types of questions in Eng - multiple choice, in Kor *** different proportions of subjects**
		Eng	*** greater proportion of everyday context,** *** more experimentation oriented questions** *** higher proportions of discrete scientific investigations**
		Kor	*** greater proportion of Earth science(physics)** *** greater proportion of laws, principles and theories** *** greater proportion of mathematical content**

Table 67-2 Summary of documentary analysis (examination papers)

Similarities	Differences	
* Emphasis on sc1	**A significant difference in the level of reflection of the aims, content in the assessment**	
	Eng	* varied proportions of each subject in the examination papers * increased proportions of scientific enquiry in 2004 * reduced proportions of multiple choice format in 2004 * increased proportions of descriptions * higher proportion of open-ended question * higher proportion of questions, asking how and why * higher proportion of discrete scientific investigation * the elements of nature of science included in 2004 * a wider spectrum of Klopfer's specifications in 2004 * given more information on a question * demanding lower conceptual understanding: falling into recall and comprehension in Bloom's taxonomy
	Kor	*even proportions of each subject * remain the same proportion of scientific enquiry in 2004 * remain the same proportion of multiple choice format in 2004 * no discrete investigations * concentrated on the area of data interpretation * included a compact type of question which can include a large amount of information in a single question * demanding higher conceptual understanding, falling into application and comprehension domain.

Table 67-3 Summary of teachers' survey from questionnaire

Questionnaire	Similarities	Differences	
A(background)	30-40s, dominated by female respondents	***specialty**: 'biology', 'chemistry' in Eng 'integrated science', 'biology' in Kor * **experience of studying**: more Eng. teachers have no experience of studying NOS related disciplines	
B(views about NOS and Sc1)	naïve views about the NOS	Eng	*inconsistent, indeterminate responses in the items concerning NOS *skewed toward deductivism and process orientated
		Kor	* better views about the NOS
C-1(perceptions) -Aims of teaching science, -Aims of doing practical work -Aims of teaching sc1	similar perceptions -motivating pupils and understanding science concepts	Eng	* concerned more about skills
		Kor	*concerned more about conceptual enquiry
C-2(teaching science)		Eng	* main teaching methods - teachers' talking, experimentation, teachers demonstration, discussion * more practical work * give more freedom to pupils when they do investigations
		Kor	*main teaching methods - teachers talking, worksheet, teachers demonstration, experimentation *less practical work *give less freedom to pupils when doing investigations
C-2(teaching sc1)		Eng	* to describe patterns and relationships in data from investigation
		Kor	* to draw conclusions and to state the evidence concerning the conclusion by presenting a graph
c-3(opinions) Confidence in teaching sc1		*English teachers are more confident in teaching sc1	
Causes of mismatches	*Pupils' lack of skills *Limited time and space	*Korean teachers note this occurs: when the concepts and the investigations are not being related	
Positive effect of investigations	*agree		
Preassure of Attainment targets		Eng	* a little
		Kor	* a lot
Obstacles toward more sc1	*Large class sizes	Eng	* the pressure of examinations
		Kor	*inflexible timetable

Table 67-4 Summary of teachers' survey from questionnaire D (opinions concerning each set of questions)

Opinions	Similarities	Differences	
How well...	* their pupils would do well in TIMSS questions	Eng	*TIMSS-2003: Very well *Korean HE: Not very well *English KS3; Well
		Kor	*TIMSS-2003 : Well *Korean HE: Well *English KS3: Not answer at all
How would you teach.....			
TIMSS	*more practice concerning the identification of the variables *more explanations of methods and fair tests	Kor	*more open investigations
HE	*more practice to familiarize with worksheets *more explanations about science concepts		
KS3	* more practice concerning identification of variables * more open investigative work	Kor	* More explicit teaching concerning the elements of sc1
Those questions would affect teaching	KS3 would affect a lot TIMSS	Eng	KS 3 and HE would affect
		Kor	KS3 questions would affect being followed by TIMSS
Opinions about multiple choice		Eng	Would be easier but not much
		Kor	Would be much easier
Opinions about the curricular content or context		Korean teachers show a stronger agreement that assessment content and context should be within the national curriculum	

67-5 Summary of teachers' survey from focus group discussions

	Similarities		Differences
What do you think, these questions are testing?	* **English KS3**: process of science, application based, scientific investigation ***Korean HE**: Scientific enquiry, Maths ability	Eng	Some of teachers indicate that the Korean HE questions are not science but maths
		Kor	
How well would students perform?	* Pupils would do well in TIMSS (60-70%)	Eng	1TIMSS-2003 2 English KS3 3 Korean HE
		Kor	1TIMSS-2003 2 Korean HE 3 English KS3
Differences between each set of questions	*unfamiliarity/openness of question/ application based *content based/ cognitive level/mathematical content		
Difficulties in answering	*unfamiliarity	Eng	*** to teach Korean HE** -pupils' maths ability insufficient -requires KS4 syllabus work -demands too much work to teach, would need (repetitive explanations)
		Kor	*** to teach English KS3** - problems are assessment related - barriers not to do practical work (too much content, traditional content, time table, lack of facilities and large class size) -teachers' strong belief in knowledge-based teaching
Current teaching practice		Eng	*By doing practical work *By familiarising with the new type of questions for KS3
		Kor	*By explaining terms, principles and processes. *By demonstrating process of problem solving * By familiarising with any new type of questions
How to prepare to answer each set of question	**English KS3** * To do more practical work/ investigations * To give time to think * To familiarise by using practice papers and past examination papers **Korean HE** * To breakdown information * To explain every single things * To familiarise by using practice papers and examination papers **TIMSS 2003** * The same way to teach English KS3		
Which of these 3 sets of questions would cause you to change your teaching practice	English KS3	* Some of English teachers indicate Korean HE questions	
Questions to enhance sc1 ability	English KS3	* The Korean teachers do not agree with employing more of KS3 questions	

As shown in the above tables, the findings from the teachers' survey show more commonalities between both groups of teachers than there is between the two countries curricula and assessment. It is clear that both groups of teachers show much in common in their perceptions about the aims of teaching science, doing practical work and teaching scientific enquiry as well as other various opinions.

All the findings are inter-related and often over-lap so that they can support each other, which can provide details in depth to add strength to the conclusion. The findings from the focus group interviews support the findings from documentary analysis as well as the findings from the questionnaire survey.

Although the aims of the national curricula put emphasis on scientific enquiry as well as both groups of teachers recognizing the importance of scientific enquiry, this study shows teachers' shortcomings in teaching elements of the nature of science and scientific enquiry in an integrated manner for meaningful learning to take place.

It is clear that assessment driven school curricula influence teachers' perceptions and teaching practice. The assessment content seems to affect how teachers perceive the importance of scientific enquiry and influences the way in which they teach science. Both groups of teachers show a difference in the teaching of scientific enquiry although they recognize its importance.

Following, emerging issues are discussed, with regard to the main factors and the effect the above shortcomings may have. Then, the implications are sought.

8-2 Findings about the national curricula

Curricula in England and Korea stem from different historical and cultural backgrounds as well as the content within the national curricula being structured in different ways although both curricula are heading towards similar goals by putting emphasis on scientific literacy and by incorporating more scientific enquiry into the science classroom (DfES, 2001; MOE, 2001a). Both curricula also have much in common concerning the aims and content of the curricula and the amount of time allocated on the time table for science subjects at the KS3 level.

However, the documentary analysis shows differences in the definition of scientific enquiry in the national curricula. It also reveals a difference in the reflection of the aims of the national curriculum on the curriculum content and on the assessment content. The teachers' survey shows that this curriculum presentation of scientific enquiry influences teachers' perceptions about scientific enquiry. Teachers are influenced by the interpretations of scientific enquiry activities within the national curricula.

8-2-1 Differences in presentation of scientific enquiry in the national curricula

As shown in chapter 4 (section, 4-4), there are differences in presentation concerning scientific enquiry between the two curricula.

Scientific enquiry is mentioned as a separate strand along with other science subjects as Sc1 in the ENSC. It is defined as 'a process of science' comprising 'ideas and evidence' and 'investigative skills' (DfES, 2001). As the 'ideas and evidence' is a distinctive strand in scientific enquiry, it refers to interplay between empirical questions requiring evidence and scientific explanations using historical and contemporary examples (OCR, 2003). Thus, the ENSC describes the tentativeness of scientific knowledge and its cultural influence in the development of science. The ENSC also mentions scientific enquiry as the way to teach science mentioning that scientific enquiry generally should be linked directly to practical work with science key ideas being integrated into most lessons and not being left to special investigative science (DfES, 2002). Therefore, scientific enquiry (Sc1) includes the elements of the nature of science, methods and activities of science as well as its social implications.

On the other hand, The KNSC mentions scientific enquiry as a 'process of science' referring to the way of learning and teaching science (MOE, 2001b). It comprises 'basic enquiry' and 'integrated enquiry' and 'enquiry activities', including observation, classification, measurement, prediction, reasoning, finding problems, hypothesizing, interpretation, control variables, drawing conclusions and so on. There is little incorporation of the elements of the nature of science such as tentativeness of scientific knowledge and its cultural influence in the development of science apart from the implications of STS (science-technology-society). These refer to a teaching method confined within the curriculum to help with the understanding of science knowledge and to enhance problem-solving abilities to acquire skills and practices and to foster scientific literacy (Sung M W, et al, 2000).

This narrower interpretation of scientific enquiry in the KNSC is recognised on the findings from teachers' survey as shown in sections 6-3-2, 6-3-3 and 6-3-4 which also show different notions concerning scientific enquiry activities. The Korean teachers also indicate a stronger agreement that the assessment content and context should be within the national curriculum content. Thus, the presentation of scientific enquiry in the national curriculum can influence teachers' notions and beliefs and the ways in which they interpret and teach the curricula content.

From the perspective of contemporary view of science, the ENSC describes scientific enquiry more comprehensively with a better reflection of science, portraying methods and activities of science in the real world (Ratcliffe, 1998; Ratcliffe, et al, 2004; Oh P S, 2005). By contrast, the narrower interpretation of scientific enquiry seems to impoverish the nature of science in the curriculum content. Subsequently teachers confined their concept of scientific enquiry as enquiry based instruction within the national curriculum (Sung M W, 1994).

As mentioned above, due to scientific enquiry being described as a separate strand in the ENSC, it gives a higher profile to scientific enquiry in the national curriculum and the elements of scientific enquiry become a statutory teaching requirement for teachers (Robers & Gott, 2004). Thus, the ENSC applies more fully the aims to its curriculum content and the assessment content.

By contrast, the KNSC emphasizes scientific enquiry only as the aim of the curriculum but it is not integrated into the curriculum content so that the elements of scientific enquiry are non-statutory in teaching. Thus, the elements of the nature of science are not incorporated in the KNSC content nor are the asserted purposes and aims of the curriculum statutory so that the nature of science seems to be extremely marginalised in the classroom.

In this respect, the KNSC seems to be more problematic in implementing scientific enquiry into the curriculum. It may be necessary to redefine or broaden the interpretation of scientific enquiry in the national curriculum. In order to introduce the aims into the curriculum content, it may be better to include the element of scientific enquiry in the curriculum content as statutory.

However, having a separate strand of scientific enquiry in the ENSC has raised its profile, but it has caused the link between scientific enquiry and other subjects to weaken (Robert & Gott, 2004). This weakened link between scientific enquiry and substantive science content can encourage teachers to continue to focus on scientific enquiry as a unique element of assessment separate from and discontinuous with the content (Robert & Gott, 2004). On the other hand, the KNSC has structured the elements of the nature of science and STS as a strand in year 10 science curriculum rather than in an integrated manner.

These factors may reflect different ways of structuring the national curriculum content as described in chapter 4 (4-3-1); the content in the ENSC is structured like a spiral whereas in the KNSC it is like a staircase. Yet, either way, there is a need to integrate the nature of science and scientific enquiry with the current strands in order for there to be a coherent and interwoven curriculum content. It may also be necessary for the KNSC to employ scientific enquiry and the nature of science as an inherent part of all science within the traditional science content rather than in a segregated and fragmented manner, as found in the current year 10 science curriculum.

8-2-2 Traditional curriculum content

Both curricula contain a considerable amount of traditional content as mentioned in chapters 2 and 4. Due to this, there is much in common in the curriculum content in both curricula and over 60% of examination content reveals common topics. The traditional content consists of mainly factual science knowledge with an extremely marginal area of understanding about the methods and processes or the nature of science (Shwartz, et al, 2004).

The appropriateness of this traditional content has been doubted. Kim J H & Lee M K, (2003) mention that the traditional content can cause teachers to place the emphasis on science knowledge and in turn, tends to put pupils off the subject of science itself. Osborne and Collins (2000) support this and saying that pupils would enjoy the real-life applications of science more than any other aspect. For example, the more abstract topics such as the periodic tables are not perceived to be useful for later life. Fensham (2000) supports this by saying that this kind of scientific knowledge can easily be forgotten after leaving school.

The continued high amount of traditional curriculum content in both countries does not necessarily help the teaching of scientific enquiry. Research shows that teachers have more difficulty in accommodating and fitting in the appropriate elements about the nature of science and enquiry activities into the current curriculum content than teaching contemporary issues or new content knowledge (Shwartz, et al, 2004). The Korean teachers also support this and mention that they find more difficulty in teaching traditional curriculum content with scientific enquiry (7-2-4).

Delphi studies from both countries (Osborne, et al, 2003: Kim J H & Lee M K, 2003) may show a recognition that the curricula need inclusions concerning the element about the nature of science (i.e, tentativeness of science knowledge), and contemporary issues as well as the process of how the knowledge has been generated in order to nurture scientific literacy for future citizenship. As Solomon (1998) suggested, relevant curriculum content can include current issues and interesting applications of science, be exciting and place an emphasis on the creative activity of human culture. There seem to be still ongoing debates concerning what should be taught in school science (Osborne, et al, 2003; Kim J H & Lee M K, 2003).

In practice, it may be necessary to consider how to incorporate scientific enquiry into the traditional content. Teachers may have to teach the processes which the scientific knowledge creates and incorporate scientific enquiry activities with the relevant elements of the nature of science (Shwartz, et al, 2004). In this respect, there is still a need to change curriculum content including relevant aspects of the nature of science as well as scientific enquiry activities. At the same time, there is a need to support teachers so that they recognize the interdependence of the nature of science and the relevant views about the nature of science with the science knowledge as well as introducing appropriate scientific enquiry activities (Shwartz and Lederman, 2002).

8-2-3 The amount of curriculum content

Teachers from both countries have criticized the national curricula for having too much content knowledge as shown in chapters 6 and 7. The curriculum content has been reduced since the ENSC was implemented in 1989. The current KNSC (the 7^{th} national curriculum) has also been reduced in content although the science-for-all movement has caused an increase in the curriculum content (Fensham, 2000). Yet, both curricula are still considered to have too much content knowledge. According to the teachers' survey, Korean teachers complain that there is too much content in the national curriculum and that there is too little time to teach in the way they wish. Topics must be covered quickly and then left. There is little time for reflection and consolidation or to consider the interesting applications of a topic. Teachers feel unable to spend time following up science topics that are in the news or are of particular interest to their students or to allow students time to discuss scientific issues and express their own points of view (Chapter 7). Shortage of time also appears to have affected the amount of time spent on practical work. The same complaints have been identified from English teachers in other research (Nicolson and Holman, 2003).

Similarly, the amount of content seems to result in teacher-centred teaching, lack of time to do scientific investigations and too much emphasis on content knowledge. As the research shows, although teachers recognise the importance of scientific enquiry, English teachers indicate their current teaching methods as explaining and experimentation whilst in Korea it is explaining, and worksheet activity. This has been a far cry from enhancing pupils' scientific enquiry ability. The amount of content also causes teachers to be reluctant to do scientific investigations in practice because investigations for learning seem to take more time and the learning outcome evolves slowly (Osborne, et al, 2003; Oh P S, 2005). Therefore, content reduction may be needed in order for them to be able to teach in the way, which the national curricula recommend.

However, the Korean teachers criticise simple reduction of curricular content in chapter 7(7-2-4). The latest curriculum revision in Korea has involved a considerable amount of curriculum reduction and places an emphasis on scientific enquiry and practical work (MOE, 2002). The Korean teachers point out that the curriculum has become fragmented as each topic and subject has been separated from the underlying values and processes. This lack of integration of the nature of science and scientific enquiry may cause teachers to regard them as further requirements for the teachers' scheme of work.

A more holistic approach may need to be considered and the elements of the nature of science and scientific enquiry be implemented in an integrated way into the curriculum revision content reduction. It may also be necessary to regard the nature of science as a way of achieving coherence by regarding it as an underlying educational purpose as well as overarching all the science subjects (Shwartz & Lederman, 2002).

To sum up, The ENSC reflects the aims of the curriculum more fully in the curriculum assessment content with having scientific enquiry as a separate strand in the national curricula. The description of the term scientific enquiry is closer to contemporary view of science. On the other hand, the KNSC has a narrower interpretation of scientific enquiry. This is recognized by the findings from the teachers' survey showing different notions concerning scientific enquiry and boundaries of scientific enquiry and as to how they interpret and teach the content. Thus, the descriptions of scientific enquiry in the national curriculum affect teachers' notions and how they interpret and teach the content. In this respect, the KNSC is shown to be more problematic in terms of reflecting the aims of the curriculum in its content and assessment. The elements of the nature of science are not incorporated in the KNSC content nor are the asserted purpose and aims of the curriculum statutory so that scientific enquiry seems to be extremely marginalised in the classroom.

Both curricula have much in common having too much content and too much traditional content. Thus, in order to implement the elements of the nature of science and scientific enquiry, curriculum revision or curriculum reduction may be necessary. Therefore, it is necessary to implement the elements of the nature of science and scientific enquiry into the aims and into the curriculum content in a holistic and consistent manner. The following section discusses the findings about assessment

8-3 Findings about the standardized examinations

As mentioned in chapter 2, the aims of both curricula are similar in wanting to implement scientific enquiry in order to foster pupils' scientific literacy. The curricular content has much in common with considerable proportions of traditional content knowledge. However, the examinations show a greater difference concerning purpose, type of questions and questions demanding scientific explanation and higher conceptual understanding.

Based on similarities and differences between two sets of assessments, this section deals with issues and their implications, discussed from the perspective of implementing scientific enquiry into the classroom in order to reflect more fully the aims of the curricula in assessment.

8-3-1 Assessment driven school curricula

There seems to be a universal dilemma concerning examination policy. The dilemma relates to the potential difficulties because of a narrow selection of examinations to cater for a wide range of pupils' ability and a wide range of scientific enquiry including content knowledge, processes and skills as well as the backwash effects on testing and teaching (Little, 1990). Although there are different levels of high-stakes involved in examinations between the two countries, high-stake examinations are prevalent and the norm. Both groups of teachers seem to practise assessment driven teaching and the findings about assessment seem to provide a much closer link to their teaching practice rather than to the aims or the content of their national curricula (7-2-5).

Examinations of both countries send messages about what is valued and important. If it is not in the test, it cannot be important (Wiliam, 2003). Although the nature of science and scientific enquiry are emphasized as the aims of the national curricula, scientific enquiry is not going to achieve a higher profile unless it has a more important place within assessment. In this respect, both curricula show their shortcomings in implementing the nature of science and scientific enquiry although they put an emphasis on such in the aims of the national curriculum. As shown in this research, very few questions have been found concerning the nature of science as opposed to the broader field of scientific enquiry in either set of examination papers.

Under this assessment driven school curricula, there may be two ways of approaching an improvement of the assessment regime: one is to improve the quality of assessment content and methods. This assessed content should be reflected more fully and in a coherent and integrated within the manner within the aims of content of the national curriculum. The other possibility is to use examinations effectively as a lever to change the way in which teachers teach. As Noar & Ecktern (1990) suggested, assessment may serve as a vehicle for curriculum change yet, this requires increasing investment in teachers.

In respect of the above, the assessment in Korea is more problematic.

Firstly, the aims of the national curriculum are not fully reflected in the assessment content. According to the findings from this research, less implementation of scientific enquiry comes from two main sources. One is from curriculum content, which does not incorporate scientific enquiry in its aims but only in recommendations for teachers (chapter 4 and chapter 7). The other may come from the over-emphasis on scientific knowledge and the fragmented way of assessing scientific enquiry. Korean teachers tend to think of performance assessment for assessing pupils' scientific abilities and of examinations for assessing scientific knowledge along with conceptual enquiry (Chapter 7).

However, performance assessment cannot cover a wide enough spectrum of scientific enquiry ability.

Secondly, the English teachers indicate that assessment driven school curricula is the largest obstacle against implementing more scientific enquiry (6-3-3). Yet, they agree to have a greater proportion of KS3 questions in order to enhance pupils' scientific enquiry ability. They also show their satisfaction about the way in which they would teach to prepare pupils to do KS3 questions. Whilst the Korean teachers indicate that they feel a lot of pressure due to the attainment targets set by schools. They also show a greater constraint between the aims of the curriculum and their teaching practice. Thus, there appears more resistance and dissatisfaction amongst the Korean teachers.

Thirdly, both sets of examination papers show similar proportions of scientific enquiry in 2003. English test papers have increased their proportion of scientific enquiry questions and have had a greater variety in sub-categories in 2004 whereas Korean test papers have remained the same in proportion and variety in sub-categories. In addition, there were newly implied questions in 2004 KS3 test papers which included the elements of the nature of science although it was a tiny proportion in 2004 KS3 test papers. Thus, there may be a need to reflect more fully the emphasis of the curricular aims into the assessment content in order to use examinations as a lever to change teaching practice.

Therefore, it is clear that there is a need to reflect the aims of the national curricula in the assessment content in order for the nature of science and scientific enquiry to achieve a higher profile in the classroom.

The following section will discuss issues, which can be barriers into implementing more scientific enquiry in the assessment content.

8-3-2 Purposes of assessment and quality of assessment

In order to employ more scientific enquiry in the assessment content, the assessment regime may need to have a certain level of flexibility in order to reflect a wider range of scientific enquiry with various types, content and context of questions. This is because scientific enquiry as methods and activities of science comprising the elements of the nature of science, processes, skills and related science knowledge.

However, changes in assessment content, types of questions and context have hardly occurred in Korean HE examinations as shown in chapter 5. Only that 4 options of multiple choice format has changed into 5 options in 2004. As shown in chapter 4, the school based examinations retain similar features to the HE examinations having only small portions of short answer questions and a majority of multiple choice formats.

This tendency can stem from the purpose of assessment in Korea (Kim J H & Lee M K, 2003). Originally the purpose of the standardized assessment was to select and to classify able pupils who can be predicted to carry on with high school education. Although almost all pupils go to high school nowadays the Korean assessment regime is still dominated by selecting and classifying pupils with traditional norm referencing (section, 4-3-4). This tendency not only demands higher comparability, validity and reliability but also gives rigidity to the system (Kim J C, 2004). In this respect, 100% multiple-choice format seems to fit into this purpose as it enables the assessment of a large amount of scientific knowledge with a compact form of questions. It is known that the objective questions have the advantage of high reliability because they cover a wider range of content and marking is easy (Taber, 2003). In terms of validity for this, there are well-developed statistical techniques to pretest items, which easily check validity (Taber, 2003).

Consequently, Korean teachers are over concerned with reliability and validity in the assessment content whether they produce school based tests or they prepare pupils for these tests as shown in section 7-2-4. As mentioned by some Korean teachers, they prefer objective and clear-cut questions rather than open-ended questions asking 'why' and 'how'. Because they cover a wider range of content they ensure that pupils can secure their marks, having familiar content and context within the national curriculum. Indeed, the Korean teachers were apprehensive concerning open-ended questions, which have no clear-cut right or wrong answers as well as concerning assessment content and context beyond the national curricular boundary (6-4-5 and 7-2-4).

On the other hand, the purpose of English KS3 tests was originally to maintain the standard of achievement at the KS3 level based on criterion referencing. Recently, target attainments and standard achievements have been imposed on each year so that the purposes of English KS3 tests has to embrace making predictions about an individual's future performance, evaluating public accountability and producing certifications.

English teachers indicate that they have 'a little pressure' about target attainment set by schools but 'the pressure of examination' is the largest obstacle in implementing more scientific enquiry (section 6-3-3). The English teachers may see the pressure comes from national assessment schemes including its nature and use of national assessment in league rather than from the school. As Taber (2003) argues, the assessment for multi-purposes can cause constraints. Each assessment should serve its own purpose in order to minimize the constraints. However, compared with the Korean assessment regime, the English counterpart seems to remain under less constraint and is able to modify the content and context of assessment.

In respect to the quality of assessment, as the English teachers point out (7-2-4), the English KS3 test papers require good readers to understand what the questions are asking for. While high scores would certainly imply good knowledge, low scores might indicate either lack of science knowledge or an inability to understand the questions. Therefore, for weak readers, the test may not be said to be valid. In addition, girls tend to earn more marks in biology whereas boys tend to earn more mark in physics (Wiliam, 2003). If a test includes more biology items, then girls tend to earn higher marks than boys. Indeed, English KS3 test papers include varied proportions of science subjects in each tier of papers (section 5-3-1). The proportions of scientific enquiry are also varied in each test paper. On the other hand, the Korean test papers consist of similar proportions of each science subject. The proportions of scientific knowledge area and scientific enquiry area have shown a regular ratio, which is represents 70 to 30. In terms of reliability, Wiliam & Black (1999, quoted in Black, 2003, p75) analysed published data for KS3 tests and concluded that the chances of a student's level result being wrong by one level were at least 20-30%. Compared with to the English KS3 tests, the Korean test papers show a higher validity and reliability of assessment in technical terms.

As Wiliam (2003) argues, the traditional view of validity of an assessment is inadequate because validity cannot be the property of a test rather it is a process to interpret assessment results. The same test can be valid for some purposes and not for others and may work well with some populations but not with others.

Thus, assessment should be valid and reliable but there may be something more to consider in the current assessment regime. In particular, as the questions broaden the role of scientific investigations and introduce aspects of the nature of science and the ways in which scientists work, then more open-ended questions having no wrong or right answer may be included. As the aims are to foster pupils' enquiry ability including reasoning ability and creativity, multiple-choice format or rigid assessment structure may not fit into it.

Indeed, English KS3 tests for 2004 show a reduced tendency towards multiple-choice format but increased proportions of description or explanation (section 5-3-1). As the emphasis moves towards elements of the nature of science and scientific enquiry, then it becomes impossible to cover the assessment of scientific enquiry ability including skills and conceptual enquiry by using multiple choice questions as has been shown by other research (Lee H R, 1999; Taber, 2003).

Therefore, there is an ongoing debate to change the purpose or nature of assessment with a modern approach in Korea to give many more students the chance to demonstrate what they have learnt rather than pick out what they do not know (Kim J H & Lee M K, 2003). Taber (2003) also supports this and argues that pupils need to be given a better opportunity to demonstrate the requisite knowledge whether pupils can recall specific items of information or apply it to particular problems, that is a structured question (Black, 2003; Kim J C, 2004). There are also ongoing debates concerning the validity and reliability of the national assessment (Taber, 2003).

To sum up, the quality of assessment such as validity, reliability and suitability for the purposes must be important. The Korean assessment regime places emphasis on quality of assessment in technical terms so that the multiple-choice format has dominated. However, there is a need to reconsider types of questions, which can assess various abilities of scientific enquiry in the national assessment as the methods of science can be varied in content as well as context.

The following section will discuss issues concerning the spectrums of scientific enquiry based on the analysis of questions by using Klopfer's specifications.

8-3-4 Spectrum of scientific enquiry

Klopfers' specifications are a useful framework for showing the comprehensive range of assessment expectations in science. The spectrum indicates how widely the examinations consist of questions, which demand pupils' varied ability.

According to Klopfer's specifications, the areas of scientific enquiry consist of 'Observing and measuring' (**b1-b5**)' 'Seeing a problem and seeking ways to solve it' (**c1-c4**) 'Interpreting data and formulating generalisations' (**d1-d6**) and 'Building, testing and revising a theoretical model' (**e1-e6**), 'Application of scientific knowledge and method' (**f1-f2**) 'Manual skills' (**g1-g2**) 'Attitude and interest' (**h1-h5**) and 'Orientation' (**i1-i6**). They are also included 'Knowledge and comprehension' (**a1-a11**)

Generally, scientific enquiry abilities are assessed by performance assessments and various examinations. The areas of 'Manual skills' (**g1-g2**) and 'attitude and interest' **(h1-h5)** can be assessed well by performance assessment. The areas concerning 'Building, testing and revising a theoretical model' (**e1-e6**) and 'Application of scientific knowledge and method' (**f1-f2**) are regarded as demanding higher cognitive ability (Hur M, 1984). In this research there was not a question which falls into the areas 'Building, testing and revising a theoretical model' (**e1-e6**) and 'Application of scientific knowledge and method' (**f1-f2**).

As shown in section 5-3-3, scientific enquiry questions in English test papers show a wider spectrum including of 'Observing and Measuring' (**b1-b5**) 'Seeing a problem and seeking ways to solve it' (**c1-c4**) 'Interpreting data and formulating generalisations' (**d1-d6**), and 'Manual Skills' **(g11-g2)** and Orientation (**i1-i6**). The outstanding area is 'Seeing a problem and seeking ways to solve it' (**c1-c4**) which mainly covers discrete scientific investigative questions, and 'Orientation' (**i1-i6**) which includes elements of the nature of science despite being only a tiny proportion of questions. Thus, the Korean test papers reflect a narrower range of assessment content. As the documentary analysis has revealed (section 5-3-3), the 2004 English test papers show changes in the diversity of scientific enquiry by having increased the areas of 'Observing and Measuring', ' Seeing a problem and seeking ways to solve it (c1-c4), 'Manual skills' (g1-g2) and 'Orientation'. By contrast, the Korean test papers show no significant changes from 2003 to 2004. It is clear that the English KS3 test papers have been developing toward a higher proportion of scientific enquiry and a wider spectrum in the Klopfer's specifications. The report (Osborne & Ratcliffe, 2000, p17) supports this by showing Klopfer's specifications of the English KS3 test papers during 1998, 1999 and 2000.

Yet, there still needs to be a wider range of questions in Klopfer's spectrum because the elements of the nature of science have been found in 2004 test papers with only a few questions. In addition, the English test papers tend to narrow the notion of a scientific investigation to an exploration of the effect of one or more independent variables on a dependent variable. This may mean that the net outcome has been to narrow the range of tasks which can count as 'investigations' so that the sort of work undertaken bears little relation to the real work of scientists (Welford, et al, 1996). In practice, scientific investigations in English schools always tend to involve practical work as apart from collecting relevant information, argumentation, communication and so on (Welford, et al, 1996). Therefore, although English test papers show a little wider spectrum including the discrete scientific investigative questions, there may still need to be more diversity in the assessment content.

On the other hand, all the questions in the Korean HE examinations fall into only four categories in Klopfer's specifications which are 'Knowledge and comprehension' (**a1-a11**), 'Observing and measuring' (**b1-b5**)' 'Interpreting data and formulating generalisations' (**d1-d6**) 'Manual skills' (**g1-g2**). In addition, the scientific enquiry area has been concentrated on 'interpreting data and formulating generalisations' (**d1-d6**).

Comparing to the English test papers, the Korean counterparts show extremely limited domains of science and scientific enquiry. It may show that the Korean test papers reflect a narrower range of assessment content, which reflects on a narrower presentation about scientific enquiry in the national curriculum. The emphasis on the elements of the nature of science and scientific enquiry in the aims of the curriculum were not found in the assessment content.

The Korean teachers recognize a need for diversity and variation in content and context in assessing scientific enquiry and a need for offering variety experience of science for pupils (appendix 36, Kor-16). They also recognize that the Korean test papers have concentrated on the area of data interpretation. Nevertheless, they would easily give in these needs in their teaching in practice as they have to prepare pupils to get the tests because teaching scientific enquiry is not their priority.

There is a tendency for the national curricula context to be narrowed even further when teaching and learning is concentrated upon familiarization with assessment content. It is clear that this feature impoverishes many aspects of knowledge and skills that are considered science in the real world (Osborne & Ratcliffe, 2000). As Korean teachers in the focus group interviews mentioned, the elements of the nature of science including history of scientists may be used only for motivating pupils' interests rather than essential agenda for their scheme of work. In this respect, it is clear that the aims need to reflect to the curricular content and the assessment content more fully with consistent, coherent and integrated manner.

To sum up, it is important that the national assessment is developed to reflect curriculum intentions accurately and should encourage teaching methods (Osborne & Ratcliffe, 2002). In this respect, it is clear that there is a need for more diverse and varied types of questions, content and context of assessing scientific enquiry in the Korean examination papers.

8-3-5 Conceptual understanding

This section is based on the findings from the analysis by using Bloom's taxonomy. It describes how the assessment content, which includes questions demanding a different conceptual understanding, affects teaching in practice under assessment driven school curricula, then, issues and implications. Although the analysis includes all the questions in the test papers, in both areas of scientific enquiry and science knowledge, scientific enquiry questions tend to demand higher cognitive abilities as well as being a powerful determinant in teachers' teaching practice in the classroom as recognized in chapter 7 (7-2-5).

Bloom's taxonomy is useful in distinguishing between questions demanding higher and lower cognitive domains. Each question in all the test papers can be classified into six domains: 'Recall' 'Comprehension' 'Application' 'Analysis' 'Evaluation' and 'Synthesis'. Questions in the English KS3 tests fall into mainly 'Comprehension' and 'Recall' domains with a relatively lower level of 'Application' domain. Questions in the Korean HE tests fall into mainly 'Application' and 'Comprehension'. The Korean HE tests also show more in 'Analysis', 'Evaluation', and 'Synthesis' domains than that of English KS3 tests (section 5-3-2). The English KS3 tests in 2004 show more higher cognitive domains than that in 2003 more questions appearing in 'Comprehension' and less in 'Recall' domain as well as more questions in 'Application', 'Analysis', 'Evaluation' and 'Synthesis' than those in 2003. The Korean HE tests in 2004 also show a little change to higher cognitive domains than in 2003 with more questions appearing in 'Analysis', 'Evaluation' and 'Synthesis'.

Compared with Korean test papers, the English KS3 test papers include a variety of context, discrete investigative questions, more experimental questions and questions with real life applications, yet demanding a lower level of cognitive domains as shown in chapters 4 and 5. Under assessment driven school curricula, this tendency has accordingly affected teachers' teaching practice. As shown in sections 6-3-3 and 7-2-5, the English teachers do more practical work indicating that more than a half of the lessons involve practical work. They believe that pupils would gradually build up the ability to understand the elements of scientific enquiry and the ability to carry out scientific investigations through doing practical work.

There are some doubts about the effectiveness of this way of teaching. As shown in section 6-3-3, the English teachers do not often teach in ways in which scientific enquiry can be fostered such as scientific investigations, discussions, research activities and so on. Then, they assume pupils would acquire the elements of scientific enquiry and skills by doing practical work. For example, the English teachers assume that pupils would understand the term 'variables' and 'control variables' and other elements of 'ideas and evidence' as they have done continuous practical work since year 7.

As mentioned in section 2-5, this implicit approach helps pupils to acquire 'skills' but is not effective for all the elements of scientific enquiry. Much research has consistently shown that scientific enquiry should be taught in an explicit and reflective manner (Shwartz & Lederman, 2002; Khishfe & Abd-El-Khalick, 2002). According to Batholomew, et al, (2003, p6), the elements of the nature of science and practice and processes of science should be taught explicitly and as a way of teaching science concepts because developing and understanding practice and processes of science is a reflective endeavour.

It is clear that the English teachers are more concerned about fostering pupils' skills area and tend to assume that scientific investigations always involve practical work (sections, 6-3-3 and 7-2-5). Although the English teachers indicated the aims of teaching scientific investigation as 'encouraging reasoning and critical thinking' as their 2nd high focus item, they put their emphasis on the empirical nature of science rather than on conceptual enquiry in general. They also show less concern about the item 'in fostering an understanding of the nature of science' than their Korean counterparts.

Subsequently, this may result in the English teachers' confidence in teaching scientific enquiry and positive responses concerning the English KS3 questions but in neglecting about the conceptual enquiry including the elements of 'ideas and evidence': although the English KS3 questions are relatively new to them, they would be willing to teach the new way. As shown in the focus group discussions, both groups of teachers agree that the English KS3 questions demand enquiry skills so that they would teach these by doing more practical work and scientific investigations. Teachers from both countries agree that these questions are shallower and easier questions than the Korean ones so that they would train their pupils easily due to the questions are mainly assessing skills area (section, 7-2-2).

This finding has been supported by the research report (Osborne & Ratcliffe, 2000) that scientific enquiry questions in the English KS3 test papers are largely testing a limited subset of skills. Although the English KS3 tests in 2004 show a greater proportion of questions demanding higher cognitive ability than those of 2003, there is still a need to include more questions encouraging the use of higher order skills of 'Analysis', 'Synthesis' or 'Evaluation' (section, 5-3-2).

By contrast, the Korean HE examinations include questions, which demand problem solving ability and a more abstract form of science knowledge and mathematical ability as shown in chapter 5. Under assessment driven school curricula, the above tendency has accordingly affected teachers' teaching practice.

The Korean teachers tend to teach science in a similar way in which they would teach mathematics: they would explain scientific terms, knowledge and even skills. They would demonstrate the process of solving problems and the ways in which to reach an understanding of the science concepts.

They do not expect that all pupils will be able to understand the science concepts, which they are teaching in the classroom. Some Korean teachers point out around 30% of pupils can understand the science concept initially and after repetitive practising using work-sheets or past examination papers, around 50% of pupils will be able to understand yet they would not expect more than half of their pupils to understand the content (appendix 36, Kor-29). However, the Korean teachers disagree that the curriculum content should be replaced with an easier content. They strongly believe that learning science is more than understanding science concepts and acquiring skills. They believe that learning science can include practising the ways to solve problems and the process of understanding science concepts. By repetitive practising, pupils would learn the process of problem solving, the process of understanding and the way of thinking so that pupils would be able to broaden their understanding of science knowledge when they go to high school or college (section, 7-2-5). Korean teachers feel there are advantages, that as they teach them to be able to answer the questions demanding higher conceptual understanding, their intense and explicit teaching enlarges the pupils' learning capacity (Chapter 7).

There are concerns about this tendency to demand too high a cognitive ability. As Taber (2003) argues, the cognitive level required should be reasonable at which pupils are challenged but not demotivated. Too much challenge leads to frustration and incomplete or incorrect work (Taber, 2003). As Kim J H & Lee M K(2003) have suggested, this demotivation can affect pupils' experience about science in school and their attitude toward science. Indeed, compared with the English students, Korean students show less interest and a lack of confidence in science subjects despite their higher achievements (KICE, 2004). As such, assessment, ways of teaching, national curriculum content and other factors such as facilities, time tables and large class sizes seem to inter-relate with each other affecting pupils' experience of science and their attitude toward science.

In addition, Korean questions encourage pupils to solve problems but may not encourage them to find problems or to plan investigations in unfamiliar situations. As the Korean teachers mention, even though Korean children are able to interpret graphs they may not be able to create graphs by using the tables (appendix36, Kor-3). Thus, this way of teaching does not seem to foster pupils' creativity.

Korean questions may encourage pupils to become conscious of their own thinking and encourage their ability to process information but they would not give them enough time to think but are constantly pushing them to become familiarised with the assessment content.

Nevertheless, this may have become a typical teaching tradition in Korea, which can be found in other subject areas. The Korean teachers recognize the importance of scientific enquiry as an aim of the national curriculum. They also agree that scientific investigations would enhance pupils' enquiry ability. They also recognize that there is a need for their pupils to enhance their practical skills (6-3-3). Yet, they show strong resistance to doing more practical work.

Korean teachers suggest the obstacles hindering the carrying out of more practical work in sections 6-3-3 and 7-2-4. They raise assessment related problems and other factors such as lack of laboratory facilities, a limited timetable and large classes. They also point out that they feel doing practical work is ineffective: pupils are not interested in the aims of the practical work so that only 25-30% of pupils pay attention to what they are doing and the majority of children tend to look at the process and keep asking what the next step is (appendix 36, Kor-21). Subsequently, the teachers need to explain over again after doing practical work. This tendency is continued when pupils do a research project, which relies heavily on an information survey as their major investigative method (Oh P S, 2005).

It is not clear whether this tendency comes from the teachers' own beliefs in the greater value of abstract forms of knowledge such as basic theories, laws and principles or whether it comes down from an academically orientated curriculum. Yet it is clear that Korean teachers give more weight to conceptual enquiry than to empirical enquiry.

Based on the above discussions, the following implications can be drawn. **Firstly,** it is clear that there is a need to clarify the term scientific enquiry in curricula and with teachers, which comprises not only the empirical nature of science but also conceptual enquiry. As Osborne, et al (2003) explained, enquiry activity can be multifaceted; either way may be reflective in manner to create more authentic science learning than simply teachers talking.

Unclear understanding about scientific enquiry is evident in teachers' perceptions from both countries: for the English teachers, they often regard scientific enquiry as doing practical work and as for the Korean teachers, they show resistance to doing more practical work yet they agree that their pupils need more skills. In practice, the Korean teachers often plan to do scientific investigations such as doing research projects without involving practical work (Oh P S, 2005).

Secondly, it may help teaching if English KS3 tests comprise more questions, which can enhance pupils' conceptual enquiry whilst the Korean HE examinations could include more skills.

Lastly, the typical teaching traditions may not be easy to change. Thus, the direction for improvement may be toward minimizing disadvantages and maximizing advantages. For example, despite many disadvantages in the typical teaching tradition in Korea, there can be some advantages in terms of teachers' commitment to pupils' learning, their explicit approach in teaching the elements of scientific enquiry and the emphasis on conceptual enquiry. As shown in sections 6-3-3 and 7-2-5, the Korean teachers show their commitment to pupils' learning of concepts by training the process of thinking in order to solve problems involving hard work. Even in process skills and the elements of the nature of science they would teach explicitly (sections 6-3-3 and 7-2-5) Similarly, the typical teaching tradition in England can have advantages in terms of pupils' skills, teachers' satisfaction in their teaching approach, more autonomy for pupils as they carry out investigations and so on. Therefore, it may be better to keep these tendencies and replace content and context so that the assessment would be culturally sensitive (Noah and Eckstein, 1990).

In this respect, both groups of teachers could be encouraged to employ more whole group discussions and research projects considering the need to enhance more conceptual enquiry in the English assessment as well as considering teachers' resistance and other negative factors being barriers to doing more practical work in the Korean classrooms.

As Oh P S & Shin M K (2005) suggest, Group Investigation (GI) can be helpful in developing pupils' cognitive abilities, giving them time to think for themselves as well as offering a variety of content and contexts which can offset the above traditional tendency in Korea. This is because the method involves higher-level thinking tasks such as identifying information relevant to their research as well as providing pupils with a personal challenge and essential time for reflection and discussion within such a lesson (Oh P S & Shin M K, 2005).

However, there are concerns that enquiry based teaching of science is too slow to cover all the requirements of the national curriculum whether or not practical work is involved (Osborne, et al, 2003). As Woolnough (1991) argued, pupils construct their knowledge relating previous knowledge and new knowledge produced by investigation and this evolve slowly. Thus many teachers avoid this way of teaching.

However, Oh P S & Shin M K (2005) advocated taking this enquiry based teaching and using data from a nationwide science test found that students in cooperative enquiry settings scored significantly higher on 44% of the items as compared with a national sample (Schneider, et al, 2002 quoted in Oh P S & Shin M K, 2005). They emphasised that it may be an unjustified myth that enquiry based teaching does not fit into preparing for high-stake national assessment (Oh P S & Shin M K, 2005).

Adey (1998) supported this by mentioning 'thinking science' based on cognitive intervention theory. According to Adey's explanation, pupils' formal thinking starts to be formed at about level 5-6 in the national curriculum, which is at KS3. During this period of time, teachers can provide opportunities for developing the forming of the complex process of high-level thinking by challenging pupils in their own problem solving, encouraging pupils to become conscious of their own thinking, questioning which can aid in the construction of a reasoning pattern and bridging the use of this reasoning pattern over to science and to a real life context. This 'thinking science' requires stepping back from a delivery view of teaching and giving time to pupils to encourage the development of reasoning concerning the way in which science knowledge progress in certain ways. Adey (1998) suggested that time spent in encouraging the development of this general processing mechanism may immediately be lost from covering the curriculum but it provides pupils with the tools with which they can learn more effectively in the future.

To sum up, the assessment content seems to be the most crucial factor for implementing more scientific enquiry into the classroom under the assessment driven school curricula. The assessment contents, which contain questions demanding different levels of cognitive abilities, directly affect teachers' teaching and this can become typical teaching method.

Korean assessment seems to be more problematic in terms of purpose and having a narrower range of Klopfers' specifications and types of questions. Neither group of teachers appear to teach in a way in which scientific enquiry ability can be enhanced. The English teachers do more practical work and the Korean teachers teach science in a similar way to teaching mathematics. It has also been discussed that the higher level of conceptual understanding makes Korean examinations distinctive in assessment, teaching and learning. At this point, this discussion implies that changing teaching to accommodate changes in 21st century science and motivating pupils would require a great deal of change in the attitude of teachers. The following section discusses issues and implications from teachers' research.

8-4 Findings from teachers' research

The findings from the teachers' survey show more in common between England and Korea than the findings from documentary analysis. However, the distinctive areas are perceptions and opinions concerning teaching methods. The findings from the teachers' survey were able to offer explanations to differences from the documentary analysis as well as supporting the findings from the questionnaires and focus group interviews.

As a supplementary way of supporting the findings from the documentary analysis and the questionnaire survey, the focus group interviews reveal more details about teaching practice in the classroom, the teachers' constraints and conflicts between their values, pedagogy and practices in depth. For example, from the questionnaires both groups of teachers indicate that the English KS3 questions are better for enhancing pupils' scientific enquiry. Yet, the findings from the focus group interviews reveal the Korean teachers' resistance against preparing pupils to answer the English KS3 questions, which stems from the pressure of covering curriculum content, preparing pupils for examinations, having lack of laboratory facilities and large class sizes and their strong belief in the importance of science knowledge and an emphasis on conceptual enquiry.

The following section will describe the implications of teachers' perceptions and teaching practice based on all the findings from the survey research. As mentioned in 2-6, teachers play a pivotal role in implementing scientific enquiry. As teachers teach science, they are not only imparting knowledge but also demonstrating scientific ways of questioning, thinking, handling and facing particular problems (McComas, 1998). Ultimately, teachers' views, perceptions, opinions and the way they teach science can mould pupils' attitude toward science and their experience about science (Kim J H & Lee M K, 2003). In this respect, it is important to assess teachers' views, perceptions and opinions as well as various factors affecting teachers' teaching practice in order to help teachers to implement more scientific enquiry in the classroom.

8-4-1 Implications from the commonalities

Both groups of teachers seem to be only aiming at the development of an understanding of science concepts and methods of science. The rest, which includes the elements of the nature of science and scientific enquiry, lies beyond the boundary of their schemes of work. This coincides with the findings from documentary analysis revealing the fact that there are shortcomings in the reflection of the aims of the national curricula in the teachers' teaching practice. Some Korean teachers mention that they often tell some history of science or a scientists' biography in order to stimulate pupils' interest but not for the purpose of enhancing pupils' understanding of the nature of science (appendix 36, Kor-21).

Both groups of teachers favour TIMSS-2003 questions whilst the Korean HE questions are the least popular. They recognize that the Korean questions involve teaching a considerable amount of science knowledge and that much harder work is needed to familiarize them with those questions demanding higher conceptual understanding. They also agree that skills can be acquired more easily than conceptual understanding.

Both groups of teachers recognise that they can train their pupils to answer each set of questions by using similar methods. For example, they suggest that they would use past examination papers in order to familiarize them with the assessment content as they are told to prepare new types of questions (sections 7-2-5 and 7-2-6).

Therefore, the comments imply that both groups of teachers would prepare their pupils in a similar way if they were given the same questions to teach (sections 7-2-5 and 7-2-6). Most of the English teachers indicate that they would prepare their pupils to take Korean HE questions in a similar way in which the Korean teachers would do with more explaining of details of the required knowledge and familiarizing them with the assessment content by practising repetitively. The Korean teachers answer that they would prepare their pupils to answer the English KS3 questions by doing more practical work and carrying out more investigations. As mentioned above, both groups of teachers would familairise their pupils with each set of questions by practising past examination papers and doing work sheet activities. Therefore, once they are given well-constructed questions, which reflect the aims of the national curricula in the test papers including the elements about the nature of science and scientific enquiry with various content and context, they would teach in similar ways.

In this respect, the disparities in the national curricula and in the assessment may need to be improved first rather than teachers' teaching practice. As shown in section 6-3-2, the national curricula descriptions influence teachers' perceptions and teaching style. For example, the KNSC suggests that scientists' biography or history of science can be used in order to stimulate pupils' interest rather than to be used as a way to understand the nature of science (MOE, 2001b). Indeed, some of the Korean teachers from the focus group interviews indicated that they use history of science or scientists' biography mainly for maintaining pupils' interest (section, 6-3-2). Subsequently, the intentions and definitions being described in the national curricula can be important in respect of teachers' interpreting and implementing the aims of the national curricula into their own perceptions. Therefore, it may be necessary to communicate the national curricular aims and intentions in a way that teachers will understand the concept of scientific enquiry more fully.

In conclusion, findings from the teachers' survey show more similarities than the findings from the documentary analysis. Both groups of teachers reveal that they fall short of the national curriculum aims for the teaching of the elements about the nature of science and scientific enquiry. Both groups of teachers show similar perceptions concerning the aims of teaching science, of doing practical work as well as of carrying out scientific investigations. Both groups of teachers would teach similar ways as they prepare their pupils to take each set of questions. Descriptions and intentions in the national curricula can influence teachers' perceptions so that the aims and intentions in the national curriculum need to be communicated clearly and accurately to teachers. The following section will discuss issues based on differences from the survey research.

8-4-2 Implications from differences

The majority of the Korean teachers indicate that they have studied at least one of the following subjects, Philosophy, History, Philosophy of Science or Sociology of Science whilst the majority of the English teachers indicate that they have studied none of those subjects.

This studying experience seems to affect teachers' views about the nature of science. Although a considerable proportion of teachers from both countries show unrefined views about the nature of science, the Korean teachers show slightly better views. The Korean teachers are more consistent in answering within sub-questions and between items amongst different questions in the questionnaire concerning teachers' perceptions and teaching practices and show higher correlations between related questions (sections 6-3-2 and 6-3-3). Subsequently, the Korean teachers show a clearer tendency throughout this survey research in terms of a certain view and toward the way they teach, the way their pupils' learn and the disparities between their teaching practice and the national curricular recommendation.

By contrast, the English teachers show a more deductivist and process-oriented tendency, yet they show unsophisticated and outdated views of science. Their views on certain points are indeterminate and they give inconsistent responses with other items in the questionnaire. One question may produce diverse opinions. For example, in responses to the questionnaire, most of the English teachers indicated their pupils would do *'not very well'* whilst 'not be able to answer at all' was the response from the focus group interviews (sections 6-3-4 and 7-2-2). In addition, in the focus group interviews, the English teachers do not seem to be aware of the cause of mismatches between their pupils' understanding of science concepts and their understanding of what they are doing in their practical work. The majority of English teachers indicated the causes as being 'limited time and space' and 'pupils' lack of skills' although they do more practical work whereas a half of the Korean teachers indicated the reasons for mismatches being 'when the science concepts and investigations were not related' (section 6-3-3). In the focus group interviews, the Korean teachers gave reasons for their resistance to do more practical work as being these mismatches (section 7-2-5).

Comparing views about the nature of science, perceptions about the aims of teaching and perceptions about their teaching in practice, there is a smaller gap between the two groups of teachers in their views about the nature of science but there is a bigger gap in their perceptions about their teaching in practice (sections 6-4-2, 6-4-3 and 6-4-4). For example, in the views about the nature of science, both groups of teachers show a process-oriented tendency yet the English teachers were more skewed in that direction. Then, both groups of teachers show similarities in the aims of teaching science, of doing practical work and of carrying out investigations. However, in the findings from the focus group interviews it appears that the Korean teachers have a resistance to doing more practical work (sections 7-2-4 and 7-2-8). In the perceptions about teaching in practice, teachers employ different styles of teaching. The Korean teachers show a similar tendency to the inductivist view (6-4-2, 6-4-3 and 6-4-4).

This tendency amongst the Korean teachers may cause teachers' constraint and lack of confidence as shown in section 6-3-3 because it shows a discrepancy between how they believe science should be taught and their teaching in practice. In this respect, the English teachers may have less constraint between their views about the nature of science, their perceptions about the aims and perceptions about their teaching in practice. Indeed, most English teachers show inadequate views about the nature of science yet, they show confidence in their teaching of scientific enquiry which does not correspond with a commonly accepted idea in current literature. According to Batholomew, et al, (2002), teachers' lack of knowledge about the nature of science undermines their confidence and ability to teach science.

Therefore, there seems to be a complexity of issues affecting teachers' perceptions about their teaching in practice so that many factors such as their views, the national curricula content and assessment content inter-lock with each other. As mentioned in section 8-3-5, assessment content can directly affect teachers' perceptions about their teaching, particularly under assessment driven school curricula. The national curricula content, large class sizes and laboratory facilities can also affect teachers' perceptions about their teaching.

On the other hand, views about the nature of science such as teachers' philosophical tendency concerning process/ content orientation may not be a major determinant for their perceptions about their teaching yet there seems to be a certain level of relationship which can be inter-related to their perceptions about the aims of teaching as shown by the responses from Korean teachers (section, 6-3-2). The teachers' perceptions about the aims of teaching science, doing practical work or carrying out scientific investigation can indirectly affect their teaching in practice such as Korean teachers' resistance to doing more practical work (section, 6-3-3). However, this does not mean that the teachers' views about the nature of science only play a limited role in their teaching practice. Rather, teachers' views and perceptions about the aims of teaching may still hold an important position although they may be less influential concerning teachers' teaching in practice. These can affect teachers' value, their attitude toward science and confidence in teaching scientific enquiry and how they interpret the national curricula and more importantly their resistance to adapting a new way of teaching which ultimately can affect pupils' values, attitudes and confidence (KICE, 2004). Thus, teachers' views about the nature of science can be overtaken by other priorities such as covering the national curriculum or preparing pupils to take tests these views may have an important effect on their philosophical stance, confidence attitude and so on.

Therefore, along with improving assessment content as mentioned in section 8-3-5, there is a need to support teachers in giving them a better understanding about the nature of science. As shown in this teachers' survey, the national curriculum revisions and policymaking can be aimed at implementing scientific enquiry in a way to reduce teachers' current constraints.

To sum up, the teachers' survey shows similarities and differences between two groups of teachers. The teachers' survey supports the results from the curriculum analysis as well as supporting other findings from different methodologies. Both groups of teachers seem to be only aiming at the development of an understanding of science concepts and methods of science, which are essential to an education in science rather than fostering the nature of science and scientific enquiry ability. Thus, there are shortcomings in reflecting the aims of the national curricula in the teachers teaching in practice. Considerable proportions of teachers from both countries have inadequate views about the nature of science. However, the Korean teachers show slightly better views about the nature of science, a clearer tendency in answering other questions both in the questionnaire and in the focus group discussions reflecting that they have clearer understanding about their teaching and their pupils' learning throughout the survey research, yet they show lack of confidence in teaching scientific enquiry.

Therefore, although teachers' understanding about the nature of science and their perception about the aims of teaching may not be a major determinant of teaching in practice, it is still important to improve these because they can affect teachers' values, attitudes toward science, resistance and confidence.

8-5 Implications as an international comparative study

This section describes several issues concerning the use of this study as an international comparative study.

As Schmidt, et al (1998, p7) argue, test results alone or comparative rankings based on them are not directly relevant. Unless these outcomes are connected to meaningfully manipulable factors that educational policies can affect, the outcome of assessments provide minimal if any information for educational improvement. Thus, it may be necessary to carry out more qualitative research, such as undertaken in this research in order to find out the factors, which can be connected to the results in large-scale international comparative studies such as TIMSS being used in this study.

Although much research has shown concerns about the use of rankings and total test scores in the TIMSS, it has been an important reference for revising the national curricula and making new policies in both countries (Schmidt, et al, 1998: Kim S S, 2004; Kyriakides and Charalambous, 2005). Since 1999 the TIMSS survey has included other factors such as students' backgrounds, attitudes toward science, classroom characteristics and so on (KICE, 2004).

Since 1995, Korean students have consistently achieved higher marks in TIMSS assessments in science than English students have. In particular, TIMSS 2003 results reveal that Korean students were ranked in 3rd place with a score of 566, whilst English students achieved 5th place with a score of 533 when compared with 46 OECD countries. However, this high score does not mean that the Korean educational system is better or more effective. This study reveals that

behind this high achievement the KNSC is more problematic in terms of its incorporation of aims, curriculum content and assessment as well as teachers' being dissatisfied and constrained within their professional situation. In addition, Korean test papers assess an extremely narrow range of scientific enquiry abilities in the area scientific enquiry and show less consistency between the aims of the curriculum and assessment content.
This study as a comparative and qualitative research may give explanations for the TIMSS results and identify factors, which could improve the quality of education. By comparing the national curricula of England and Korea, assessment and teachers' views, perceptions and opinions, it can be seen that the process of implementing scientific enquiry is a complex process and is likely to be different in the two countries because factors within both countries can affect the classroom situation at different levels. Thus, policy making or curricula revisions can be based on qualitative research rather than simply making use of TIMSS results.

Nevertheless, this research has not shown clearly why pupils from both countries perform highly in TIMSS and why Korean pupils in particular have performed better. It is said that the assessment content of TIMSS cannot include curriculum content from all participating countries. As Kim S S, (2004) points out Korean educators are not involved in the process of developing the assessment content for TIMSS, which could place Korean students at a disadvantage. On the other hand, English students may have an advantage because of the similarity of their own tests with TIMSS. Both groups of teachers agree that they would prepare their pupils in a similar way for the TIMSS questions as they would for English KS3 questions.

A possible reason why Korean students have performed well in TIMSS despite the above disadvantages may be speculated based on this study. As discussed in section 8-3-5, the KNSC and Korean teachers place more weight on conceptual enquiry rather than empirical enquiry. Although both groups of teachers recognize the importance of scientific enquiry, they disagree about the importance of practical work. The English teachers are more concerned with practical skills and expect their pupils to acquire abilities to carry out scientific investigations during practical work, whilst the Korean teachers put their emphasis on pupils' conceptual enquiry and are more concerned to help their pupils understand science concepts and acquire problem solving abilities by repetitive demonstrations and explanations.

In spite of differences in terms of curricula, it may be speculated that since children of both countries have done well in TIMMS, a possible reason is that both countries put emphasis on scientific enquiry. Korean children's better performance may be due to a greater emphasis on conceptual enquiry. English educators are now recognizing the limitations of practical work and are encouraging teachers to introduce argumentation and discussion to foster conceptual enquiry. Further study is needed to explore this area

Finally, both national curricula are heading towards similar goals by fostering the future citizenship of young people by putting an emphasis on scientific enquiry, which includes the nature of science and its processes and practices. They also include similar curriculum content because science itself is a universal subject, being known as an international endeavour (Solomon, 1998). In addition, teachers in both countries were familiar with TIMSS content and questions and both favoured the questions. Moreover, teachers in both countries would prepare their pupils to answer different types of science questions in more or less the same way. Therefore, this tendency may continue as TIMSS is being held every 4 years. Interestingly, TIMSS-2003 test papers in the scientific enquiry area show similar features to English test papers in terms of proportion, distribution and nature of questions. However, TIMSS-2003 test papers contain more multiple-choice format and less discrete scientific investigative questions than English test papers. TIMSS-2003 test papers contain 'Seeing a Problem and Seeking Ways to Solve it' (c1-c4) and other elements of contemporary science, including the view of the nature of science although the proportion of scientific enquiry is more or less similar to the Korean tests. As teachers in both countries pointed out TIMSS-2003 questions seem to be somewhere between English test papers and Korean ones.

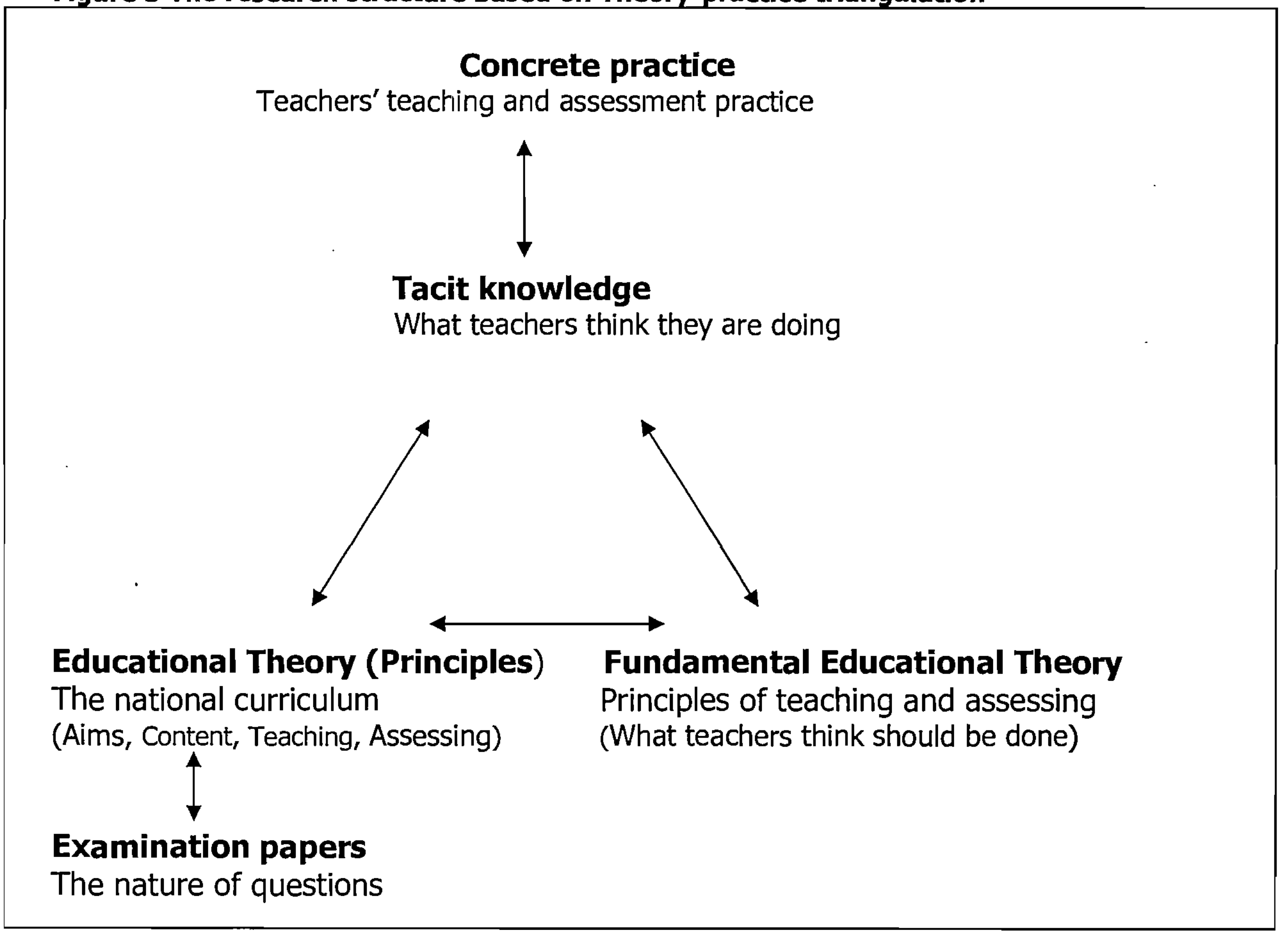
To sum up, although TIMSS results have been an important reference in policymaking and the national curricular revision, they have limitations in affecting policymaking. In addition, an international achievement test, TIMSS assessment should perhaps be more comprehensive. The achievement results may be used with caution.

This comparative study as a qualitative research can provide explanations and identify the factors, which can be connected to the results in TIMSS. Thus, eventually the outcomes from this comparative study could be used to improve the quality of education as well as enhancing research based policymaking and curriculum revision. As other research shows, this study may be used as a way of identifying factors that could aid in the design of intervention in an educational programme (Schmit et al, 1998; Kyriakides & Charalambous, 2005).

8-6 Theoretical framework

As a conceptual framework, this research has employed the theory and practice triangulation as shown in figure 3 below (Chapter 3). Scientific theory, which refers to a hypothesis, which has been confirmed by observations, is inappropriate for giving explanations to educational research. This is because educational research often has an amorphous nature with many concrete and uncontrolled contexts (Grenfell, 1998). Thus, educators need to address the theory and practice triangulation so that how each may be defined and ways in which they are linked may be discussed (Grenfell, 1998).

Figure 3 The research structure based on Theory-practice triangulation



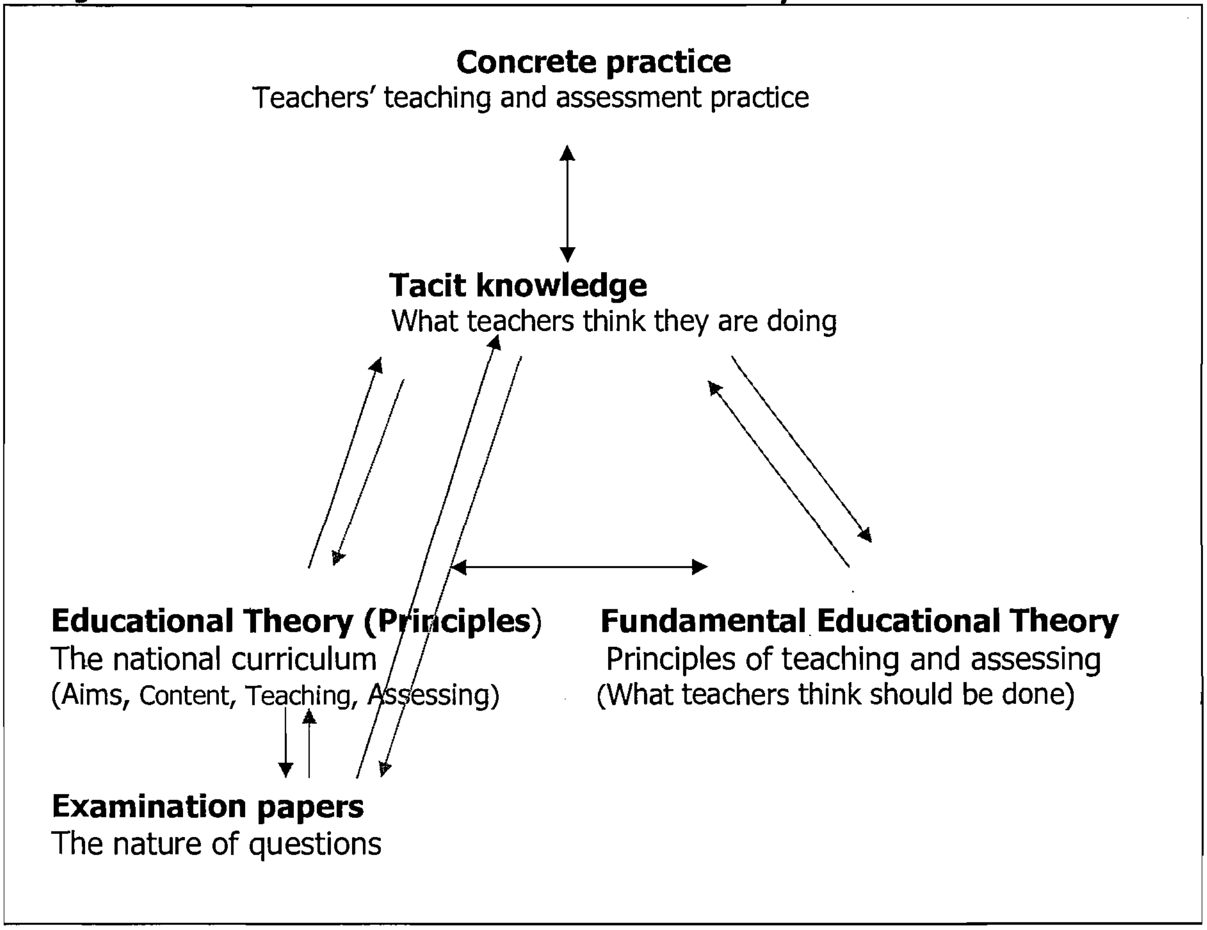
The theory-practice triangulation has fitted into this study because the research area was in the relationship between educational theory (principles of curriculum and assessment) and practice in assessment and teaching. This framework has been useful not only in guiding the research but also in analysing and synthesizing the results.

According to Grenfell (1998), the *concrete practice* is partly constituted by *tacit knowledge* articulated in *fundamental educational theory* and generalized in order to eventually form *justifying educational principles* (section, 3-3-1).

Teachers' actual practices depend on the interaction of what the teachers teach and what the teachers' pedagogy is including their views, perceptions and opinions about their teaching.

However, the findings from this study imply that the above triangulation is not enough to show the interactions and the links between factors. Based on the finding from this study, the theory-practice triangulation can be altered as shown in figure 31.

Figure 31 The theoretical framework based on this study



* ⟷ Original arrows in the theory-practice triangulation
→ A Weaker influence
→ A stronger influence

The theory-practice triangulation did not show the level of tension between *'tacit knowledge'*, the national curriculum and the principles of teaching and assessing. As shown in figure 31, the *'educational theory'* side appears to dominate in shaping teachers' *'tacit knowledge'*. This may indicate that the teachers regard the theory as the product of power through mastery of techniques, which undermine their own craft knowledge. Teachers appear to prioritise the assessment content and the requirements of the national curriculum in their teaching rather than fulfilling their preferred pedagogy. In particular, the content of assessment appears to affect directly what teachers perceive they are teaching (tacit knowledge) under the assessment driven school curricula.

Subsequently, the theory-practice triangulation seemed to be rather linear with *'Educational Theory (Principles)'* dominating teaching in the classroom. Similarly, the link and interaction between *'Fundamental educational theory'* and teachers' *'tacit knowledge'* are considerably weak. Therefore, this research has suggested that the relationship between pedagogic principles and teachers' tacit knowledge is not as strong or linear as shown in the theory-practice triangle. The relationship between pedagogic principles and practice is worthy of further study, particularly an observational study that has been outside the scope of this study.

As mentioned in section 8-4, the discrepancy between what teachers think they are doing and their views and perceptions due to being dominated by *'Educational theory (principles)'* can lead to their lack of confidence, their resistance to change and their discontent. Therefore, improvement in the relationship between principles and practice may be towards the direction in which the teachers can exercise their pedagogy more, or by a way in which teachers feel less pressure and can have more confidence in their teaching of scientific enquiry. As the English teachers appear to be content with what they are teaching concerning scientific enquiry and their schemes of work, the interactions between two corners of the triangulation show less discrepancy, which leads to less tension. For example, to reduce tension for the Korean teachers, the national curriculum recommendations and teachers views on the teaching of science need to be more convergent.

8-7 Reflection

The research set out to answer the question ***'What is the impact of assessment in scientific enquiry on the perception of teaching science at age 14 in a comparison between England Korea?'***

This study was a comparative research, comprising documentary analysis and survey research. The survey research consisted of two different methods: questionnaires and focus group interviews. These were regarded as the best-fit methods to explore the research question. The findings from these different methods not only support one another but also provide explanations concerning particular results although some of the findings overlap. The documentary analysis was undertaken systematically. In particular, the theoretical frame works for analysis (Bloom's taxonomy and Klopfer's specifications) allowed triangulation across analysis. There is thus considerable confidence in the findings. For the vast majority of elements in the two instruments, (questionnaire and focus group interviews) the results reinforced each other, suggesting confidence in the findings.

Therefore, the research has been able to answer the research question although there are difficulties in sampling from the examination papers due to different educational systems. The samples in the two countries in terms of experience are very similar. This makes the comparison valid. Although the sample is reasonably large and results triangulated, the findings are not necessarily generalizable to the whole population. Rather the results show some similarities and differences between two similar samples. The results are thus valuable as an exploration of how a 'typical' set of teachers perceives the teaching of scientific enquiry.

8-7-1 Limitations and further research

This research only judges perception of teachers, it does not report on the actual practice. Therefore, it may be worthy to carry out further study in the area of teachers' teaching by classroom observations.

As has been mentioned, implementing scientific enquiry into the classroom seems to be a complex process. Further research may be needed in two areas, one in developing scientific enquiry questions which reflect the aims of the national curricula including the elements of the nature of science and scientific enquiry, and the other in the area of how to reduce the gaps between the teachers' views about the nature of science, their perceptions, and their practice as well as in the area of supporting teachers to apply scientific enquiry in classroom practice.

In terms of the instrument assessing teachers' views about the nature of science, question 7 with 14 items in the questionnaire (appendix 33) has been developed by being altered from the original instrument which contained 24 items Nott and Wellington (1993, p109). The items for assessing instrumentalism/realism were excluded because it was considered that this tendency was less related to the teachers' teaching in practice compared with the philosophical tendency. In addition, the items exclusively assessing contexualism/decontextualism tendency were also excluded, instead the items mutually assessing contexualism/decontextualism and relativism/positivism were included.

The result from this research was supported by Park U B (2000), revealing that Korean teachers in middle schools show a similar tendency to the findings from my research (i.e.) by using the same instrument, he showed that Korean teachers are more inductivist, relativist, and process orientated and show a tendency towards contextualism and instrumentalism (P248).

In addition, as also indicated by Park's research, it is said that teachers who have a tendency towards realism are more likely to show a positivist view. This research was not designed to be confined to the area of teachers' views about the nature of science in depth but to explore their views, perceptions and opinions in relationship to their teaching in the classroom.

Nevertheless, there may be limitation in generalizing the views about the nature of science from the result of this research because considerable items were excluded from the original instrument.

As mentioned in section 8-5, as an international comparative study, this may lead to further research concerning possible reasons why the English students have performed highly and the Korean students have performed even better than their English counterparts despite their national curriculum and assessment having been more problematic.

8-8 Conclusions and Recommendations

Assessment appears to dominate a lot of teaching and learning in both countries and especially in Korea where it involves high stakes. Even if the national curriculum in each country puts emphasis on scientific enquiry, this area will not achieve a higher profile or be incorporated into the classroom unless it has a more important place within the assessment because the assessment content sends a message about what is valued and important: if is not in the test it cannot be important. Hence, assessment has been a great stumbling block in the way of the improvement of the quality of education.

Both national curricula put emphasis on scientific enquiry in order to meet the demands of a changing society and to improve the quality of education.

However, this research reveals shortcomings within both groups of teachers in the matter of teaching elements of the nature of science and scientific enquiry and in teaching science by implementing scientific enquiry into scientific concept in an integrated manner for a meaningful learning to take place. Both groups of teachers express that they would aim at motivating children and helping them understand science concepts.

Although they recognise that scientific enquiry is important, emphasizing scientific enquiry and the elements of the nature of science seem currently to be beyond the bounds of their tacit knowledge and therefore teaching practice for teachers of both countries.

It appears to be more problematic to implement teaching and assessment of scientific enquiry in Korea than in England. The KNSC interprets scientific enquiry only as teaching science that is enquiry based. This interpretation has a narrower range with respect to the contemporary view of science as well as when it is compared with the ENSC. The ENSC describes it, not only as a strand in the science programme of study but also as the way in which to teach science. The precise interpretation in the KNSC seems to lead to a restricted range of assessment content. By using Klopfer's specifications, this tendency towards a narrower spectrum was confirmed. Both curricula have been heading in a similar direction, incorporating more scientific enquiry into the curriculum but the level of implementation has been different.

Due to the inclusion of scientific enquiry as a strand of the national curriculum, the ENSC reflects the aims more fully on the national curricular content and the assessment content than the KNSC. The English test papers appeared to have discrete scientific investigation showing in a variety of questions whereas Korean test papers contain scientific enquiry questions concentrated in the area of interpretation of data. Although the proportions of scientific enquiry questions in both countries are similar with 20-40% overall, yet English test papers in 2004 show an increased proportion of scientific enquiry questions whereas the Korean test papers remain more or less the same as those of 2003. Thus, the greater proportion and variety of questions in the English test papers reflects the policy to empower scientific enquiry in the national curriculum.

Under assessment driven school curricula, assessment content directly affects teachers teaching in practice. The analysis by Bloom's taxonomy shows that more Korean questions fall into higher cognitive domains. Korean test papers contain more mathematical content and abstract forms including laws, principles, theories and so on, whereas more English questions were found in the lower cognitive domains. The Korean teachers acknowledge that they are teaching science too difficult for some 14 year olds to understand, yet, they show a strong belief in the need for pupils to develop conceptual enquiry by emphasising the importance of practising the process of problem solving by repetitive explanations. By contrast, the English teachers are familiar with the questions, which originate from the empirical nature of scientific enquiry because they engage in practical work for at least half of their science lessons.

Neither group of teachers appears to teach in a way in which to enhance pupils' scientific enquiry abilities by scientific investigation, whole group discussion or research. Rather the English teachers expect that pupils would gradually build up their ability to carry out scientific investigation by doing practical work and they do not necessarily teach the elements of the nature of science. By contrast, the Korean teachers recognize the importance of scientific enquiry and agree that English KS3 questions would be good at enhancing pupils' scientific enquiry ability. Yet they show resistance to doing more practical work. The causes of teachers' resistance stem from assessment related issues, lack of facilities and pressure of the timetable. More importantly, the Korean teachers hold a strong belief about conceptual enquiry and the importance of science knowledge: they believe that pupils need to have some basic knowledge to use with their process skills

In this respect, Korean assessment content has been more problematic in terms of the narrow range of scientific enquiry questions and least reflection of the aims of the national curriculum as well as questions demanding too high conceptual understanding. On the other hand, scientific enquiry questions in English assessment content are mainly skill based with a relatively lower cognitive level, which may lead to pupils' poor understanding of science concepts.

For the KNSC, prior to the incorporation of scientific enquiry in assessment content, the aims of the national curriculum needs to be reflected more fully in the national curriculum content. This is because the assessment content is closely related to the curricular content, the curricular content may need to bring more scientific enquiry into the conventional curricular content or assessment be given new content in order to reflect the aims of the curricula to the assessment content. In order to do this, the elements of scientific enquiry need to be included as statutory in the national curriculum rather than as non-statutory or simply as a recommendation. Eventually, scientific enquiry would need to be incorporated into examination questions with a variety of scientific enquiry questions.

Both groups of teachers appear to have misconceptions about the term 'scientific enquiry. English teachers are satisfied that they are covering scientific enquiry by doing practical work whilst minimizing the importance of conceptual enquiry. Korean teachers put more emphasis on conceptual enquiry but are under constraint because they feel they should be doing more practical work to fulfill the teaching of scientific enquiry. These misconceptions underline the need for clarification of the term scientific enquiry.

There is also a need to develop good assessment items, which can reflect more fully on the aims of the national curriculum, which can be a major determinant in encouraging teachers to teach scientific enquiry. Both groups of teachers indicate that they would prepare their pupils in similar ways if they were to teach each other's sets of questions. This may suggest that assessment becomes a major determinant in the teaching of scientific enquiry and that teachers are prepared to modify their teaching given appropriate assessment techniques. Both groups of teachers can be encouraged to teach the elements of the nature of science and scientific enquiry explicitly rather than expecting pupils would acquire automatically during their practical work.

In terms of teachers' views about the nature of science, their perception about the aims of teaching and their opinions, both groups of teachers show more in common than the findings from documentary analysis would suggest. Both groups of teachers show unrefined views about the nature of science. Yet the Korean teachers tend to have exposure to the nature of science in their education and seem to show more considered views of the nature of science as well as in their answering of the items concerning their perceptions about aims for teaching science, doing practical work and teaching scientific enquiry. The majority of Korean teachers also recognise the causes of mismatch as being due to the lack of understanding of scientific concepts and pupils having not enough skills in carrying out scientific investigation. In addition, they also show their commitment to their pupils' learning by repeating explanations over and over again. They would even teach skills or the elements of scientific enquiry explicitly.

By contrast, the majority of the English teachers express misconceptions and inadequate views about the nature of science. English teachers appear to be content with their routine way of teaching but would agree to introduce more scientific enquiry into their teaching as they appear under less pressure with assessment and have fewer constraints to cover curriculum content. The majority of English teachers do not consider the causes of this mismatch to be the scientific concept and the investigation not being related rather they point out that the investigations are being carried out within limited time and space.

Korean teachers show less confidence in teaching scientific enquiry, and there is more pressure because of target attainments set by schools. They express that they are not content with the routine way of teaching. They also express their conflict between the views about the nature of science, their perceptions and their practices in the classrooms although they have slightly better views about the nature of science.

However, teachers' views about the nature of science and perceptions about the aims of teaching appear not to be major determinants for teaching scientific enquiry. Rather, these views are more related to teachers' philosophical stance, attitude, confidence and resistance. Even if these views are not major determinants of practice, it is necessary to improve teachers' views about the nature of science and scientific enquiry, including how to enhance pupils' scientific enquiry ability and clarifying the empirical and the conceptual nature of enquiry.

As educators from both countries point out, implementing more scientific enquiry is a complex process (Osborne, et al, 2003; Kim J H & Lee M K, 2003). Various factors interlock with each other such as the aims, content and assessment, teachers' views, perceptions, opinions as well as facilities, timetable and so on.

As a comparative study, this study has attempted to provide some explanations and identify the factors, which can be connected to the results in TIMSS as an international achievement test. This study indicates that the achievement results may be used with caution. Yet, this study has not shown clearly why pupils from both countries perform highly in TIMSS and why Korean pupils have performed better.

Along with TIMSS survey, this study indicates that the aims of the national curricula and teachers' opinions are heading toward similar directions which may reflect a hint of globalization in science education from both countries.

In terms of theory- practice interface, the conceptual framework shown in figure 31 (section, 8-6) can be changed to show how assessment policy and practices, rather than pedagogical principles, impinge on teachers' perceptions on teaching for understanding of scientific enquiry. Under assessment driven school curricula, the content of examination papers directly impinges on teachers' *'tacit knowledge'.* This research suggests that the link between principles of teaching and assessing and *'tacit knowledge'* is weaker. Thus, the conceptual framework becomes skewed toward *'Educational Theory'* (Principles) as impacting on teachers' practice rather than a balance between *'Educational Theory'* (Principles) and *'Fundamental Educational Theory'.* There is a need to redress the balance towards development of effective pedagogy in teaching scientific enquiry. Agencies developing assessment items should appreciate the impact which item design has on teaching practice.

References

Abd-El-Khalick F, Bell R L, Lederman N G(1998), The nature of science and Instructional practice: Making the unnatural natural, International Science Education vol 82, pp412-436
Abd-El-Khalick F (2000), Improving science teachers' conception of NOS : Critical review of the literature review, International Journal of Science Education, Vol 22,no7,pp665-701
Adey P(1998), Children's thinking and Science learning, Ratcliffe M(Ed), ASE guide to Secondary Science Education, ASE
Anderson R T, Hughes J A, Sharrock W W (1986), Philosophy and Human Sciences, Routledge, London
Akinhead G (2000), Renegotiating the culture of school science In Millar.R, Leach.J and Osborne.J(Eds), Improving science education, Open University Press, Buckingham
Asoko (2000), Learning to teach science in the primary school, In Millar.R, Leach.J and Osborne.J(Eds), Improving science education, Open University Press, Buckingham
Batholomew H, Osborne J F, Ratcliffe M(2002), Teaching pupils 'ideas-about-science': case studies from the classroom, Paper presented at the Annual conference of the National Association for Research in Science Teaching, New Orleans, April 7-10 2002
Batholomew.H, Osborne.J, Ratcliffe.M (2003), Teaching Students 'Ideas-About-Science':Five dimensions of Effective Practice, London King's College, London
Black.P (2000), Policy, Practice and research : the case of testing and assessment, In Millar.R, Leach.J and Osborne.J(Eds), Improving science education, Open University Press, Buckingham
Black.P(2003), Testing, testing: listening to the past and looking to the future, School Science Review, 85(311)
Bell R L, Leaderman N G, A, Abd-El-Khalick F (2000), Developing and Acting upon One's Conception of the Nature of Science : A follow up study, Journal of research in science teaching, Vol 37,no 6,pp 563-581
Bell R L, Blair L M, Crawford B A, Lederman N G(2003), Just do it? Impact of a science apprenticeship program on high school students' understandings of the nature of science and scientific enquiry, Journal of research in science teaching, vol. 40, no 5, pp 487-509
Best.J.W.(1981), Research in Education,Prentice-Hall, Inc,New Jersey
Bloom B S (1956), Major categories in cognitive domain of the taxonomy of educational objectives, in Gronlund N E (1970), Stating Behavioural Objectives for Classroom Instruction, Mcgraw-Hill Book, UK
Bloom B S (1971), Klopfer Specifications, Handbook on formative and summative evaluation of student learning, McKay, Newyork
Brooks.V (2002), Assessment in Secondary schools, Open University, London
Brown.A & Dowling P(1998), Doing Research/ Reading Research,Falmer Press, London
Clare E, Secker V, Lissitz R W (1999), Estimating the impact of instructional practices on student achievement in science teaching, Journal of research in science teaching, Vol.36,no10, pp1110-1126
Chalmers A F (1982), What is this thing called science?, Open University, Buckingham
Charles C M (1998), Introduction to Educational Research (Ed), Longman, Newyork
Cho.J.Y,Won.H.H,Lee.M.S(2003), Analysis of Student's Interest toward Biology in middle school science, Curriculum Evaluation, 6-1,

Collins S, Osborne J, Ratcliffe M, Millar R and Duschl R(2001), what ideas should be taught about science: A Delphi study of the Expert community, Paper presented at the Annual Conference of the National Association For Research in Science Teaching, St Louis
Cohen.L, Marion.L,Morriosn.K(2000),Research Methods in Education, Routledge Falmer
Dalen.V(1962),Understanding Educational Research, Mcgraw-Hill book company,Inc.
DfEE(1999), Science in the National Curriculum, London:HMSO
DfEE(2001), Science in the National Curriculum, London: HMSO
DEfS(2002), Framework for teaching science year7,8 and 9, London, Department for Education and Employment
DfEE (2003), Science in the National Curriculum, London: HMSO.
Donelly J (2001), Contested terrain or unified project? ' The nature of science' in the National Curriculum for England and Wales, International Journal of Science Education , vol. 23, no 2 pp 181-195
Driver.R, Leach.J, Scott.P (1996), Young people's images of science, Open University, London
Duschl R(2000), Making the nature of science explicit, In Millar.R, Leach.J and Osborne.J(Eds), Improving science education, Open University Press, Buckingham
Dunne D(1998), The place of science in the curriculum, Ratcliffe M(Ed), ASE guide to Secondary Science Education, ASE
Fensham.P (2000), Providing suitable content in the science for all curriculum. In Millar.R, Leach.J and Osborne.J(Eds), Improving science education, Open University Press, Buckingham
Gerald, 2003).
Grenfell M (1995), The initial training of modern language teachers: a social theoretical approach, Southampton university Theses
Grenfell M(1998), Training teachers in practice, Multilingual matters Ltd, Clevedon
Goss J.D., Leinbach T.R. (1996) 'Focus groups as alternative research practice', Area 28 (2): 115-23.
Han. J H (1995), The quest for National Standards in Science Education in Korea, Studies in Science Education, 26 (1995), pp 59-71
Harlen.W(2003), Developments in the assessment of scientific literacy in the OECD/PISA project, School Science Reviews,85(311)
Hirst P H(1966), Educational theory, In Tibble J W(ed), pp29-58
Hofstein A and Lunetta V N(2004) The laboratory in Science Education:Foundation for twenty first century, International Science Education 88 pp28-54
Hogan K(1999), Thinking aloud together, Journal of research in science teaching, Vol.36,no10,pp1085-1109
Hur M (1984), The development of an assessment framework for enquiry learning in science, Science Educational Research, pp 37-53
Jenkins E(2000), Science for all: Time for a paradigm shift?, In Millar.R, Leach.J and Osborne.J(Eds), Improving science education, Open University Press, Buckingham
Kang.D.H,(1999), A comparison between the 6th National Curriculum and the 7th National Curriculum, Kyung Sang Science Education department.
Korean Educational Development Institute (KEDI,1988), Korean Education 2000, The KEDI Press
KEDI (2001) The background report for OECD, the KEDI press

Kelly G P, Altbach P G and Arnove R F(1982), trends in comparative education : A critical analysis, , Altbach P G, Arnove R F and Kelly G P(Eds), comparative Education, Macmillan Publishing Co, New york
Keys.W, Harris.S, Fernandes.C (2001) Third international Mathematics and Science study First National Report part 2, TIMMS
Korean Institute of Curriculum and Evaluation (2001), Curriculum and assessmen development, KICE Seminar report
Kshife r and Abd-El-khalick F(2002), Influence of explicit and reflective versus implicit inquiry-oriented instruction on six grade's view of nature of science, Journal of research in science teaching, vol 39,no 7,pp 551-578
Kim C J(2004), A perspective and a project in science achievements in international comparative studies, KICE research seminar
Kim.H K and Song J W (2004), So, What is the correct answer? : Barriers to Scientific Inquiry in School Science, Session 10F, Strand 4b Symposium, Paper presented at the meeting of the National Association for Research in Science Teaching.
Kim K M and Kim S W (2002), A study on the weight of assessment domain in science Education focused on the teacher's view points, the Journal of Korean Science Education, Vol. 20, no.1, pp 101-111
Kim H K, Kang T W, Song J W(2003), The features of practical work for physics in middle school science text books based on the 7th National Curriculum in Korea The Korean Physical society, Vol 47, no 6, pp1-8.
Kim S W and Suk H Y(1993) A comparison of cognitive levels in middle school physics areas between Chinese and Korean pupils, Ihwa-NonChong, 1994,vol 4,pp129-136
Kim J C(1998), A research for diversifying content and assessment in the National Curriculum, the KICE press, Seoul
Kim.J W(2004), What is authentic achievement ?, KEDI press, Seoul
Kim J H and Lee M K(2003), Structure of aims and content of the national curriculum in Korea, KICE research report, 2003-4
Kim Y C and Cho J S(2005), Now and forever; portraits of qualitative research in Korea, International journal of Qualitative Studies in Educaton, vol.18 no 3, pp 355-377
Kim Y S(1994), A study of Science teachers' perceptions about STS, Chosun University Educational Research, 94, pp45-68
KICE(2001), Curriculum and assessment development, KICE seminar report 2001.
KICE (2004), the results of TIMSS-2003, KICE
Available on line: www.kice.re.kr (Consulted on 15-12-04).
KICE (2003) High School Entrance examination paper "Common", KICE
KICE (2003) High School Entrance examination paper "Kyungi", KICE
KICE (2004) High School Entrance examination paper " Common" KICE
KICE (2004) High School Entrance examination paper "Kyungi" KICE
KICE (2004) High School Entrance examination paper " Junnan", KICE
Kind P(2003a), TIMSS put England first on scientific enquiry, but does pride come before fall? School Science Review, December,2003,85(311)
Kind P(2003b), Students' idea about scientific enquiry in the context of the science classroom and the context of real science, Paper presented at ESERA 2003, PS3-F-Symp
Kitzinger J. (1995) 'Introducing focus groups', British Medical Journal 311: 299-302.

Kwon J S (2003), Klopfer's Classification of Educational Objectives for Science Education, Korean National Teachers' University
Kyungi-do(2003) the High school entrance Examination Paper
Available on line: Http://www.kice.re.kr, 03-01-04
Kyriakides L and Charalambous C(2005) Using education effectiveness research to design international comparative studies: turning limitations into new perspectives, Research papers in Education, vol 20 no 4 pp 391-411
Lederman.N G (1999), Teachers' understanding of the nature of science and classroom practice : factors that facilitate or impede the relationship, Journal of research in science teaching Vol.36, No. 8, pp 91-929
Lederman N G, Abd-El-Khalick F, Bell R L,Schwartz R S (2002), View of Nature of Science Questionnaire : Toward Valid ad Meaningful Assessment of Learners' Conceptions of Nature of Science, Journal of Research in Science Teaching, Vol. 39, no6,pp497-21
Lederman N G and Bell R L(2003), Understanding of the nature of science and decision making on science and technology based issues, International Science Education, vol 87,no 3, pp352-377
Lee H R (1999) A difference of identifying variables' skills, Assessment between performance and multiple choice items, the Journal of Korean Science Education, vol 19, no 1, pp146-158
Lee S M, Chae K P, Kim K D, Lee M W, Kwon S M, Son, Y W, No T H, Jung J H, Seo I H, Kim Y S, Kim Y T and Lee S Y(2000), Middle School Science 1, Kumsung Publishing Co. : Seoul
Lee S M, Chae K P, Kim K D, Lee M W, Kwon S M, Son, Y W, No T H, Jung J H, Seo I H, Kim Y S, Kim Y T and Lee S Y(2001) Middle School Science 2, Kumsung Publishing Co. : Seoul
Lee S M, Chae K P, Kim K D, Lee M W, Kwon S M, Son, Y W, No T H, Jung J H, Seo I H, Kim Y S, Kim Y T and Lee S Y(2002) Middle School Science 3, Kumsung Publishing Co. : Seoul
Little A(1990), The role of assessment, re-examined in international context, Broadfoot P, Murphy R, Torrance H(Eds), Changing Educational Assessment, Routledge : London
McComas W F(1998), Assessing nature of science understanding: A historical perspective, Lederman N, Wade P, Bell R L, McComas W F(Eds), Kluwer Academic Publishers: Netherland
Mertens.D.M(1998),Research Methods in Education and Psychology, SAGE Publication,London
McComas.W F(1998), Assessing nature of science understanding:A historical perspective,Leaderman.N, Wade.P, Bell R L, McComas.W F(ed), Kluwer Academic Publishers, Netherland
Millar. R (1989) Doing science images of science in science education, The Falmer Press London
Millar R and Lubben F(1996), Knowledge and action: Students' understanding of the procedures of scientific enquiry, Welford G, Osborne J and Scott P(Eds), Research in science Education in Europe, Falmer Press: London
Millar.R (2003), Teaching and learning about scientific enquiry, Paper presented at ESERA 2003, PS3-F-Symp B
Available on line : www.phys.vv.nl/esera2003/program.shtml, 17-03-05

Mathews M R (2003), Thomas Kuhn's impact on science education: What lesson can be learned?, International Science Education, 88, pp90-118
MOE (Minister of Education, 2001), The explanation of the 7th National Curriculum, MOE, Seoul
MOE (2001) The 7th National Curriculum, MOE
MOE (2001) The standard of achievement and target attainment, the KICE Press
MOE (2001) A research concerning the implementation of the 7th National Curriculum into individual schools, MOE
MOE(2002), The plan for reinforcing investigation and experimentation centred science classroom in middle schools, MOE, Seoul
Millar R(1991), A means to an end:the role of processes in science education, Open University, Buckingham
Morgan D.L. (1988) Focus groups as qualitative research. London: Sage.
Morgan D.L. and Kreuger R.A. (1993) 'When to use focus groups and why' in Morgan D.L. (Ed.) Successful Focus Groups. London: Sage.
NCES (2004), What is TIMSS?,
Available on line : www.nces.ed.gov/timss (Consulted on 24-11-04)
NFER(2004), Where England stands in the trends in TIMSS, the National Foundation for Educational Research, Berkshire
Niaz M (2001), Understanding nature of science as progressive transitions in heuristic principles, International Science Education, 85, pp 684-690
Nicolson P and Holman J(2003), The national curriculum for science: looking back and forward, School Science Review, 85 (311), pp 21-27
Noah H J &Eckstein M A(1990), Trade-offs in examination policies: an international comparative perspective, Broadfoot P, Murphy R, Torrance H(Eds), Changing Educational Assessment, Routledge(London).
Nott M & Wellington J(1993) Your nature of science profile: an activity for science teachers, School Science Review, 75(270), 109-112.
OCR (2003), Oxford Cambridge and RSA Examinations, GCSE Science E(Pilot) Appendix E: Indeas-about-Science, p 119
Oh P S(2005) Discursive Roles of the teacher during class sessions for students presenting their science investigations, International Journal of Science Education, vol 27, no 15 pp 1825-1851
Oh P S and Shin M K(2005) Students' reflections on implementation of group investigation in Korean secondary science classrooms, International Journal of Science and Mathematics Education, vol 3, no 2, pp327-349
ONS(2002) ONS-The Office for National Statistics(2002) Student achievement in England Education and Skills : Results from PISA, 2002
Oppenheim A N (1966), Questionnaire design and Attitude Measurement, Heinemann, London
Osborne J and Ratcliffe M(2000), Keeping National Curriculum Science in Step with the changing world of the 21st century, Interim report to QCA
Osborne.J&Clooins.S (2000), Pupils' and Parents' views of the school science curriculum, London King's College London.
Osborne J and Ratcliffe M (2002), Assessment of 'Ideas and Evidence', School Science Review, May 2002

Osborne.J, Duschl.R, Fairbrother.R (2002), Breaking the Mould? Teaching Science for Public Understanding, The Nuffield Foundation, London
Osborne.J, Racliffe.M, Collins.S, Millar.R, Duschl.R (2003), What should we teach about science? A Delphi study, ESRC(Economic&Social Research council) Report
Philips D C (1987), Philosophy, Science and Social inquiry, Oxford Pergamon
Park S J (2003), Research of ways in which improve teaching materials fro middle school science, MOE
P middle school (Poong Nap middle school), 2003 science examination papers,
Avaliable on line : http://www.zocbo.com, 03-01-04
Powell R.A., Single H.M., Lloyd K.R. (1996) 'Focus groups in mental health research: enhancing the validity of user and provider questionnaires', International Journal of Social Psychology 42 (3): 193-206.
QCA(2001), Framework for teaching science year7, 8 and 9, London, DfES
QCA(2001), Standard at key stage 3, Science
Available on line: http://www.qca.org.uk/ 20-11-03
QCA(2001), A scheme of work for key stage 3 Science, London, Department for Education and Employment
QCA (2002) Year 9 booster kit: Science Suppliment2002/3, QCA
QCA(2003), Curriculum and Assessment –The National Curriculum and its Assessment
Available on line: www.qca.org.uk/ca/5-15/gen5_14asp (Consulted on 20-11-03)
QCA(2003), Tests and tasks
Available on line: http://www.qca.org.uk/ca/5-14/gen5_14asp , 20-11-03
QCA(2003), National Curriculum assessments from 2003 in science
Available on line: http://www.qca.org.uk/ 20-11-03
QCA (2003) KS3 Science test paper 1, 3-6, QCA
QCA (2003) KS3 Science test paper 1, 5-7, QCA
QCA (2003) KS3 Science test paper 2, 3-6, QCA
QCA (2003) KS3 Science test paper 2, 5-7, QCA
QCA (2004) KS3 Science test paper 1, 3-6, QCA
QCA(2004) KS3 Science test paper 1, 5-7, QCA
QCA(2004) KS3 Science test paper 2, 3-6, QCA
QCA(2004) KS3 Science test paper 2, 5-7, QCA

Ratcliffe M (1998), The purposes of Science Education,In Ratcliffe M(Ed), ASE Guide to Secondary Science Education, ASE, Cheltenham
Ratcliffe M, Batholomew H, Hames V, Hind A, Leach J, Millar R, Osborne J(2004), Research report, Science education practitioner's views of research and its influence on their practice, University of Southampton
Roberts.R,Gott.R (2004), A written test for procedural understanding : a way forward for assessment in the UK science curriculum?, Research in Science&Technology Education, Vol. 22, No.1
Ruddock R, Evaluation (1981): A Consideration of Principles and Methods, Manchester Monographs 18, Bournemouth
Russell.T and McGuigan.L (2003), Introducing scientific enquiry into national statutory assessment for pupils at age 11 and 14 in England, In paper presented at ESERA 2003, Available on line : www.phys.vv.nl/esera2003/program.shtml, 17-03-05

Sapsford.R and Jupp. V(Ed)(1996), Data collection and Analysis, SAGE publications,London
Solomon J(1998), Science Education from a European perspective, Ratcliffe M(Ed), ASE guide to Secondary Science Education, ASE
Song. J W, Lee. K H, Kwak. S I, Kang. T W, Lee.M S (2003), MOE Report: A research to improve ways using resources for teaching and learning in the science classrooms, Middle school science department. Seoul.
Song J W and Kim H K (2004), So what is correct answer? :Barriers to Scientific enquiry in school science, Paper presented at the annual meeting of the National Association for Research in Science Teaching, Vancouver, April1-3,2004
Sung M W(1994), Assessment for the scientific enquiry area in middle schools by analysis of university entrance examinations in the scientific enquiry, Science Education Symposium, Vol 1,no 1
Sung M W, Kim H J, Kang D H(2000), An investigation on science teachers' evaluation practices in the secondary schools, Korean science education, Vol.20, no 1,pp 101-111
Swain J, Monk M, Johnson S(1999), Science Education in Egypt, Korea and the UK, International Journal of Science Education, Vol 21,no 12,pp 1311-1323
Swartz. R S and Leaderman. N (2002), It is the nature of beast : the influence of knowledge and intentions on learning and teaching nature of science, Journal of Research on Science Teaching, vol. 39, No. 3, pp 205-236
Swartz.R S, Leaderman N, Crawford.B (2004), Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific enquiry, International Science Education, pp1-36, DOI 10.1002/sce.10128
Swift B(1996), Preparing Numerical Data, in Sapsford R and Jupp V(Eds),Sage Publications, London
Taber.K.S(2003), Nature and purpose of summative assessment, School Science Review,85(311),
TIMSS-2003, released items
Available on line: www.http://timss.bc.edu/timss2003i/released.html (consulted on 11-11-04)
Turner T(2000), The science curriculum, In Sears J and Sorenson P(Eds), Issues in Science Teaching, Routledge Falmer, London
Watson R and Wood-Robinson(1998), Learning to investigate, Ratcliffe M(Ed), ASE guide to Secondary Science Education, ASE
Weloford G (1996), Developing and understanding models in science education, Welford G, Osborne J and Scott P(Eds), Research in science education in Europe : current issues and themes, Falmer : London
William D(2003) Validity: all you need in assessment, School Science Review, 85(311), pp 79-81
Wiliams J(2006), Education in Science, no 218 June 2006, ASE
.Wellington J (1998), Practical work in science:time for reappraisal, In Wellington J(Ed), Practical work in School Science which way now?, Routledge, London
Woolnough.B (1991), Practical Science, Open University Press, Buckingham
. Woo J O, Kim B K, Ann C H, Hur M(1998), development of the National Assessment System in Scientific enquiry domain, Journal of Korean Science Education, Vol.18 no 4,pp 617-626

Zuzovsky R and Tamir P (1999), Growth patterns in students' ability to supply scientific explanations, Journal of science Education, Vol.21 no 10

Appendices

Appendix (Chapter 4)

Appendix 1

Table 1-1 Cells in the ENSC

Cells in the ENSC		
Year 7	**Year 8**	**Year 9**
* A simple model for cells *Common features and differences between animal and plant cells *One cell organisms and multi-celled organisms *Grouping of similar specialised cells -cells→tissues→organs→organism *Fertilisation as joining sex cells	* To understand all cells need nutrients -Main nutrients in the body -A balanced diet * Digestion (enzymes, breaking down of large molecules, digestive system) * Circulation (in transporting the products of digestion to cells) * Respiration (how cells obtain energy through respiration, aerobic respiration in animals and plants) * To classify Bacteria, Fungi, and Viruses.	* To describe and explain respiration by using a word or symbol * To describe Photosynthesis -As a source of biomass -That other nutrients are used to produce proteins and other substances as fertilizer -How leaves and roots are adapted to their function -Conditions in which plants grow well -Distinguishing between photosynthesis and respiration * Nucleus in a cell contains genes - Fertilisation - Selective breeding *To Explain how multi-celled organisms survive well only if all their parts work well together -Immunisation -Disease -Classifying Bacteria, Fungi, and Virus. -How smoking, alcohol and drugs affect our body. -How exercise affects human body

Table 1-2 Cells in the KNSC

Cells in the KNSC		
Year 7	**Year 8**	**Year 9**
*A simple model for cells *Common features and differences between animal and plant cells *One cell organisms/multi-celled organisms. *Cells→Tissue→Organ→Organism	*3main nutrients for our body * Digestion - Enzymes - Digestive systems * Circulation - Blood - Composition of blood - Circulatory system - heart * Respiration - Respiratory system - Structure of lungs - Exchange of gases -How cells obtain energy * Excretion -Excretory systems -How metabolism works in human body -How human waste is produced -Function of kidneys/ Sweat * Respiratory related diseases - smoking	* Inheritance and evolution - Mendel's law - Mixed inheritance - Various features of inheritance in humans (blood types, colour blindness) - Mutation - Family tree, genes * Evolution, various theories * Reproduction/ Development -How living things grow/reproduce by cell division -Comparing body cell division to sex cell division -Action of chromosomes * Various ways of reproduction: -A sexual reproduction -Sexual organs of humans (The process of fertilization, development, pregnancy and delivery among mammals) The process of fertilization, development of endosperm * Stimulus/ Response -Structure/function of sense organs (eyes, ears, nose, tongue, skin) -Structure and function of neurones and the nervous system -The process of response to stimuli -The mal effect of drugs relating to the nervous system -Function of hormones (in pregnancy) results of deficiency/excess of hormones -Exercise/health (contracting and relaxing of muscles, disease, smoking, drugs, alcohol, obesity) * Structure/function of plants -Structure of roots, process of absorbing water and nutrients and factors affecting growth of plants -Structure of stems and their function -Differences between double seed plants and single seed plants -Structure of leaf (evaporation, respiration and photosynthesis) -Structure of flower and its function -How seeds are produced -Various seeds

Appendix 2

2-1 Particles in the ENSC

Particles in the ENSC		
Year 7	**Year 8**	**Year 9**
*A simple particle model for solid, liquid and gas -The size, arrangement, proximity, attractions and motion of particles -The relationship between heating and movement *Why? -Compressibility -Heating and expansion -Diffusion -Changes of state -Mass conservation when substances dissolve to form solutions -Temperature and solubility -The formation of a saturated solution	*To explain movement of substances through cell membrane using the simple particle model. -How crystals form and that slow cooking results in the formation of larger crystals from molten material and solutions *To describe a more sophisticated particle model for matter - Atoms - Elements - Compounds -Atoms and combinations of atoms (represented by symbols and formulae) * To explain how chemical reactions take place using the more sophisticated particle model.	*To Identify evidence that a chemical reaction has taken place. *Modelling chemical reactions by rearrangement of atoms. $A+B \rightarrow AB$ $AB+CD \rightarrow AD+CB$ * To use the particle rearrangement model -Predicting the names and formulae for products that -Writing words and symbol equations for simple reactions -Explaining why mass is conserved in chemical reaction -Explaining how acids react with bases and neutralisation occurs * To describe how metals react with oxygen, water, acids and oxides, solutions of salts of other metals *To identify differences in reactivity of metals to construct a reactivity series

2-2, Particles in the KNSC

Particles in the KNSC		
Year 7	**Year 8**	**Year 9**
* Three states of materials -Evaporation, -Liquefaction, -Solidification -Melting and sublimation -Changes of states -Models of molecules -Changes of molecules -States of materials and arrangement of molecules *Movements of molecules -Evaporation and diffusion -The relationship between volume and pressure of gases -The relationship between volume change and heating -Changes of states and energy -Temperature change: state changes -Heat energy: molecules' movement	* Properties of substances -Boiling point, melting point, density and solubility * Chemical changes and compounds -Oxidation -Chemical changes and physical changes -Compounds and mixtures *Chemical reaction -Mass changes in chemical reaction -Mass preservation law *Atoms -Atomic number -Atomic symbol -Metals/non metals -Flaming reaction/spectrum -Atomic model * Molecules -Gas reaction law -.Avogadro's law -Size of molecule and chemical formulae -Chemical equations * Molecular movement -Molecular movement -Pressure and volume -Temperature and volume	* Chemical reaction -Electrolyte, non electrolyte -Reaction of ions -Electrolysis *Oxidation and reduction - By flaming - By movement of ions - Metals and acids - Oxidant and reductant * Alkali - Properties - Strength - Various bases * Acids - Properties - Strength - Various acids * Salts * Neutralization * Movement of ions and chemical batteries

Appendix 3

3-1 Forces in the ENSC

Forces in the ENSC		
Year 7	**Year 8**	**Year9**
* Explore the forces acting on stationary objects * Describe the forces acting on objects moving at constant speed * Distinguish between mass and weight * Describe some ways of reducing friction between an object and a soil surface * Some situations in which friction is useful * A force has both magnitude and direction (identifying the directions and balancing forces) * Forces can change the shape of an object - The direction of a moving object - The speed of a moving object	*To understand magnetic materials and their properties including forces of attraction and repulsion * To understand the pattern of magnetic fields * To understand how to produce permanent magnets/electro-magnets * To predict how the magnetic field pattern changes when the strength of an electromagnet increases	* To use friction in liquid and gases to explore how resistance to an object moving through changes with the object's speed and shape. : explain how streamlining reduces an object's resistance to air and water. * To recognise how the moment is related to the size of the force and the distance of the force from the pivot :use moments to explain how a simple object can be balanced. *To recognise how the effect of a force depends upon the area. The pressure exerted by solids The pressure within liquids and gases * To recognise gravity : How weight is different on different planets : How stars, planets and natural and artificial satellites are kept in position in relation to one another. * Pressure (by solids) -Within liquid/gas how the effect of forces depends upon the area to which it is applied and that the force acting per unit of time

3-2 Forces in the KNSC

Forces in the KNSC		
Year 7	**Year 8**	**Year9**
* Various forces and how to measure them - Elastic power, friction, magnetic power, electric power and gravity -How to measure forces, -the unit of forces -How to measure forces using a spring balance -Composing two forces to show ways in which forces are balanced or unbalanced	* Moment -Work using pulleys and pivots - Work at a slotted ground -Potential energy -Kinetic energy -Energy preservation law * Work/energy -How to measure work by using time and force (lifting, pulling) -Unit of work -Efficiency of work and the relationship between work and kinetic energy	* Various motions -Motion without force -Motion with changing speed -Motion changing direction -How to describe motion by time, changed direction and law of inertia -How to measure the dropping time of water drops -Finding out the point where on object drops in a moving bus

Appendix 4

4-1 Energy in the ENSC

Energy in the ENSC		
Year 7	**Year 8**	**Year 9**
*To identify fuels -Use of fuel by living and non-living -uses of electricity as a resources -To explain why conservation of fuels is important due to being finite resources. -To use a simple model of energy transfer -The transfer stage in a range of living and non-living systems -The purpose of cells in an electric circuit -The electric current carries energy to components in a circuit. -That energy is transferred to components in both series and parallel circuits.	*To describe energy transfer in different temperatures -Heating -Changing temperature -Radiation *To recognise that when light travels from a source it is transferring energy -Describe the nature and propagation of light -The behaviour of light (reflection, absorption) To recognise when sound travels by vibrations from the source, it is transferring energy. -Transmission, production reception of sound. -Amplitude, frequency *Energy and particles -To explain energy transfer using the particle model -The process of conduction, convection and evaporation -What happens when substances change state -Thermal conductor and insulator	*To recognise energy conservation idea. -Explain energy transfers in familiar situations -Energy efficacy and energy dissipation _Develop from a simple model of energy transfer in electrical circuits, the idea of potential difference in electrical circuits. *To use the model of energy conservation -the potential difference measured across cells or components. -Electrical energy can be generated using fuels. (involving energy transfer, environmental effects)

4-2 Energy in the KNSC

Energy in the KNSC		
Year 7	**Year 8**	**Year 9**
*The primary school curriculum contains similar content on conservation of fuels *Similar content concerning electricity is covered in yr8. *Light -Reflection, refraction -Observing the light disperse through a prism or a spectrum * Waves -Types of wave -Ways to mark a wave -Properties of waves -Water wave -Reflection/refraction of waves * Sound -Strength of sound -High/Low tune	*Some of this work on energy/light comes under particles. *Some part of this work on particles is done in yr7 *Electricity and energy -Electricity and heat -Electrical power -Series circuit -Parallel circuit * Electromagnetism -Magnetic bar -Electromagnet	*Work and energy -Energy transfer and energy preservation -Work and heat energy

Appendix 5

5-1 Interdependence in the ENSC

Interdependence in the ENCE		
Year 7	**Year 8**	**Year 9**
* To understand classification of organisms by their r similarities and differences * To Identify some of the main taxonomic groups of animals * To understand about food chains *To describe ways in which organisms are adapted to daily or seasonal changes in their environment and to their mode of feeding	*To Identify some of the main taxonomic groups of plants and describe common features *To explain interdependence and energy -To explain that energy is transferred between organisms in food chains and webs -To relate the abundance and distribution of organisms to the resources available within a habitat -Begin representation of this using pyramids of numbers	*To understand the importance of photosynthesis for humans * To know why maximising human food production can significantly affect other animals and plants *To know the effects of pesticides, weed killers and the accumulation of toxins in the environmental system * How pyramids of numbers represent feeding relationships in a habitat * To explain physical, chemical and biological factors in changing habitats * To describe a model for the whole environment -how the materials making up all living organisms are recycled - how energy from sunlight flows through the system - use this to explain the need for sustainable development

5-2 Interdependence in the KNSC

Interdependence in the KNSC		
Year 7	**Year 8**	**Year 9**
None	None	*Environment/humans -What is adaptation -To know the relationship between organisms and environment -Composition of ecosystem -The importance of photosynthesis -Provider, predator, decomposer -Food chain and food pyramid -Circulation of matter in ecosystem -Balance of ecosystem *Environment and humans -Growth curve -Pyramids of numbers represent feeding relationships in a habitat -Population growth *Pollution (air/water/soil) -Pollutants -Acid rain, smog, green house effect, destruction of ozone layer -Accumulation of heavy metals -Heavy metals, fertilizers, and pesticides * Preservation of resources -Preservation of nature -Ecosystem ↔ recycling

Appendix 6

6-1 Earth in the ENSC

Earth in the ENSC (Physics area)		
Year 7	**Year 8**	**Year 9**
*To understand the solar system and beyond - To explain phenomena such as eclipses and the seasons - To learn that planets and satellites are seen by reflected light whereas the sun emits light. - To compare the sun with other stars	*Rocks and weathering -To classify different rock types and to explain rock texture, -To understand the processes of weathering, erosion, transportation and sedimentation -To understand and to relate the processes of evaporation and dissolving, involved in rock formation * The rock cycle -Major rock forming processes -Use the concept of rock texture as one of the key characteristics of igneous, sedimentary and metamorphic rocks -Related processes -crystallisation	*Gravity and spaces To recognise gravity : How weight is different on different planets : How stars, planets and natural and artificial satellites are kept in position in relation to one another.

6-2 Earth in the KNSC

Earth Science in the KNSC		
Year 7	**Year 8**	**Year 9**
*The structure of the Earth *Materials of the Earth's crust _ Materials of the Earth crust -Rocks -The changing surface of the earth: weathering, erosion, transportation of soils and underground water -The changing surface of the Earth ; Wind, ice, sea, water	* Radiant energy *Radiant energy of the Earth *The composition of the atmosphere and atmospheric pressure *Water in atmosphere *Clouds and rain *Circulation of atmosphere *Composition of sea water -Movement of sea water * Changing weather	*The size of the earth, moon and sun *Rotation and revolution of the Earth *Revolution of the moon *Appearances of the sun and the earth *The solar system *The movement of planets and their orbit *Stars *Space and galaxies

Appendix (Chapter 5)

Appendix 7 Bloom's taxonomy

Bloom Level	Relation to science	Examples of questions
Knowledge/Recall	*Recall of specific bits of information *Knowledge of specific symbols *Knowledge of specific facts	* Which two cells pass on information from parents to their children? (3-6-1-2004. ques.1-a-3) * Picture 1 shows a process of reproduction. Drawing 2 shows a female reproductive organ. Choose the place where picture 1 takes place.(Common-2004-ques.36)
Comprehension/ Understanding	*Explanation or summary of a communication *Extrapolation-extension beyond the given data to determine implications, consequences, corollaries.	*A blood clot may stop an organ working properly. Give one reason for this.(3-6-1-2004, ques.3-b) *Followings are classified by cell division methods. Choose the right explanations(common-2004-ques.35)
Application	*The use of abstracts in particular and concrete situations *example the ability to predict the probable effect of a change in a factor on a biological situation previously at equilibrium	*The diagrams below show symbols for a battery, a bulb and a switch. Connect the symbols to make a series circuit (3-6-1-2004, ques. 7-a-2) *The drawings show pulleys to lift a mass M matter. Works has been done at A and B pulling down 5 m. What is work at B? (Common-2004, ques.27)
Analysis	*Breaking information down *Contrasting information *Seeing pattern	*Look at their bar charts for investigations 1 and 2. How can you tell that they used different numbers of pupils in each investigation? (3-6-1-2004, ques. 2-e) * Drawing A and B are experiments showing the current, volt and heat. Choose the right answers(common-2004, ques.45)
Synthesis	*Putting together of elements and parts so as to form a whole *Arranging and combining them in such a way as to constitute a pattern or structure not clearly there before	*Imran added as witch to the circuit so that he could turn all three bulbs on and off at the same time Place a letter S on your circuit diagram where this switch could be placed. (3-6-1-2004, ques. 17-c) *The graph shows the mass of copper oxide after copper is oxidised. Choose the right explanations in the box. (Common-2004, ques.44)
Evaluation	*Comparing and discrimination between ideas, * Summarising ideas *Making choices based on reasoned argument * Verifying the value of evidence	* Harry and Yasmin came to the following conclusions. Explain why Yasmin is better than Harry's conclusion. (3-6-1-2004, ques.11-c,d) * Following table is shown changes in the colour of barks and the numbers of butterflies after industrial revolution in England Manchester. What is the best theory to explain the table?(Junnam-2004, ques.50)

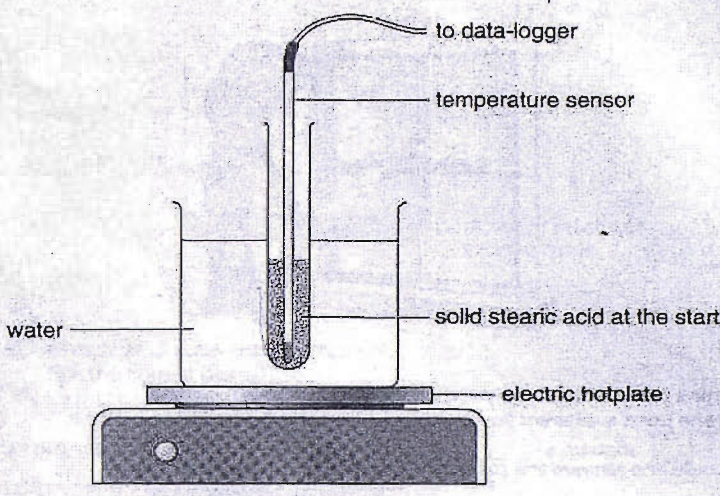
Appendix 8 Kloper's specifications

Klofer's specifications		Subcategories	Examples
Knowledge and Comprehension (a1- a11)		a1 specific facts	3-6-1-2004,1-b-1
		a2 scientific terminology	3-6-1-2004,4-b-1
		a3 concepts of science	3-6-1-2004,1-a-1
		a4 conventions	Common-2004,48
		a5 trends and sequence	3-6-1-2004,7-b-1
		a6 classification categories and criteria	3-6-2-2004,8-a
		a7 scientific techniques and procedure	3-6-1-2004,4-b-2
		a8 scientific principles and laws	3-6-2-2004,10-a
		a9 theories and major conceptual schemes	3-6-2-2004,10-6-e
		a10 identification of knowledge in a new context	3-6-1-2004,5-a-2
		a11 translation of knowledge from one symbolic from another	3-6-1-2003,15-b-2
Processes of Scientific enquiry	Observing and Measuring (b1-b5)	b1 observation of objects and phenomena	3-6-1-2004,2-c
		b2 descriptions of observations using appropriate language	3-6-2-2004,17-a
		b3 measurement of objects and changes	3-6-1-2004,11-a
		b4 selection of appropriate measuring instruments	3-6-2-2004,7-c
		b5 estimation of measurements and recognition of limits in accuracy	3-6-1-2003,15-a-1
	Seeing Problem and Seeking ways to Solve it (c1-c4)	c1 recognition of a problem	5-7-1-2004,14
		c2 formulation of a working hypothesis	5-7-1-2004,14
		c3 selection of suitable tests of a hypothesis	5-7-1-2004,14
		c4 design of appropriate procedures for performing experiments	5-7-1-2004,14
	Interpreting Data and Formulating Generalisations (d1-d6)	d1 processing of experimental data	3-6-1-2004-2-d
		d2 presentation of data in the form of functional relationships	3-6-1-2003,9-b-1
		d3 interpretation of experimental data and observations	3-6-1-2004,5-b-1
		d4 extrapolation and interpolation	5-7-2-2004,10-b-1
		d5 evolution of a hypothesis under test in the light of data obtained	3-6-1-2004,15-c
		d6 formulation of generalisations warranted by relationships found	Common-2003,41
	Building, testing and Revising Model(e1-e6)	e1 recognition of the need fro a theoretical model	None
		e2 formulation of a theoretical model to accommodate knowledge	
		e3 specification of relationships specified by a model	
		e4 deduction of new hypothesis from a theoretical model	
		e5 interpretation and evaluation of test of a model	
		e6 formulation of a revised, refined or extended model	
Application of Scientific Knowledge and Methods (f1-f2)		f1 application of new problems in a different field of science	None
		f2 application to problems outside of science	
Manual Skills (g1-g2)		g1 development of skills in using common lab equipment	Common-2004,28
		g2 performance of common lab techniques with care and safety	3-6-1-2004,6-b
Attitude and Interests (h1-h5)		h1 manifestation of favourable attitudes towards science and scientist	None
		h2 acceptance of scientific enquiry as a way of thought	
		h3 adoption of scientific attitudes	
		h4 enjoyment of science learning experiences	
		h5 development of interests in science and related activities	
Orientation (i1-i6)		i1 development of interest in pursuing a career in science	
		i2 relationships among various types of statements in science	
		i3 recognition of the philosophical limitations and influences of scientific enquiry	
		i4 historical perceptive; recognition of the background of science	3-6-2-2004,17-b
		i5 realisation of the relationships among science, technology, economics	3-6-2-2004,17-b
		i6 awareness of the social moral implications of scientific enquiry	

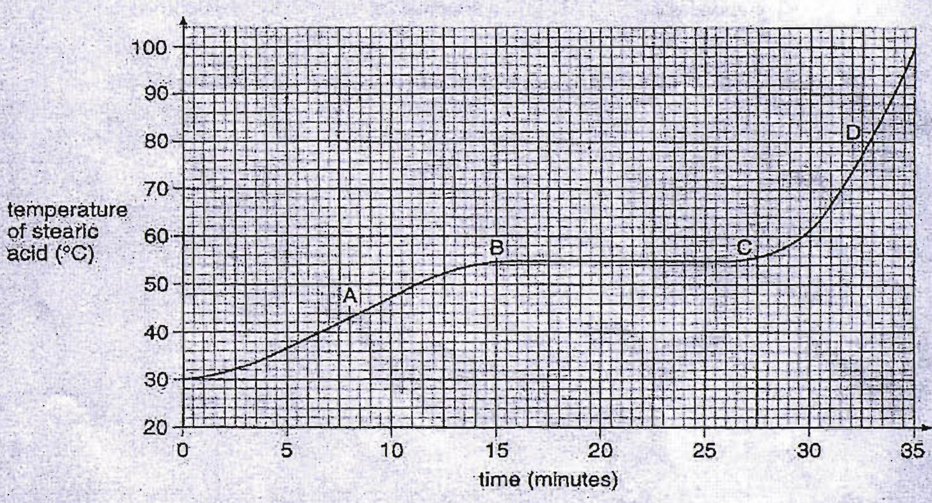
Appendix 9

Eng 3-6-1-15-2004

15. Alan put a test-tube containing solid stearic acid into a beaker of cold water.
He heated the water until it boiled.



He used a temperature sensor attached to a data-logger to record the temperature of the stearic acid over a period of 35 minutes.
A graph of the results is shown below.



Appendix 9

Eng 3-6-1-15-2004

Stearic acid is a solid at room temperature.

(a) (i) Which **letter** on the graph opposite shows the point at which the stearic acid began to change state?

_______ 15ai 1 mark

(ii) Use the graph to find the **temperature** at which the stearic acid began to change state.

_______ °C 15aii 1 mark

(iii) Look at the graph. What was the physical state of the stearic acid:

at point A? ______________________ 15aiii 1 mark

at point D? ______________________ 15aiii 1 mark

(b) The test-tube transfers thermal energy from the water to the stearic acid.

By what method is most of the thermal energy transferred?
Tick the correct box.

conduction	☐	evaporation	☐
convection	☐	radiation	☐

15b 1 mark

(c) Stearic acid boils at 360°C.
The stearic acid could **not** boil in this experiment.
Give the reason for this.

____

______________________________________ 15c 1 mark

maximum 6 marks

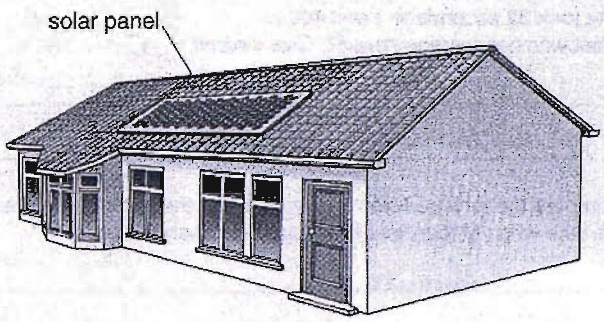
Total

6

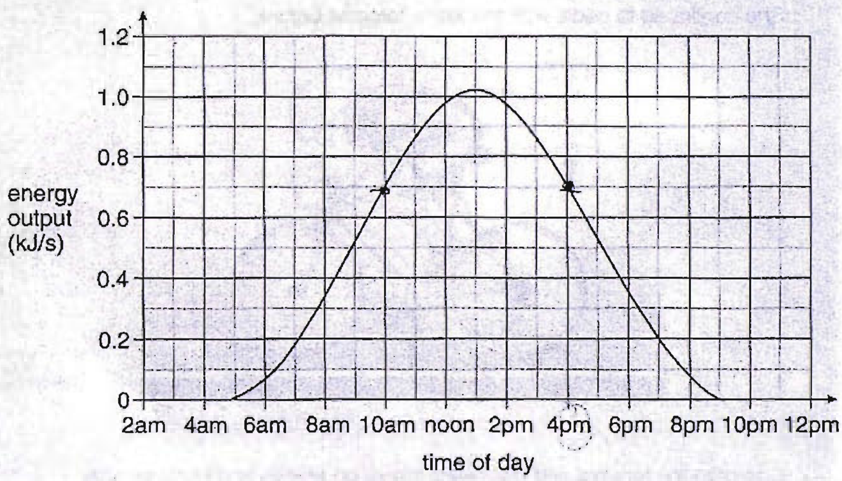
Appendix 10

5-7-2-10,2004

10. The drawing below shows a solar panel fixed to the roof of a house in Britain.



(a) Daniel measured the energy output from this solar panel during one day in June. The graph below shows his results.



(i) Why does the energy output from the solar panel vary during the day?

____

____

10ai
1 mark

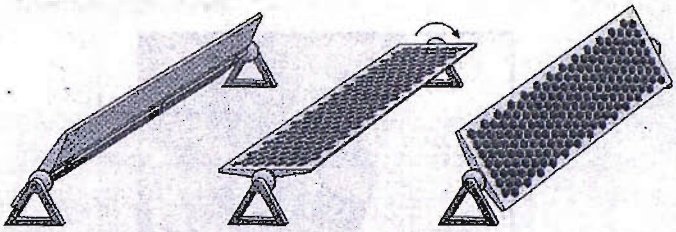
(ii) Daniel used the solar panel to run a motor.
The motor needs 0.7 kJ/s to run at full speed.
Use the graph to find how long Daniel's motor would run at full speed.

________ hours

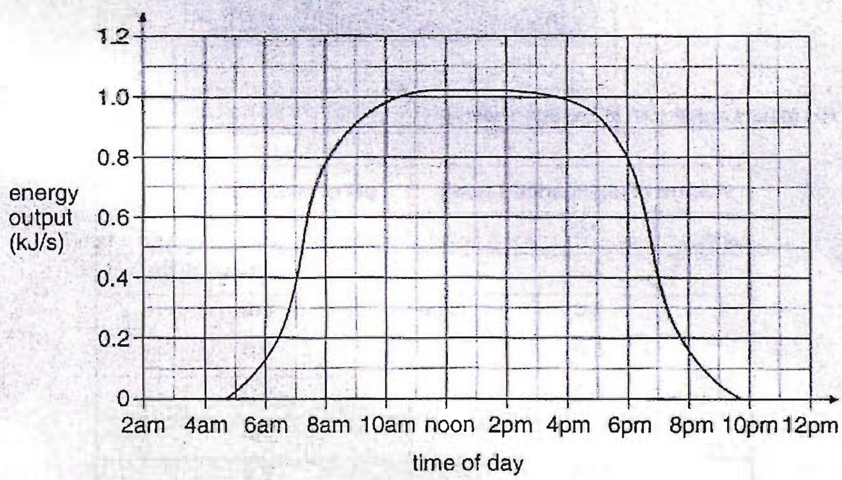
10aii
1 mark

Appendix 10
5-7-2-10,2004

(b) Daniel measured the energy output from a different solar panel.
This type of solar panel turns so that it always faces the Sun.



The graph below shows the energy output for this panel during one day **in mid-summer.**



10bi
1 mark

(i) On the graph above draw another curve to show how the energy output for this solar panel might vary on a day in **mid-winter**.

10bi
1 mark

(ii) Between 7am and 7pm the solar panel turns through an angle of 180°.
Calculate the angle the solar panel turns through each hour.

____

______________________________ degrees

10bii
1 mark

maximum 5 marks

Total

Appendix 11,
3-6-1-6-2003

6. The table below gives information about three fuels that can be used in cars.

✓ shows a substance is produced when the fuel burns.
X shows a substance is **not** produced when the fuel burns.

fuel	physical state	energy released, in kJ/kg	some of the substances produced when the fuel burns		
			carbon monoxide	sulphur dioxide	water
petrol	liquid	48 000	✓	✓	✓
hydrogen	gas	121 000	X	X	✓
ethanol (alcohol)	liquid	30 000	✓	X	✓

(a) Which fuel, in the table, releases the **least** energy per kilogram (kg)?

1 mark

____

(b) Some scientists say that if hydrogen is burned as a fuel there will be less pollution.
From the information in the table, give **one** reason why there will be less pollution.

1 mark

____

____

(c) Which of the three **fuels** in the table can be compressed into a small container?

1 mark

____

Appendix 11,
3-6-1-6-2003

3-6-1-2003-6b

(d) **Which gas in the air is needed for fuels to burn?**
Tick the correct box.

1 mark

- carbon dioxide ☐
- nitrogen ☐
- oxygen ☐
- water vapour ☐

(e) Petrol and ethanol are both fuels. Petrol is made from oil.
Scientists say that oil could run out in 100 years.
In some countries people plant sugar cane and use it to make ethanol.

Sugar cane will **not** run out. Explain why.

1 mark

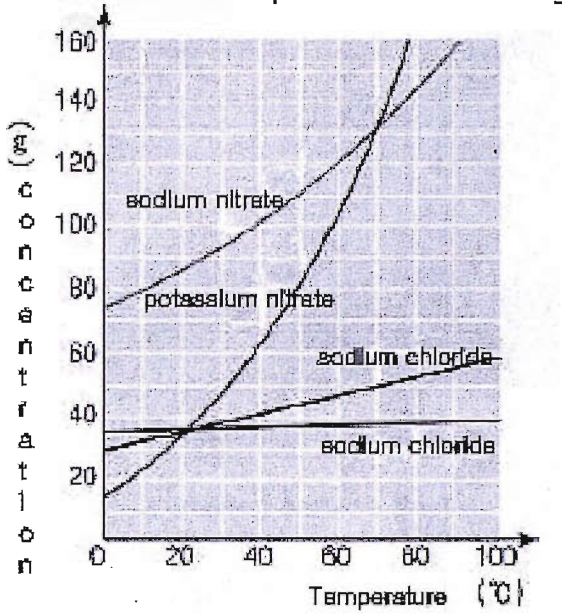
____

____

maximum 5 marks

Appendix 12 ,
Common-30-2004

30 The graphs show the curves of solubility in several solid materials. Choose the incorrect explanation about the graph.



1) Solubility of solid increase as it temperature goes up.
2) Potassium nitrate shows the biggest change in solubility following the temperature change.
3) As 30g potassium chloride dissolve in water 100g, it will be saturated solution.
4) Sodium nitrate shows the highest concentration of saturated solution in 60.
5) The mixture of potassium nitrate and sodium chloride can be fractionated by separated crystallization.

Appendix 13,
5-7-2-15-2003

5-7-2-2003-15

15. A group of pupils recorded some different characteristics of pupils in their class.

The table below shows their results.

name	gender	height, in cm	mass, in kg	hand span, in cm	arm span, in cm	eye colour
Julie	girl	152	48	17.2	160	blue
Laura	girl	157	54	15.0	141	green
Aftab	boy	159	49	18.4	172	brown
Jenna	girl	144	46	17.4	161	hazel
Barry	boy	148	49	17.4	162	blue
Oliver	boy	172	57	21.5	204	brown
Safina	girl	155	48	16.8	158	brown
Maria	girl	154	50	17.9	166	green
Amanat	girl	162	46	16.2	150	brown
Thomas	boy	157	49	19.9	186	blue

(a) Oliver concluded that boys do **not** have green eyes.

Explain why his conclusion is **not** justified.

1 mark

____

(b) Name **two continuous** variables in their table.

1. ______________________

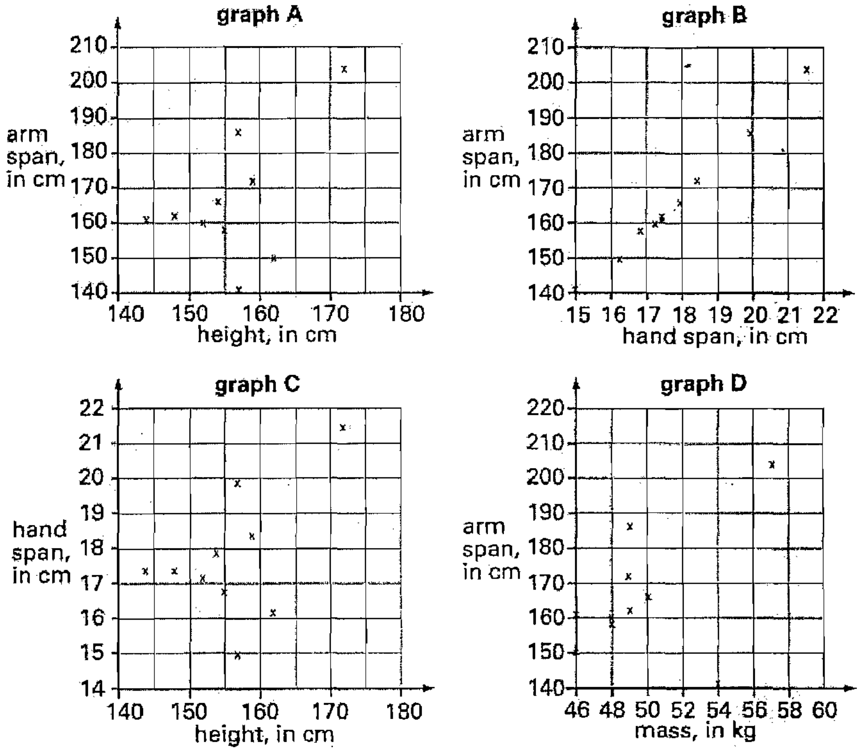
2. ______________________

1 mark

Appendix 13,
5-7-2-15-2003

5-7-2-2003-15b

(c) Look at the scatter graphs below.



Use the data in the scatter graphs to show whether each of the conclusions below is **true**, **false** or you **cannot tell**. *2 marks*

conclusions	true or false or cannot tell
Graph C shows that the shortest pupil has the smallest hand span.	______
Graph B shows the strongest correlation between two variables.	______
Graph A looks similar to graph C because of the high correlation of arm span to hand span.	______
Boys are generally taller than girls.	______

maximum 4 marks

Appendix 14

5-7-1-14,2004

14.

'Wilting roses are a thing of the past.'

Scientists at the University of Leeds have found a way to modify the genes of flowering plants.
They claim that flowers from modified plants remain fresh in a vase of water for up to six months longer than flowers from unmodified plants.

Plan an investigation you could carry out in the school laboratory to test the claim that flowers from modified plants last for much longer than flowers from unmodified plants.

You will be provided with flowers from modified plants and from unmodified plants.

Appendix 14

5-7-1-14b,2004

In your plan give:

- the **one** factor you will change as you carry out your investigation; (This is the independent variable.)
- the factor you will measure; (This is the dependent variable.)
- **one** of the factors you should control to ensure a fair test;
- the time scale for the investigation.

14 1 mark

14 1 mark

14 1 mark

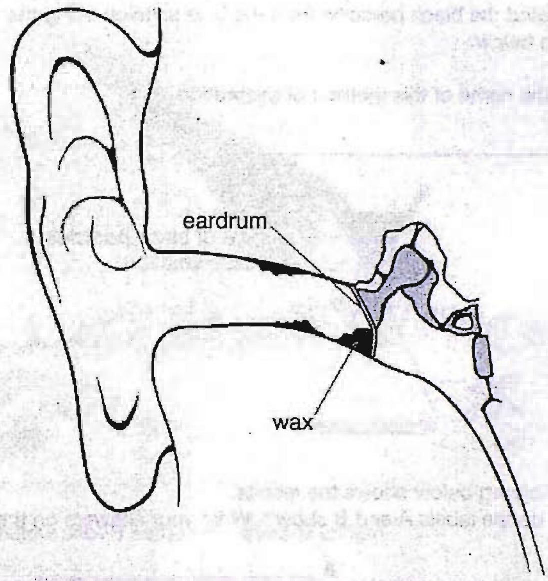
14 1 mark

maximum 4 marks

Total 4

Appendix 15
3-6-1-5-2004

5. The diagram below shows part of the human ear.



We can hear somebody speaking because sound waves enter our ears.

(a) (i) What do our eardrums do when sound waves reach them?

____

5ai
1 mark

(ii) Sometimes a lot of wax is produced in the ear.
The wax rests against the eardrum, as shown above.

Give **one** reason why we **cannot** hear very well when our ears contain a lot of wax.

____

____

5aii
1 mark

Appendix 15 3-6-1-5-2004

(b) The table below shows the lowest and highest frequencies that five living things can hear.

living thing	lowest frequency (Hz)	highest frequency (Hz)
human	20	20 000
sparrow	300	20 000
dog	20	45 000
cat	20	64 000
rabbit	300	42 000

(i) Which **three** living things from the table **cannot** hear a frequency of 43 000 Hz?

______________ and ______________ and ______________

5bi
1 mark

(ii) From the table, choose the living thing that can hear the biggest **range** of frequencies.

____

5bii
1 mark

maximum 4 marks

Total
4

Appendix 16

TIMSS-2003-7

UniqueID S032712A	Subject S	Grade 8	MSBlock S10	MSBlockSeq 09 A

The scientists measured the volume of the crown five times. They computed the density for each volume measurement. Their results are shown in the table below.

Trial	Volume of Crown (cm^3)	Density of Crown (g/cm^3)
1	202	11.88
2	200	12.00
3	201	11.94
4	198	12.12
5	199	12.06

A. Why did the scientists measure the volume five times?

B. The scientists reported to the king that the density of the crown was 12.0 g/cm^3. Show how the scientists used their results to obtain this value for the density.

S032712

Questions for Metal Crown continue.

TIMSS 2003

Content Domain

Physics

Main Topic

Forces and motion

Cognitive Domain

Conceptual Understanding

Key

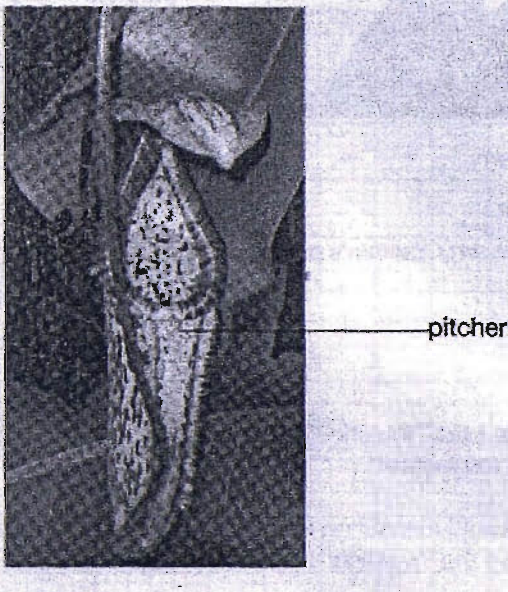
See scoring guide

Appendix 17
3-6-1-12, 2004

12. (a) Plants need nitrogen compounds for growth.
Give the name of the type of plant cell that absorbs water and nitrogen compounds from the soil.

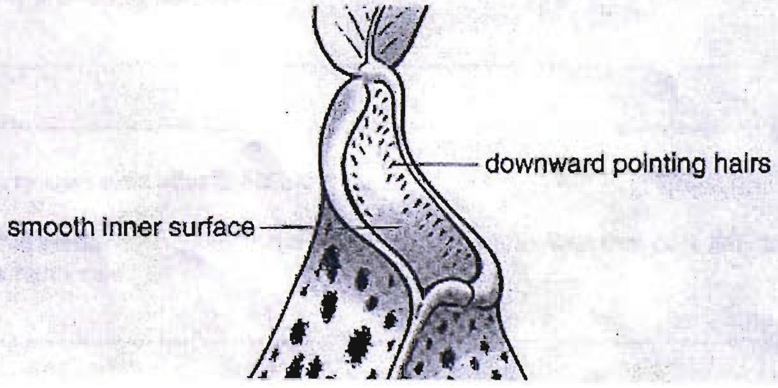
____

(b) The photograph shows a pitcher plant.
Pitcher plants get nitrogen compounds from insects.
They digest insects in leaves shaped like containers called pitchers.



In the bottom of the pitcher there is a liquid. Insects are attracted to the plant. They fall into the liquid.

The inner surface of the pitcher is very smooth and slippery with downward pointing hairs as shown below.



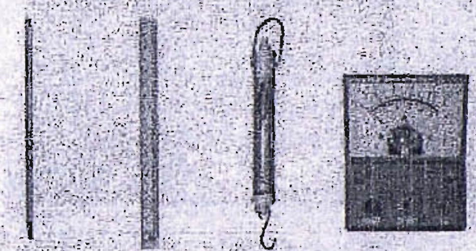
Appendix 18,
3-6-1-8,2003

E 3-6-1, Q 8

8. Lee blew across the top of paper tubes to make sounds.
He investigated how changing the length of a tube affects the pitch of the sound.

(a) What equipment could he use to measure the length of the tubes?
Tick the correct box.

1 mark



☐ ☐ ☐ ☐

(b) The photograph below shows the different lengths of tubes Lee used.

Suggest one way his test might not have been fair.

1 mark

____

____

(c) Lee made a prediction.

Which of these statements is a prediction?
Tick the correct box.

1 mark

The tubes were made of paper. ☐

The pitch of the sound is how high or low it is. ☐

The longer tube will make a lower sound. ☐

The sound is caused by the vibration of air. ☐

(d) Lee blew across the ends of 3 different lengths of tube and compared the pitch of the sound produced.

His results are shown below.

Length of the tube, in cm	pitch of the sound
5	high
25	medium
50	low

Which length of tube made the sound with the highest pitch?

1 mark

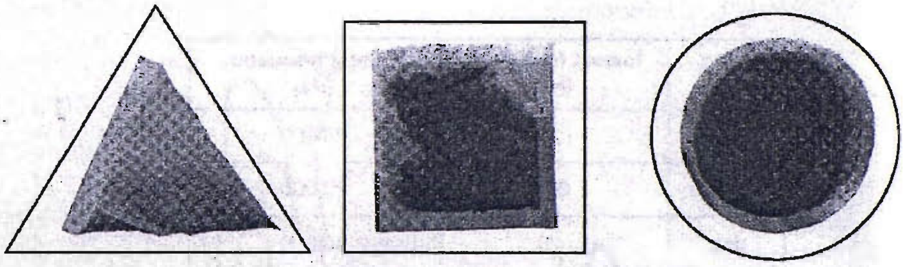
______ cm

maximum 4 marks

Appendix 19,

3-6-1-6-2004

6. Tea bags are made in different shapes.



Some pupils want to find out which shape of tea bag lets tea dissolve most quickly.
They make two plans for their investigation as shown below.

FIRST PLAN

We will use 3 tea bags and 3 beakers.

SECOND PLAN

Collect three beakers.
Collect three different tea bags.
Put one tea bag in each beaker.
Add 150 cm³ of water at 65°C.
Keep the temperature of the water the same.
Measure the time taken for the tea to dissolve.
Find out which is the quickest for making tea.

(a) How is the second plan better than the first plan?

____

____

6a
1 mark

(b) Why should they take care when they add hot water at 65°C to the tea bags?

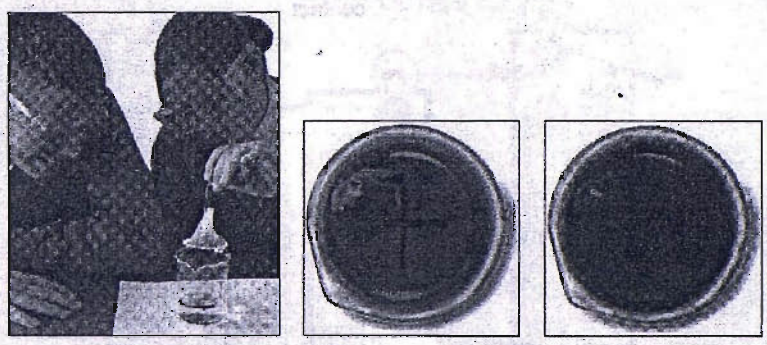
____

____

6b
1 mark

Appendix 19,
3-6-1-6-2004

(c) Ben and Vicky drew a cross on some paper. They put each beaker, in turn, over the cross. They poured hot water into the beaker, dropped in the tea bag and watched the water change colour.



To see which shape of tea bag let the tea dissolve the quickest, they measured the time until the liquid was too dark for them to see the cross.

How did the cross help to make their test more accurate?

____

6c
1 mark

(d) (i) They recorded their measurements in a table as shown below.

shape of tea bag	time taken until cross cannot be seen (minutes)
triangle	8
square	15
circle	10

Which part of their investigation was recorded in the table?
Tick the correct box.

explanations ☐ results ☐

conclusions ☐ plans ☐

6di
1 mark

(ii) Give the **three** shapes of tea bags in the order in which the tea dissolved.
Use the table above to help you.

quickest ______________ ______________ ______________ slowest

6dii
1 mark

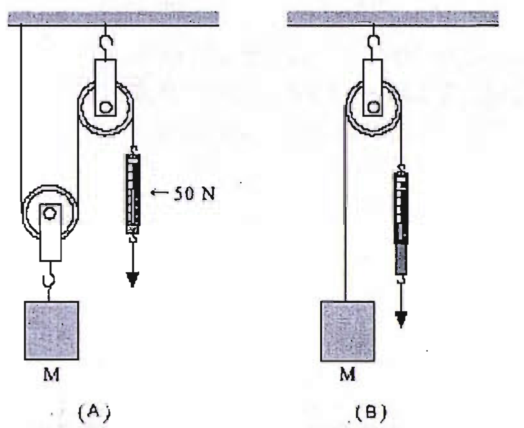
maximum 5 marks

Total
5

Appendix 20

Common-37, 38, 39, 40,2004

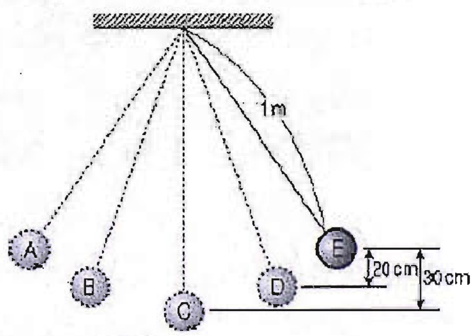
37. The drawings A and B show pulleys in order to lift up matters weighed M respectively. When you pull the end of hooks down 5 m with constant speed, how much of work is done in B? (Ignore the masses of ropes and pulleys)



④ 320J ② 200J

① 32J ⑤ 20J ③ 100J

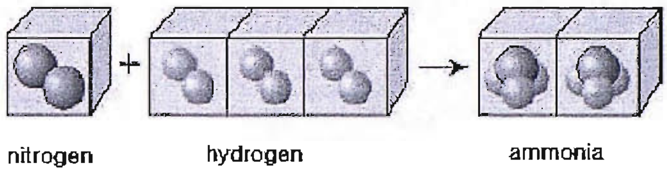
38. The drawing shows a metal ball hanging on 1m rope traveling A to B.
What is the proportion potential energy to kinetic energy at the point D ?
(Ignore the air resistance, rope's friction and mass of rope)



① 1

④ 2

39. The drawings show the model of arnmonia formation trough the reaction of hydrogen and nitrogen gas. (Regard as being constant in temperature and pressure) Choose the incorrect explanation. Choose the incorrect explanation.

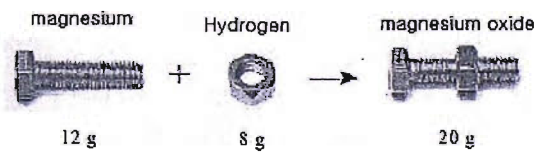


1) The same number of molecules contain in the same volume.
2) A nitrogen molecule consists of two nitrogen atoms.
3) An ammonia's molecule consists of two elements
4) The ratio of volume in the reaction of nitrogen and hydrogen is 1:3.
5) The numbers of molecules remain same after reaction.

40. The drawings represent the formation of magnesium oxide through the reaction of magnesium and oxygen. Choose the correct explanations in the box.

a) It can explain the mass preservation law through the model.
b) A new atom forms through chemical reaction.
c)It can be known the volume of oxygen through the reaction of magnesium.
d) Atoms do not change during the chemical reaction.

1) a,c
2) a,d
3) b,c
4) b,d
5) c,d



Appendix 20

Junnam-52-2004
52. Following table shows the research result concerning changes of colour in barks of trees and numbers of moths in Manchester England around the Industrial Revolution.

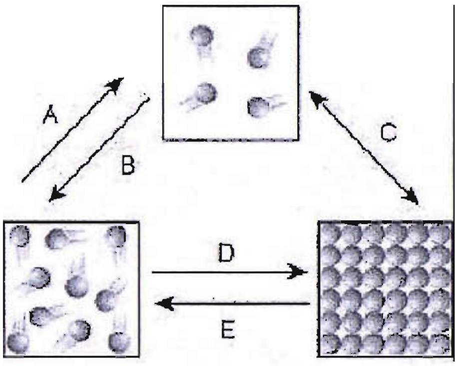
	Colours of tree barks	Number of moths	
		Black moths	White moths
Before Industrial Revolution	Light	Few	Many
After Industrial Revolution	Dark	Many	Few

Choose the most appropriate evolution theory concerning the above research result.
① Natural selection theory
② Use and disuse theory
③ Mutation theory
④ Isolation theory
⑤ Individual variation theory

Appendix 21

Common-27-2004

27. The drawing represents the process of state change.



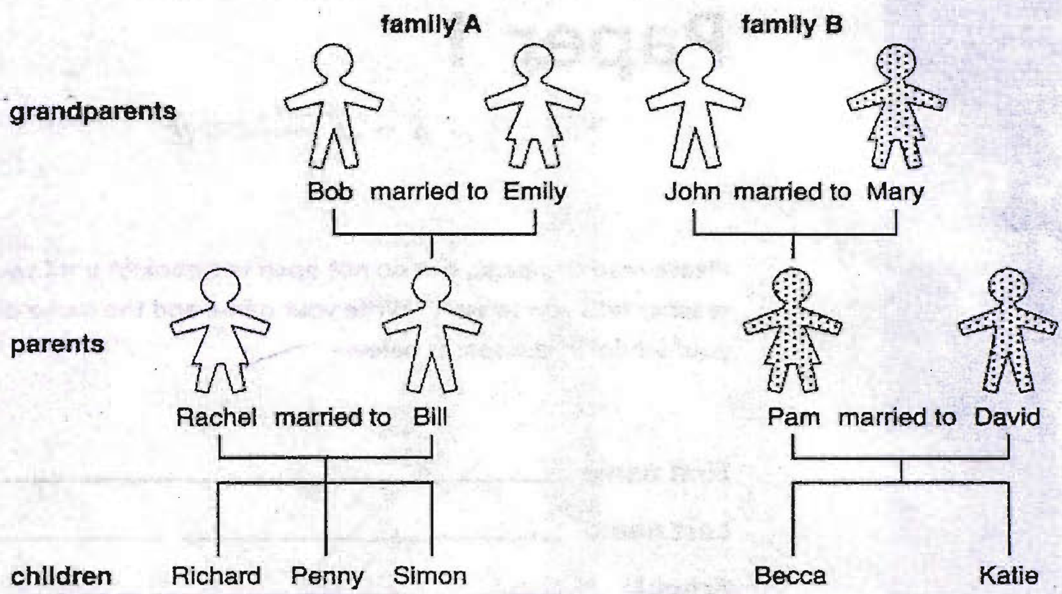
Choose the answer in which gives a right example.

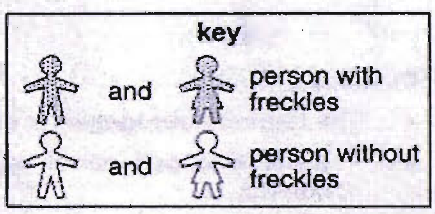
1. A – A melted candle flows and become hard.
2. B – Wet washings are getting dry in the washing line.
3. C – Naphthalene tablets in wardrobe are getting smaller.
4. D- As ice cubes are becoming water as it is put on the table from a refrigerator.
5. E – water drops appear in the surface of a cup having ice-water.

Appendix 22

3-6-1-1-2004

1. The diagram shows two families. Some of the people in the diagram have freckles.





(a) (i) Which children are most likely to have freckles?
Tick the correct boxes.

Richard ☐ Simon ☐ Katie ☐ Penny ☐ Becca ☐

(ii) How did you decide?

____

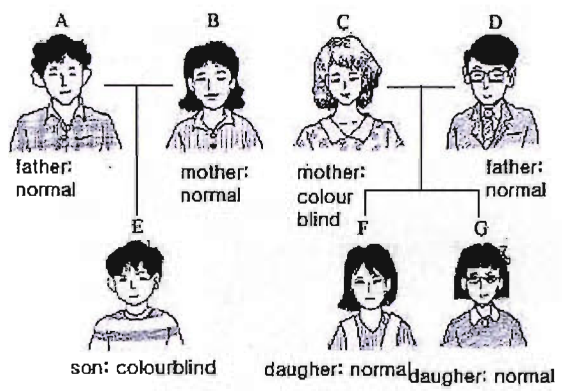
____

Appendix 23,

Common-50-2004

50. The drawings represent a family tree about colour blindness.

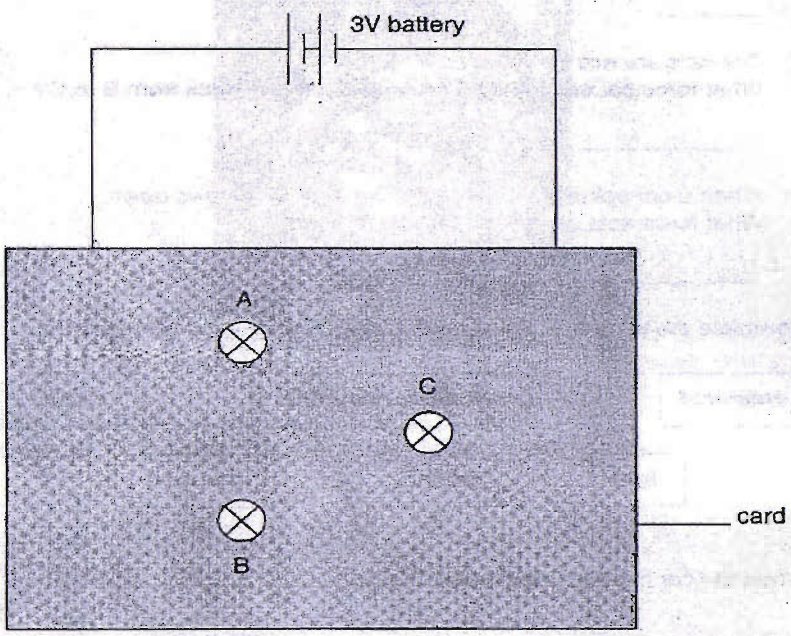
Choose the correct explanation



1) the second baby of A and B will be definitely colour blind
2) You do not know B's gene
3) the third child of C and D will be definitely colour blind
4) a child of E and F will never be colour blind
5) G does not have a colour blind gene

Appendix 24
3-6-1-17-2004

17. Imran built a puzzle circuit with three identical bulbs and a 3V battery.
He covered the connections to the bulbs with a piece of card as shown below.
The bulbs could be seen through holes in the card.



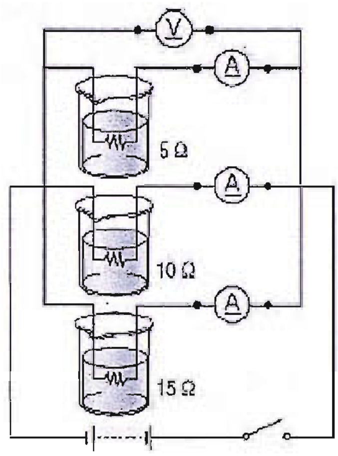
All the bulbs were on but their brightness was different.

Lucy removed bulbs A, B and C in turn. Before connecting each bulb back into the circuit she observed the effect on the other two bulbs.
She recorded her observations in the table below.

bulb removed	observations
A	B and C stayed on
B	C went off A stayed on
C	B went off A stayed on

Appendix 25
Junnam-43-2004

43. The drawing shows an experiment:
By adding the same amount of water into the three beakers and connecting the ammeter and voltmeter cells.
Choose the right explanation about the experiment

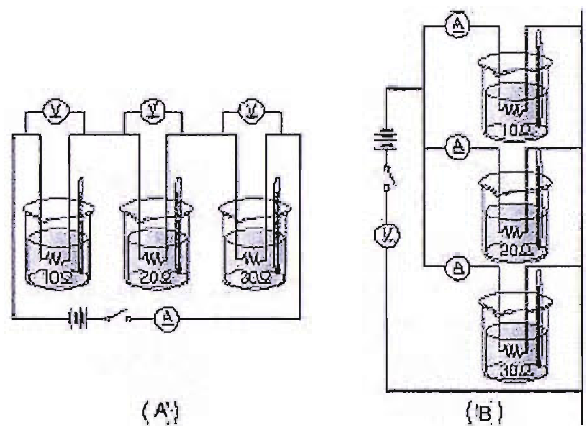


① The voltmeter is connected to the series circuit.
② The lowest voltage is in 5Ω
③ heat comes off most in 15Ω resistance
④ The experiment shows the relation to current and heating value
⑤ The current is the same amongst resistances

Appendix 25

Common-45-2004

The drawings are of an experiment to find out the relationship between current, voltage and amount of heat.



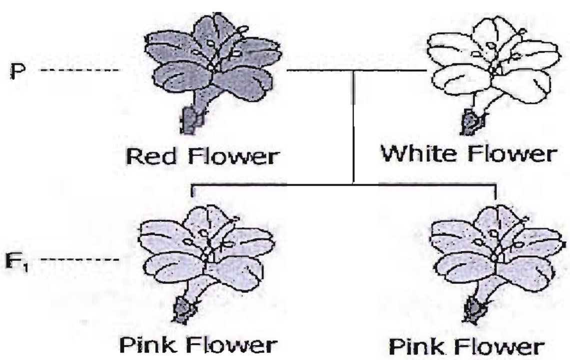
Choose the correct explanation.

1) The volt is the same in each resistance in A
2) A is to find out the link between the current and amount of heat
3) The strongest current is at resistance 10 in B
4) B is to find out the link between the current and amount of heat
5) The biggest temperature change occurs in B at 30

Appendix 26

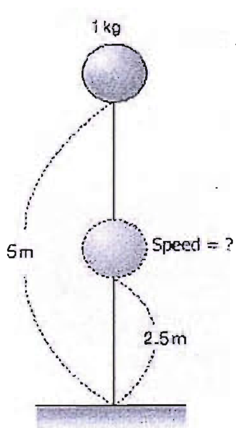
Junnam-50-2004

50. The drawing below show the inheritance of "Marvel of Peru".
What is the probability of getting white coloured flowers by interbreeding white and pink coloured "Marvel of Peru".



① 0% ② 25%
③ 50% ④ 75%
⑤ 100%

32. An object with mass of 1kg falls to the ground from a height of 5m. What is the speed with which it fell from a height of 2.5m?



① 3 m/s ② 7 m/s ③ 10 m/s
④ 49 m/s ⑤ 98 m

Appendix 27

Appendix 27; 5-7-1-14-2004

14. Almost 200 years ago, an important investigation into plant growth was carried out.

George Sinclair, the Duke of Bedford's head gardener, planted seeds in 242 plots of land, each four feet square.

Charles Darwin concluded from this investigation:

> If a plot of ground is sown with one species of grass and a similar plot is sown with several different species of grass, the second plot will produce a greater number of plants and a greater mass of plant material.

(a) Give **one** feature of the plots that was controlled in Sinclair's investigation.

____

____

14a — 1 mark

(b) Why did Sinclair use many plots rather than just two?

____

____

14b — 1 mark

(c) What **two** factors are named in Darwin's conclusion as the measurable outcomes in the investigation?
(These are the dependent variables.)

1. ______________________________

2. ______________________________

14c — 1 mark

(d) Which **one** factor was changed in Sinclair's investigation?
(This is called the independent variable.)

____

14d — 1 mark

Appendix 28

5-7-2-6-2004

In January 2002, thousands of pupils recorded the numbers of different birds seen in their gardens in one hour. They sent their results to the Royal Society for the Protection of Birds who have kept data for many years.

(a) Why are the results from this survey more reliable than one person's observation?

____

____

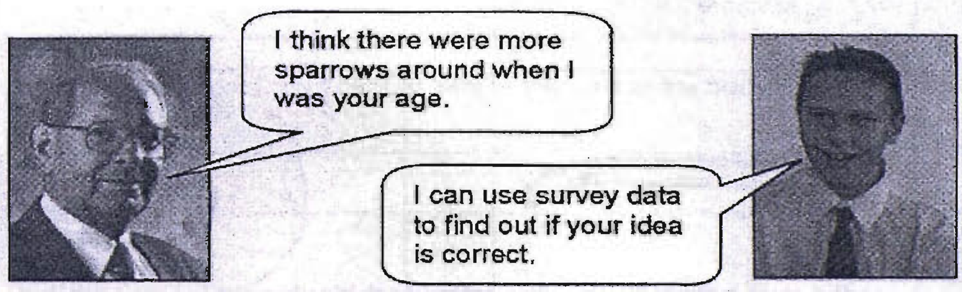
(b) Pupils observed birds in their gardens for one hour during the last week in January.

Give **two factors** which are being controlled in this survey.

1. ____

2. ____

(c) Jack's grandad says: Jack says:



Jack thinks that the results collected in 2002 **cannot** test his grandad's idea that sparrows are less common than they used to be.

(i) What additional survey data would Jack need to test his grandad's idea?

____

____

(ii) What pattern in the survey results would give Jack the evidence that his grandad was correct?

____

____

maximum 5 mar

Appendix 29,

TIMSS-2003, S1308A

When settlers came to live on the Galapagos Islands, they brought v them a number of new animals such as cats and goats. Write down (effect the introduction of cats and goats could have on the animals a plants already living on the islands.

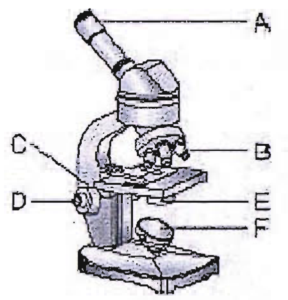
A. One effect of **cats**:

B. One effect of **goats**:

Appendix 30

Common-28-2004

28. A student wants to see the letter using a microscope as follow. However, he found that it was too dark. If he wants to see more clearly regardless the size of letter, which part of microscope, he has to control?



① A, B ② B, C ③ C, D

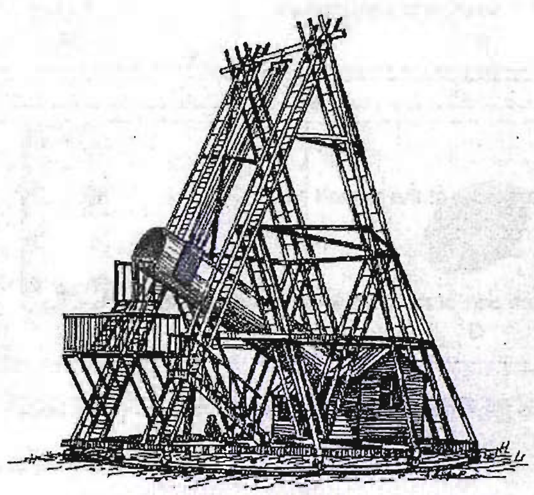
④ D, E ⑤ E, F

Appendix 31,

3-6-2-17,2004

17. Until 1781 scientists thought there were only six planets in the solar system. Then a scientist called Herschel looked through a very large telescope that could turn to follow objects in space.
He watched a bright object in the night sky for a few months and made drawings of what he saw. He concluded it was a planet.

Herschel's telescope



(a) What method did Herschel use to discover the new planet?
Tick the correct box.

He carried out practical tests in the laboratory.	☐	He asked scientists' opinions.	☐
He observed the environment.	☐	He gathered data from books.	☐

Appendix 31

3-6-2-17,2004

(b) Scientists today use satellites as well as telescopes to observe the universe.

Suggest **one** way that developments in equipment have changed the information scientists collect about planets.

____

____ 17b

1 mark

(c) Before 1781, scientists believed there were 6 planets in our solar system. Now scientists believe there are 10 planets.

What do these ideas suggest about our knowledge of our solar system?

____

____ 17c

1 mark

(d) What causes scientists to reject an idea and replace it with a new one?

____

____ 17d

1 mark

maximum 4 marks

Total

4

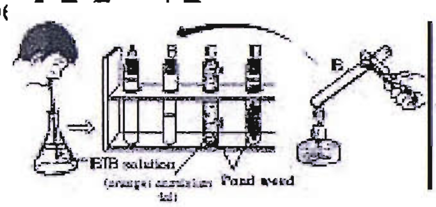
Appendix 32

Kyungi-2003-33

33. The following experiment I to know what is essential for photosynthesis to occur.

<The process>

(A) Breathe into the BTB solution in the conical flask. Then fill in the test tube



(B) Leave **A** and heat up **B** with alcohol lamp.
(C) Put the pond weed into **C** and wrap it with aluminum foil, and in **D** put just pondweed.
(D) Put bungs on each test tube and place it on a windowsill. Then observe the colour changing of the test tubes.

As a result of the experiments above, which test tube does the colour changing occur?

① **A, C** ② **A, D** ③ **B, C**
④ **B, D** ⑤ **C, D**

Appendix (Chapter 6)

Appendix 33

Questionnaire for teachers who teach KS3 science in England and Korea

This is a comparative study to explore science teachers' perceptions about teaching and assessing scientific enquiry in both England and Korea.

Please take time to answer the following questions.
Your sincere reply will be a great contribution to this study.

If you have any enquiry, please contact
Jung Cho on jrc2@soton.ac.uk
Or Prof. Mary Ratcliffe on M.Ratcliffe@soton.ac.uk
School of education, University of Southampton Highfield
Southampton SO17 1BJ

A. Personal Details

1. What is your age group?

21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐

2. Are you male or female?

Male ☐ Female ☐

3. How many years have you been teaching?

0-5 ☐ 6-10 ☐ 10-15 ☐ 16-20 ☐ 21-25 ☐ 25+ ☐

4. What is your background? (Please tick what you consider to be the most appropriate category)

Biology ☐ Chemistry ☐ Physics ☐ Other (Please specify) ☐

5. Have you ever studied any of the following subjects?

Please tick all that apply.

☐ Philosophy of science ☐ History of Science

☐ Sociology of science ☐ Philosophy

B. Perception about the nature of science and scientific enquiry

6. Please indicate activities, which you think are part of learning about **scientific enquiry**. (Please tick all that apply)

No.	Statements	Answers
1	Practical work in general	
2	Watching video	
3	Field trip	
4	Observation and thinking about phenomena	
5	Reading and thinking about phenomena (textbooks, work-sheets)	
6	Researching information and collecting data to solve problems	
7	Open ended Investigation by pupils	
8	Experimentation	
9	Discussion and argumentation	
10	Making inference from observations or other data	
11	Looking for patterns in data	
12	Drawing conclusions from evidence	
13	Teacher demonstration	
14	Teacher talking and explaining	

7. The following statements can give you some indication of your own philosophy of science. Please score your response to each statement on a scale of -2 (Strongly disagree) +2 (Strongly agree) and a score of 0 will indicate a balanced view.

No	Statements	-2 SD	-1 D	0	1 A	2 SA
1	Scientists have no idea of the outcome of an experiment before they do it.					
2	Science proceeds by drawing conclusions, which later become theories.					
3	Scientific theories are as much a result of imagination and intuition as inference from experimental results.					
4	All scientific experiments and observations are determined by existing theories.					
5	Science facts are what scientists agree they are.					
6	Scientific research is economically and politically determined.					
7	Scientific theories have changed over time simply because experimental techniques have improved.					
8	In practice, choices between competing theories are made purely on the basis of experimental results.					
9	Science education should be more about the learning of scientific processes than the learning of scientific facts.					
10	The most valuable part of a scientific education is what remains after the facts have been forgotten.					
11	Scientific method is transferable from one scientific investigation to another.					
12	A good solid ground in basic scientific facts and inherited scientific knowledge is essential before young scientists can go on to make discoveries of their own.					
13	There are certain physical events in the universe which science can never explain.					
14	Scientific knowledge is different from other kinds of knowledge in that it has a higher status.					

C. Teaching and Assessing

8. How important are the following to you in planning your teaching?
Please rate the following aims of teaching science.

Very important ←→ not important

No	Aims	1	2	3	4	5
1	To summarise and interpret the programme of study					
2	To familiarise students with the type of assessments they will get					
3	To stimulate scientific curiosity					
4	To answer all the questions asked by students.					
5	To demonstrate how to justify scientific claims based on evidence					
6	To guide and organise pupils' study					
7	To provide good understanding scientific concepts					
8	To enhance students' career prospects					

Please specify any other ____

9. How often do you use the following when **teaching science?**

		Very often	Frequently	Occasionally	Seldom	Never
1	Teacher talking and explaining					
2	Note taking					
3	Whole or group discussion / argumentation					
4	Role play					
5	Research information and collecting data to solve problems					
6	Teacher demonstration					
7	Experimentation					
8	Open-ended investigation					
9	Working from work sheets/ textbooks					
10	Video watching					
11	Field trip					

10. Indicate the importance of each of the **aims of practical work** to you in teaching science.
(Please tick all that apply.)

Very important ← → Little or no important

No	Aims	1	2	3	4	5
1	To make phenomena more real through experience					
2	To practise seeing problems and seeking ways to solve them					
3	To promote a logical, reasoning method of thought					
4	To encourage accurate observation and description					
5	To find facts and arrive at new principles					
6	To demonstrate theoretical work as an aid to comprehension					
7	To arouse and maintain interest					
8	To develop manipulative skills					
9	To verify facts and principles already taught					
10	To satisfy National Curriculum requirements					

Please specify any other____________________________________

11. How often do you do **practical work** in year 9 classes?

1	Almost every lesson	
2	70-80% of lessons	
3	50-70% of lessons	
4	30-50% of lessons	
5	10-30% of lessons	
6	Less than 10% lessons	
7	Never	

12. When you teach **scientific enquiry**, what do you focus on ?

(Please tick all that apply.) High focus ⟵⟶ Low focus

		1	2	3	4	5
1	Fostering explorative or research skills					
2	Preparing students to get practical skills for their investigations					
3	Fostering an understanding of the nature of science					
4	Encouraging students to solve problems					
5	Encouraging reasoning and critical thinking					
6	Preparing students for performance assessments					
7	Helping students understand content of topic					
8	Motivating students					

Please specify others____

13. How often do you use the following means when **teaching scientific enquiry**?

Very often ⟵⟶ Never

		1	2	3	4	5
1	Giving pupils opportunities to describing patterns and relationship in data from pupils' own or other's investigations and asking them to explain and justifying pupils' description.					
2	Making predictions of additional readings from data they have collected in their own investigations.					
3	Teaching explicitly about how to collect evidence in situations where variables cannot be readily collected, where a suitable control is not obvious.					
4	Presenting pupils with graphs of different kinds and asking them to draw conclusions and to state clearly the evidence on which they base their conclusions.					
5	Presenting pupils which conclusion others have drawn from evidence and asking them to decide whether these are justified.					
6	Providing opportunities for practical work that requires pupils to solve problems.					
7	Being explicit about how evidence from either historical or contemporary secondary data, can be used to draw conclusions and to develop scientific ideas					

Please specify others____

14. How would you describe your confidence in teaching **scientific enquiry**?

Very high	High	Neither high nor low	Low	Very Low
☐	☐	☐	☐	☐

15. When you do investigative work, who decides types, variables and apparatus for the **investigations**? (Please indicate the box)

		Always teachers	Usually teachers infrequently students	Usually students rarely teachers	Always students
1	Type of investigation				
2	Variables				
3	Apparatus				
4	Planning				
5	Collecting data				
6	Conclusion/Analysis				
7	Evaluation				

16. When teachers assess pupils' investigative work, they may find that pupils have not mastered the ideas in an investigation e.g. the conduct and the interpretation of results. When would that be most likely to happen? Please tick the boxes all that apply.

No.	Examples	
1	When the teacher's explanation concerning the related concepts was not sufficient	
2	When students were not given ownership of the investigation	
3	When the process was complicated and students did not have enough skills	
4	When the investigation was carried out within a limited time and space.	
5	When the scientific concepts and the investigation were not related	

Please specify others ______________________________

17. Which of these would be obstacles to implementing more scientific enquiry in science classroom? Please rate the size of the obstacles.

← Large obstacle No obstacle →

		1	2	3	4	5
1	Inflexible time table					
2	The organisation required for open-investigations or projects					
3	Large classes					
4	Lack of laboratory facilities					
5	Lack of appropriate resources					
6	The pressure of examinations					
6	Lack of teacher's confidence in process skills					
7	Lack of teacher's confidence in integrating practical work into a concept					
8	Lack of teacher's confidence in assessing scientific enquiry criteria					
9	Lack of teacher's own interest					
11	Lack of teacher's understanding about scientific enquiry					

Please specify others____

18. How much do you agree or disagree with the following statement: Scientific investigations and scientific enquiry activities help students perform better in science overall?

Strongly agree	Agree	No opinion	Disagree	Strongly disagree
☐	☐	☐	☐	☐

19. How much pressure do you feel under to reach the attainment targets set by your schools?

A lot	A little	Not very much	Not at all
☐	☐	☐	☐

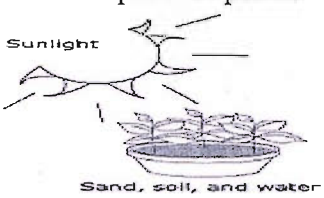
If you feel this pressure, how does this affect your planning and completion of investigative work?____

D. Different types of questions assessing scientific enquiry

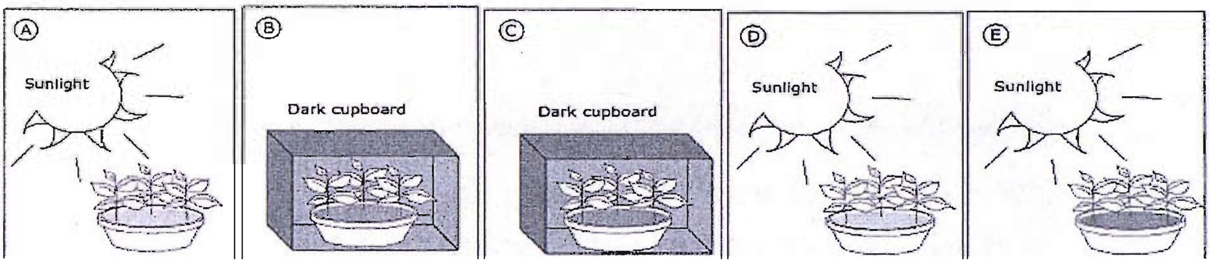
Please read each of the following questions for pupils carefully.

Question A : A question from TIMSS-2003

A girl has an idea that green plants need sand in the soil for healthy growth. In order to test her idea she uses two plots of plants. She sets up one pot of plants as shown below.



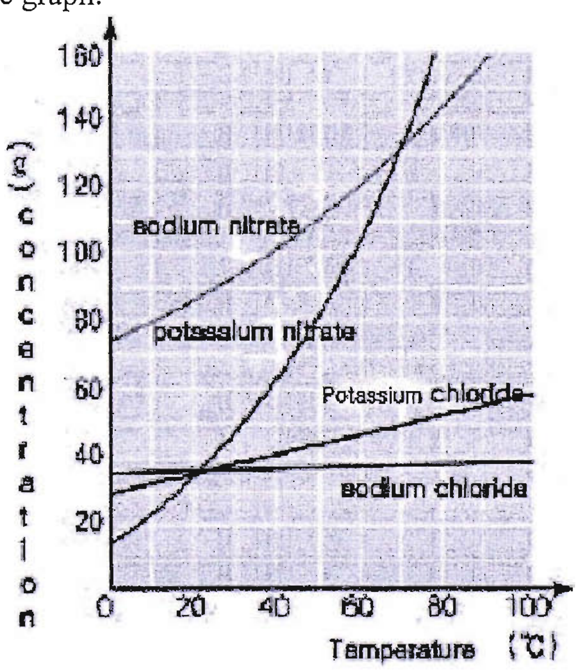
Which one of the following should she use for the second pot of plants?



sand and water | Sand, soil and water | Soil and water | Sand and soil | Soil and water

Question B: A question from Korean high school entrance examination

The graphs show the solubility curves of several different solids. Choose the incorrect explanation about the graph.



1) Solubility of a solid increases as it temperature increases.
2) Potassium nitrate shows the biggest change of solubility according to the temperature change.
3) As 30g potassium chloride dissolves in 100ml of water at 50℃, it will be a saturated solution.
4) Sodium nitrate shows the highest concentration of saturated solution at 60℃.
5) The mixture of potassium nitrate and sodium chloride can be separated by crystallization.

Question C : A question from the KS3

' Wilting roses are a thing of the past'

Scientists at the University of Leeds have found a way to modify the genes of flowing plants. They claim that flowers from modified plants remain fresh in a vase of water for up to six months longer than flowers from unmodified plants.

Plan an investigation you could carry out in the school laboratory to test the claim that flowers from modified plants last for much longer than flowers from unmodified plants.
You will be provided with flowers from modified plants and from unmodified plants.

In your plan:

*the **one** factor you will change as you carry out your investigation:
(This is the independent variable.)
* the factor you will measure:
(The is the independent variable.)
* **One** of the factors you should control to ensure a fair test:
*The time scale for the investigation

20. How well do you think year 9 pupils would answer these 3 questions ?

	Very well	Well	Satisfactorily	Not very well	Not at all
Question A					
Question B					
Question C					

21. In order for pupils to answer these questions, which **three** things would you do to prepare them? Please tick **three** boxes for each question.

No.		Question A	Question B	Question C
1	Allocate more time to do scientific investigations			
2	More practice to familiarise pupils with these new types of questions by work sheets or previous exam papers			
3	More learner-centred teaching techniques			
4	More open investigative works for pupils			
5	More practical work			
6	More explanations about appropriate methods and fair tests			
7	More explanations about the science concepts being tested			
8	More practice concerning identification of variables			
9	More explicit teaching of individual elements of scientific enquiry eg. Nature of hypothesis, theory, variables			

22. If each of these three types of scientific enquiry questions occupied up to 30 % of exam questions, would this affect your current teaching method?

Questions	A lot	A little	Not very much	Not at all
Question A				
Question B				
Question C				

If your answer is 'A lot', how would your teaching methods be changed?

____

23. If this same question C was turned into a multiple-choice format as below, how likely is it that pupils would answer correctly?

Very Likely	Agree	No difference	Disagree	Very Unlikely
☐	☐	☐	☐	☐

a. Which are the independent variable and dependent variable in carrying out this investigation
   1. Modified plants and unmodified plants, numbers of days the flower stay fresh
   2. Modified plants, numbers of days the flower stay fresh
   3. Unmodified plants, numbers of days the flower stay fresh
   4. Numbers of petal in a flower, time taken to loose from its receptacle
   5. Modified plants, amount of water in the vase reduced

b. In order to make this a fair test, which factors should you control in carrying out the investigation.
   1. The same heights of plants
   2. The same weights of plants
   3. The same variety of plants
   4. The same colour of flowers
   5. The same number of thorns

24. How much do you agree or disagree with the following statement.

" It is very important that the assessment content and context should be within what pupils have learnt during their schooling. If the content and context are outside the scope of the school curriculum, the assessment cannot be a fair test for assessing pupils' ability."

Strongly agree	Agree	No opinion	Disagree	Strongly disagree
☐	☐	☐	☐	☐

Thank you

Appendix 34

Correlations

Table 1 Correlations between the views about the nature of science and teachers' details

Factors	England	Korea
The views of the NOS vs age	-0.1556	-0. 1175
The views of the NOS vs sex	-0.0168	0.1837
The views of the NOS vs career	-0.2259	-0.0657
The views of the NOS vs Speciality	-0.070	0.0835
The views of the NOS vs study experiences	-0.0456	-0.0044

*Law data of Table 15 is used as the views of the NOS for comparing correlations

Table 2 Correlations within items of the views about the nature of science

Correlation Q7	Eng	Kor
ID/CD	0.0391	-0.0822
ID/PC	-0.1248	-0.0567
ID/RPO	0.078	-0.133
CD/PC	0.042747	0.101
CD/RPO	0.479956	0.5777
PC/PRO	-0.02228	-0.0119

Table 3-1 Correlations between the views about the nature of science and teacher's perceptions about teaching science(Eng)

Eng(Q7:Q8)	ID	CD	PC	PRO
SI	-0.14607	0.054	0.024	-0.16442
FA	0.0167	0.097	-0.016	0.285506
STCU	0.129	-0.012	-0.116	-0.093
AAQ	0.1455	0.081	-0.1941	0.0112
DHJC	0.192	-0.035	-0.1849	-0.2237
GO	0.1163	-0.1558	-0.096	0.0323
PUSC	0.028	-0.02	-0.0684	-0.0014
EC	0.063	0.041	-0.1669	-0.0354

Table 3-2 correlations items between questions(Kor)

Kor(Q7:Q8)	ID	CD	PC	PRO
SI	-0.13617	-0.02735	0.152762	-0.00768
FA	-0.02435	0.114006	0.191248	-0.02771
STCU	-0.19359	0.040616	0.187536	0.098736
AAQ	-0.11402	-0.00912	0.301728	0.060191
DHJC	0.030391	-0.0202	0.31859	-0.05057
GO	-0.12312	-0.06742	0.169784	-0.0793
PUSC	-0.22117	0.078863	0.107245	0.108712
EC	-0.04551	0.048879	0.142355	0.162685

Table 4-1 Correlations between the teacher's perceptions about teaching science and doing practical work (Eng)

Eng Q8/10	Mphenom	Pseeing	Palogical	Eaccurate	Ffacts	Dtheoret	Ainterest	Dmanipul	Ffacts	SNC
SI	0.2622	0.022	0.114159	0.262468	0.0209	0.1862	0.1981041	0.16918	0.114606	0.164
FA	0.3556	0.142	0.224132	0.256427	0.3743	0.2323	0.2587632	0.149621	0.22989	0.227
STCU	0.11	0.328	0.217423	0.134337	0.1156	0.15015	0.3354853	0.286401	0.135022	0.125
AAQ	0.08	0.047	0.135	0.087006	0.2624	0.24355	0.1899785	0.302483	0.236861	0.075
DHJC	-0.07174	0.31782	0.251314	0.295648	0.3273	0.31193	0.409987	0.269882	0.136991	0.123
GO	-0.22839	0.51349	0.248587	0.440712	0.5075	0.34639	0.2668813	0.422838	0.192246	0.233
PUSC	-0.12467	-0.34706	0.259525	0.643437	0.6569	0.35355	0.4891096	0.245374	0.191703	-0.12
EC	0.416628	0.37122	0.077371	0.31005	0.429	0.31505	0.0368671	0.197277	0.386546	0.25

Table 4-2 Correlations between the teacher's perceptions about teaching science and doing practical work (Kor)

Q8Q10Kor	Mphenom	Pseeing	Palogical	Eaccurate	Ffacts	Dtheoret	Ainterest	Dmanipul	Ffacts	SNC
SI	0.2883561	0.340298	0.322129	0.290098	0.2611	0.341353	0.24433	0.186029	0.25038	0.166
FA	0.1054499	0.139045	0.196899	0.26828	0.2192	0.138023	0.19577	0.251234	0.22037	0.2181
STCU	0.4866963	0.469033	0.408267	0.414292	0.4664	0.488496	0.50169	0.285931	0.27725	-0.014
AAQ	0.2755387	0.370717	0.303331	0.390505	0.4076	0.397427	0.42327	0.349549	0.28114	-0.077
DHJC	0.3947927	0.502737	0.551827	0.442575	0.4728	0.419132	0.4157	0.415977	0.34823	0.1445
GO	0.2621609	0.331343	0.219384	0.326252	0.4274	0.432211	0.30825	0.216319	0.25514	0.0563
PUSC	0.4376079	0.468717	0.435802	0.38628	0.4501	0.382342	0.46342	0.239952	0.28711	0.0212
EC	0.305782	0.291544	0.453414	0.52615	0.3396	0.336255	0.29726	0.348604	0.18472	0.1424

Table 5-1 Correlations within items concerning teachers' perception about teaching science (Eng)

Eng Q8	FA	STCU	AAQ	DHJC	GO	PUSC	EC
SI	0.54637	-0.07349	0.087	-0.033	0.28	0.288	0.213
FA		0.1	0.0164	0.071	0.113	0.3765	0.4628
STCU	0.1		0.2082	0.4434	0.463108	0.1813	0.1376
AAQ	0.0164	0.2082		0.27437	0.20155	0.28867	0.27
DHJC	0.071	0.4434	0.27437		0.362136	0.247205	0.08
GO	0.113	0.036	0.20155	0.362136		0.496647	0.463108
PUSC	0.3765	0.1376	0.28867	0.247205	0.496647		0.3765
EC	0.4628	0.1376	0.27	0.08	0.463108	0.3765	

Table 5-2 Correlations within items concerning teachers' perception about teaching science (Kor)

Kor Q8	FA	STCU	AAQ	DHJC	GO	PUSC	EC
SI	0.45168	0.55521	0.40079	0.39261	0.39261	0.59193	0.29285
FA		0.55521	0.24488	0.18838	0.27314	0.18228	0.37447
STCU	0.55521		0.64841	0.46239	0.59977	0.79026	0.2965
AAQ	0.24488	0.64841		0.533	0.54717	0.48432	0.2994
DHJC	0.18838	0.46239	0.533		0.53193	0.50413	0.40933
GO	0.27314	0.59977	0.59977	0.53193		0.66349	0.4015
PUSC	0.18228	0.79026	0.48432	0.50413	0.66349		0.29002
EC	0.29285	0.2965	0.2994	0.40933	0.4015	0.29002	

Table 6-1 Correlations between teachers' perceptions about doing practical work and teaching scientific (Eng)

Q10/Q12 Eng	Mphenom	Pseeing	Palogical	Eaccurate	Ffacts	Dtheoret	Ainterest	Dmanipul	Ffacts	SNC
Fexplorative	0.99974	-0.05409	-0.02168	0.19291	0.1409	0.032	0.2558	0.1461	0.024	-0.0089
Pskills	0.326207	0.082	0.093276	0.14883	0.1123	-0.004	0.098	0.1124	0.2447	0.1193
Funderst	0.119605	0.3938	0.171455	0.24573	0.4889	0.3191	0.3743	0.4794	0.1965	0.2939
Esolve	-0.0133	0.3807	0.257259	0.24666	0.1961	0.048	0.1511	0.2056	0.1965	0.1001
Ereason	0.008444	0.2377	0.3412	0.37716	0.2298	0.1254	0.1289	0.2772	0.219	0.078
Passessm	-0.105514	0.032	0.08	0.1249	0.1247	0.038	0.1142	0.0061	0.4104	0.0959
Hcontent	0.435126	0.2596	0.027014	0.11626	0.329	0.461	0.3652	0.4283	0.3906	0.209
Motivating	0.082902	0.2719	0.32228	0.22984	0.1914	0.267	0.4055	0.2827	0.2325	0.2849

Table 6-2 Correlations between teachers' perceptions about doing practical work and teaching scientific (Kor)

Q10/Q12 Kor	Mphenom	Pseeing	Palogical	Eaccurate	Ffacts	Dtheoret	Ainterest	Dmanipul	Vfacts	SNC
Fexplorative	0.01479	0.03609	0.04053	0.09037	-0.049	-0.08288	-0.02436	0.000915	-0.0263	0.1517
Pskills	0.02823	0.14696	0.26643	0.23444	0.1077	0.1311	0.22943	0.196993	0.13902	0.242
Funderst	0.23094	0.21516	0.32341	0.26252	0.1871	0.23011	0.36093	0.233311	0.19594	0.1305
Esolve	0.36109	0.41077	0.4308	0.35183	0.2632	0.31714	0.49368	0.254276	0.2042	0.0717
Ereason	0.13432	0.22852	0.31065	0.26421	0.1484	0.1135	0.32393	0.151811	0.11481	0.1673
Passessm	-0.28761	-0.24044	-0.0899	0.07435	-0.187	-0.23734	-0.1618	-0.053084	0.05354	0.2005
Hcontent	0.39918	0.294	0.35807	0.43216	0.2219	0.33106	0.39358	0.36374	0.41066	0.0341
Motivating	0.42535	0.36948	0.35829	0.43196	0.2773	0.32362	0.62945	0.394408	0.29106	-0.008

Table 7-1 The Correlations within the items concerning teachers' perceptions about doing practical work (Eng)

Eng Q10	Mphenom	Pseeing	Palogical	Eaccurate	Dtheoret	Ainterest	Dmanipul	Ffacts	SNC
Mphenom		0.4258	0.3001	0.1516	0.6122	0.2616	0.2598	0.147	0.0274
Pseeing	0.4258		0.514	0.209	0.301	0.334	0.313	0.365	0.095
Palogica	0.3	0.514		0.49	0.23	0.24	0.2	0.3	0.18
Eaccurate	0.1516	0.209	0.49		0.09	0.14	0.3	0.24	0.02
Dtheoret	0.6122	0.301	0.23	0.09		0.343	0.354	0.207	0.154
Ainterest	0.2616	0.334	0.24	0.14	0.343		0.343	0.168	0.24
Dmanipul	0.2598	0.313	0.2	0.3	0.354	0.536		0.353	0.112
Ffacts	0.147	0.365	0.16	0.24	0.539	0.361	0.09		0.252
SNC	0.0274	0.095	0.18	0.02	0.154	0.24	0.112	0.09	

Table 7-2 The Correlations within the items concerning teachers' perceptions about doing practical work (Kor)

Kor Q10	Mphenom	Pseeing	Palogical	Eaccurate	Dtheoret	Ainterest	Dmanipul	Ffacts	SNC
Mphenom		0.68057	0.63925	0.55863	0.41177	0.5941	0.4577	0.343	0.069
Pseeing	0.6806		0.06909	0.5274	0.50176	0.4114	0.65	0.338	0.116
Palogica	0.6393	0.06909		0.73844	0.42034	0.629	0.5082	0.447	0.399
Eaccurate	0.5586	0.5274	0.73844		0.42603	0.573	0.5394	0.384	0.294
Dtheoret	0.4118	0.50176	0.42034	0.42603		0.51936	0.4677	0.6187	0.0184
Ainterest	0.5941	0.4114	0.629	0.573	0.51936		0.619836	0.56	0.139149
Dmanipul	0.4577	0.65	0.5082	0.5394	0.430288	0.619836		0.467	0.187637
Ffacts	0.343	0.338	0.447	0.384	0.6187	0.480972	0.4677		0.169968
SNC	0.069	0.116	0.399	0.294	0.0184	0.139149	0.1876	0.007	

Table 8-1 The correlations between the teachers' perceptions about teaching science and their frequent teaching methods (Eng)

Q8/Q9Eng	SI	FA	STCU	AAQ	DHJC	GO	PUSC	EC
Talking	0.1350236	0.2304441	-0.110989	0.0329022	-0.284394047	-0.132773	0.1424629	0.1170314
Note taking	0.1914475	**0.0971868**	**0.2994247**	**0.0267179**	**0.21246427**	**0.1794592**	**0.2081555**	**0.1746042**
Dis-Argu	0.1233192	0.0192241	0.295726	0.2525733	0.200582087	0.1470385	0.0874916	0.1673629
Roleplay	0.1659284	0.2644806	-0.208333	-0.254116	-0.131029216	0.0102849	-0.034977	0.2256416
Res,Colle	0.2125891	0.3530555	0.1395836	0.0873082	0.265091088	0.1822304	0.1903501	0.2804812
Demo	-0.110086	-0.002136	-0.021259	-0.023017	-0.049026415	-0.162128	-0.02339	-0.166732
Experiment	0.0765404	-0.035378	0.1100457	-0.143822	0.076133523	-0.061838	-0.107236	-0.081157
investigation	-0.001217	0.1328853	0.2235746	0.0712343	0.227185482	0.014116	-0.012384	0.149045
Worksheet	0.0938889	0.05585	-0.22416	0.1244655	-0.20677562	0.0135489	-0.005637	0.2151598
Video	0.1771447	0.045724	-0.04947	0.1725384	-4.05307E-17	0.216317	0.1345129	0.1209319
Field trip	0.0422191	0.1116809	0.1046943	0.103053	0.218048718	-0.03868	0.1332945	0.1836521

Table 8-2 The correlations between the teachers' perceptions about teaching science and their frequent teaching methods (Kor)

Q8/Q9Kor	SI	FA	STCU	AAQ	DHJC	GO	PUSC	EC
Talking	0.1846827	0.095876	0.0483833	0.1059604	0.074380327	0.1299594	0.1192829	0.0748939
Note taking	0.1678433	0.0828493	0.1574525	0.1549826	0.06003453	0.0848874	0.1321228	0.0920087
Dis-Argu	-0.122592	-0.010518	-0.023559	0.1096245	-0.094955327	-0.053012	-0.088489	-0.018982
Roleplay	-0.310891	-0.131437	-0.32094882	-0.210749	-0.130674777	-0.14247	-0.130675	-0.074287
Res,Colle	-0.069981	0.0043002	0.1028696	0.1945952	0.09400114	0.0593822	0.0394901	0.0724309
Demo	-0.089037	-0.082659	-0.058944	0.0451754	0.101478653	-0.059479	-0.145249	-0.005522
Experiment	-0.181614	-0.29493	-0.019213	-0.112789	0.028095889	0.0273178	-0.042544	-0.034589
investigation	-0.12593055	-0.212073	-0.053243	-0.175505	0.011566772	-0.066684	-0.07336367	-0.007597
Worksheet	0.0817808	0.1756599	-0.021508	0.0454087	-0.007903456	0.2256043	0.1059282	0.1982676
Video	-0.048635	0.0006985	-0.01542352	-0.026879	-0.054324904	0.0315664	0.0397771	0.0822239
Field trip	-0.091674	0.033072	-0.044091	0.1069188	0.174961981	0.065046	-0.025653	0.0053749

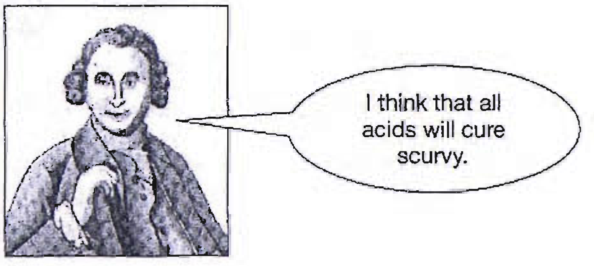
Table 9-1 Correlations between the frequent teaching method of science and the frequent teaching method of scientific enquiry (Eng)

Q9Q13Eng	Talking	Note takinc	Dis-Argu	Roleplay	Res,Colle	Demo	Experiment	investigatic	Worksheet	Video	Field trip
Gpupils	**0.123408**	**0.2634**	**0.095**	**0.263**	**0.1565**	**-0.081**	**0.095**	**-0.0386**	**-0.034**	**-0.0047**	**0.145**
Mpredictior	0.1024	0.1831	0.0685	-0.0396	0.2297	0.0538	0.0685	0.2614	0.0718	0.2442	0.0968
Texplicitly	0.076	0.1242	0.2416	-0.062	0.244	0.1653	0.2416	0.2183	0.0089	0.1808	0.2332
Pgraph	0.0051	0.02	0.1413	-0.0468	0.2177	0.068	0.1413	0.2293	0.0399	0.0524	0.293
Pconclus	-0.026	0	0.0749	-0.036	0.2118	0.082	0.0749	0.2628	0.1275	0.1237	0.3406
Res,Colle	-0.062	0.24	0.034	0.1385	0.4262	-0.044	0.034	0.2959	0.052	0.1427	0.196
Bhowevi	-0.144433	0.0094	0.24	0.1085	0.2951	-0.1026	0.24	0.0984	-0.041	0.0186	0.766

Table 9-2 Correlations between the frequent teaching method of science and the frequent teaching method of scientific enquiry (Kor)

Q9Q13Kor	Talking	Note takinc	Dis-Argu	Roleplay	Res,Colle	Demo	Experiment	investigatic	Worksheet	Video	Field trip
Gpupils	**-0.1443**	**0.017907**	**0.3074**	**0.0077**	**0.1899**	**-0.009**	**-0.0266**	**-0.0088**	**0.1273**	**0.0899**	**0.0934**
Mpredictior	0.095	-0.0172	0.213	0.1324	0.2516	0.042	0.0495	0.0227	0.1857	0.07	0.0241
Texplicitly	-0.061	0.0236	0.3342	0.1565	0.424	0.0198	0.057	0.1169	0.2087	0.1226	0.2335
Pgraph	-0.038	-0.0202	0.254	0.2542	0.3664	0.1382	0.2381	0.2202	0.0134	0.1799	0.0188
Pconclus	-0.047	0.006758	0.1221	0.1411	0.2277	-0.033	0.06	0.177	0.1075	0.1832	0.06
Popport	-0.05	0.003831	0.177	0.3347	0.206	0.026	0.3378	0.3618	-0.0155	0.0754	0.1557
Bhowevi	0.0378729	-0.016246	0.2363	0.3098	0.2306	0.0490249	0.073	0.0674	0.2619	0.2748	0.1077

13. Sailors used to suffer from an illness called scurvy caused by a poor diet on long journeys.
James Lind was a doctor who tested treatments for scurvy. He predicted that **all acids cure scurvy.**



He gave 6 pairs of sailors with scurvy exactly the same meals but he also gave each pair a different addition to their diet.

pair of sailors	addition to their diet	effect after one week
1	some apple cider	beginning to recover
2	25 drops of very dilute sulphuric acid to gargle with*	still had scurvy
3	2 teaspoons of vinegar	still had scurvy
4	half a pint of sea water*	still had scurvy
5	2 oranges and 1 lemon	recovered
6	herbs and spices and acidified barley water	still had scurvy

(a) Does the evidence in the table support the prediction that all acids cure scurvy?
Tick the correct box.

☐ yes ☐ no

Use the table to explain your answer.

1 mark

____

____

***DANGER! DO NOT TRY THIS.**

(b) (i) Give the **one** factor James Lind **changed** in this experiment.
(This is called the independent variable.)

1 mark

(ii) Give the factor James Lind **examined** in this experiment.
(This is called the dependent variable.)

1 mark

(c) James Lind's evidence suggested that oranges and lemons cured scurvy.

At a later time, other scientists did the following:

- They separated citric acid from the fruit.
- They predicted that citric acid would cure scurvy.
- They tested their prediction by giving pure citric acid as an addition to the diet of sailors with scurvy.
- They found it did **not** cure scurvy.

The scientists had to make a different prediction.

Suggest a new prediction about a cure for scurvy that is consistent with the evidence collected.

1 mark

(d) Explain why it is necessary to investigate the effects of changes in diet over a period of more than one week.

1 mark

maximum 5 marks

Appendix 36 (Chapter 7)

Transcripts from English teachers

and Korean teachers

English transcripts

(Eng-1)

,,,this one is a process of science or scientific investigation question (211005 A)

...given two which seem to be direct questions they can answer straightway whereas given applied ones... no way, we are trying to teach them. (070405 A).

(Eng-2)

....in general they are not very good at that. They look at that and say " Miss, you have never taught us about 'scurvy'..." they get hung up on the unfamiliar and do not understand the interpretation. Though they are getting better at it (070405 A).

We have never had this at KS3. So, a lot of kids are struggling because many teachers won't really be sure what sort of questions are going to be asked. As we see more and more of this type of question, we will be better prepared for the kids. As we are teaching and changing the methods, then kids will get better and better (070405 B).

.....I was looking at English ones. The English ones demand that I would expect to be able to sit down with somebody and enlist it. That they would understand that what this statement means yet if those sat down in front of it without any support or any prompt they would be thrown off the question (070405 C)

Now, as to the way of preparing them for what we have been asked to do for the examination in the new KS3 it is heading toward application one.
These application based questions will become more successful. Actually these application based questions are more valid in scientific terms (070405 J).

(Eng-3)

I would be quite happy to teach TIMSS and to teach graph (Korean ones). I would have thought pupils in higher level would work out and be OK with graph (Korean ones) I go with you... That's application one, I have not been teaching these questions by my self (070405,C)

(Eng-4)

Again its... an awful lot of reading for lower ability children and often the question includes evidence supported prediction. They are not very good at picking the relevant information from the table to see whether or not it supports the prediction (311005, B)

(Eng-5)

Pupils would do better on Korean ones. Less reading... You know what you expect from the questions and they seem to be more straitforward (040705 A)

(Eng-6)

I think you have to assume that they have seen the family tree type diagrams before (Junnam-49-2004). If it is in their cognition level, can they work it out? Can they interpret the diagram? (311005,C)

When you look at this graph, there is too much information. Only the very very bright pupil will be able to pick up anything from that. They don't know where to look. You could train them. ..lots of details. There is a lot to explain to them step by step. (121005,A)

I think they are like KS4 syllabus...(211005,A)

(Eng-7)

It is not like a science subject. It looks like something else: lots of mathematics. My year 9s would not be able to do this because maths is not the strong point for pupils, I think. (311005,C)

The thing with this, as with the other one, if you train people to extract information from graphs, it is not really about science, It's literally maths thing *isn't it? Its not really about science it's just whether they can extract information from a table. It's an interpretation of scientific knowledge- that one's maths. That's pure knowledge* (121005,C)

(Eng-8)

As for incorrect choices; they are easily misleading. These seem to ask for English rather than scientific understanding although it is also demanding a high level of understanding about scientific knowledge (040705,J)

Language in the Korean one is difficult. Imagine my year 9 bottom set coming across each of them (121005,C).

...yes I think it requires a high level of reading on that one(311005B)

(Eng-9)

One problem is, it is difficult to assess how many would get the right answer because it's a multiple choice question so there ought to be some who don't know the answer and they are just lucky (040705,J).

... If you are using multiple choice in a right way, maybe you want to try to show if you looking for proving what you want to prove in the content is design to do is right.... Open questions with multiple-choice.. I think, it would never gonna work out because 20 kids would have 20 different answers... Multiple choice in scientific investigative science... it would never gona work (040705,J).

(Eng-10)

.... Somewhere between the twos (040705,A)

They can cope with it. It's not something that is highly complicated. This is the kind of format I would use because they are so used to seeing things pictorially. I quite like that one (121005,B)

A is primary school science. When a pupil is in primary school, they would do this kind of simple, puzzle like questions (121005,A)

You can use common sense- like a puzzle. It is also a multiple-choice question (211005,P)

(Eng-11)

I think, if Korean pupils learn KS3 scientific enquiry questions straightway, then they can use the TIMSS questions as a bridge because it would be hard to jump from content based to application based. (211005,P)

(Eng-12)

If it is a new syllabus talking about dominant characteristics then teach pupils about dominant characteristics, which allow them to answer this. I think you need a combination of content and investigative skills. If they don't know about the process of scientific enquiry, they will find it difficult. So it would be the right approach to this one. I think sort of somewhere between the two (040705,A)

...although they are not talking about what are controlling variables. They are asking about those. Pupils found it difficult to think about variables(0407,E).

(Eng-13)

I think our top set would probably ... in a couple of months time would know what a dependent variable and independent variable is... My top set would not have a problem with this...(301095, A)

They found difficulties to think about variables... My higher level would be able to look at it. ...(040705, E)

These KS3 questions are quite early one. Two years ago? We would have never the same at KS3. So there is a lot of pupils are struggle because many teachers won't really sure what sort of questions gonna be asked. As we see more and more this type of questions, we would be better prepared for pupils. (040705,J)

Content based has to be 'yes' or 'no' answers to fill in. When you left, it is not being clear, right or wrong answer. We havn't been taught them actually. Language is there pupils find difficulty (040705,A)

The new KS3 is heading for application based ones. Actually these application based questions are more valid on scientific term. As we see more and more of these types of questions, we would be better prepared for pupils. As we are teaching and changing the methods, then pupils will be better. (040705,J).

We used to teach like this (Korean HE questions). But we have now changed our mode of work toward this (English KS3 questions). Now we teach more of this type (211005,A)

Yes, we used to teach science knowledge but now we do more process and enquiry (211005,H).

(Eng-14)

I think my year 9 would be good at TIMSS. In terms of Korean ones, my higher level would be able to look at the graph and interpret it. My higher level will be better on the multiple choice one than English KS questions. (040705,M)

A lot of it is KS4. These are the things that are generally taught at KS4 things like natural selection, mutation, isolation theory,,,, I mean these are even beyond KS4.,, so No,,,, I don't think my year 9 would be able to assess the question.(311005,A).

(Eng-15)

The Korean question is quite difficult. Even the able children would not be able to solve it. (121005,B)

Sadly, I don't think anyone would get that right (121005,C)

....because they've not been presented with this, I don't think my year 9s would do well on this at all (311005)

I would have thought they (the higher level pupils) would work it out and be OK with the graph. ..... exactly 4, 5 level(121005,A)

In terms of the Korean questions, my higher level pupils would be able to look at the graph and interpret and pick it out from the multiple choice. Although my *lower level would have difficulty in interpreting it, my higher level would do better on the multiple choice one than on the KS3 questions (040705,E)*

I think, TIMSS questions are easiest, then the Korean ones are easier than KS3 questions because KS3 questions have more words and application based. The Korean ones have multiple choice (211005,C)

(Eng-16)

.... TIMSS one, probably 60-70% of pupils would get right...(121005, B)

I think even the lower set would get a fair chance... planning etc...(121005,B)
I think C would be the easiest one for them because they are familiar with that kind of question (121005,C)

I think my year 9 would be good at TIMSS. I think they are quite straightforward. You can see what they are getting at, actually they are not talking about what are controlling variables. They found it difficult to think about variables (040705,E).

(Eng-17)

I was looking at the English one. The English ones demand the sort of question that I would expect to be able to sit down with somebody and go over it. So, they would understand what this statement means yet if they sat down in front of it without any support or any prompt they would be thrown off by the question and by the language (040704,C).

....there(Scurvy) is quite a lot in this question isn't there? 25 drops... 2 spoons... all sort of extraneous complications. There are higher level pupils who would be able to think that through. But what I found is really clear to them others really would not be able to do them. I mark down which questions and deduct marks they might not get there. There is a line, which you can go below certain steps. Then they would virtually get no marks. Because one, it's too much to read and two, it's a completely alien concept to them, such as 'scurvy' (040705A)

(Eng-18)

I would have thought they (the higher level pupils) would work it out and be OK with the graph. ..... exactly 4, 5 level(121005,A)

In this country, if you look at the syllabus, for example get a graph with something that is pushing the limit of what is reasonable for a year 9 and it has got sodium nitrate, potassium nitrate... The staff tend to go back to the syllabus and say ' hang on', ' it doesn't say anything about comparative solubility between this, this and this. ' Why are we asked a question like this?' Whereas pushing your luck a little bit with kids. That's what you've got to do. That's the content. But when it could have been anything than I than I think, that is pushing your luck at KS3. you are asked for kids to recall (040705, J)

I think they really would not know how to handle the Korean question. The government wants level 5 in KS3. Drawing graph is level 6. Interpreting graph is not strong point for most pupils. It is kind of maths(121005 B)

(Eng-19)

..These KS3 questions are quite early one. Two years ago? I think C because this is still new. We have to take step away from traditional experiments and put away. And take something that may be a bit odd like the 'rose'. It is not... kids would have never done before. We would have never the same at KS3 (070405,A)

I think C(the English questions) because this is still new. We have to take step away from traditional experiments and put away. And take something that may be a bit odd like the 'rose'. It is not... kids would have never done before. We may have to teach more critical thinking...(211005,P)

I think B, Korean one because we are now teaching C(English KS3) and A(TIMSS-2003) is similar to C. I go to B because the content is not the same as what we are teaching. It is not only teaching method but also the content (121005,A)

(Eng-20)

We run it by science course. KS3 and 4 and it changed the way we think in terms of making what we do to totally link to what goes on outside the classroom. Everything is now who use this, what that is for what pros and cons what is the ethics for it. I think English ones. If you wanted to develop critical thinking and investigative approach you could use cleverly cited examples like " the plant one" at the front as long as it is well developed. But you can't avoid this kind of questions if you are looking for application. (070405,J)

I quite like the English ones. I am much happier,,,. As far as producing to the thinking scientists, I think they could do best out of the three (040705,A).

(Eng-21)

Korean ones are not really investigative. Whereas for these you have to recognize fair test they have to able to plan fair test I would say probably start off with this one and move on to the plan like they do there (121005,C)

If I take my bottom set would do better in TIMSS because there are less...It is because... more familiar situation for them. There are not huge amount of read and not huge amount of write either (121005, A E)

If I choose which one of these, I would give to my year 9. I definitely choose TIMSS (121005,C).

Yes, I like A too, it is easy to show them. Perhaps low ability would be suitable (121005,E).

(Eng-22)

Pupils are familiar with this type of question because they have been continually taught this way. During lessons, they gradually grasp the meaning of terms. While, they were doing investigations, they were told about the "mark scheme."(211005,P)

I think we have to teach Sc1. Especially since year 7 gets the pupils prepared to put their own ideas forward for prediction and to be prepared to write about strange situations and about things, which they may never have heard of. That *is a way of encouraging pupils to do that sort of thing. We have to take a step away from traditional experiments and take something that may be a bit odd like the 'rose'. It is not something... pupils would never have done before (040705,A)*

The National Science Curriculum has changed since 2001. Now pupils already know about "fair test" things when they are in year 7. In the past, we used to teach those things in year 7. Also we teach them differently from how we used to. We follow National Strategy closely. We have also got "Booster kit" lessons and make sure if pupils know all about SC1 content. In particular, we run special classes during Easter for SC1 content (211005,A).

Apparently, the way of teaching has changed. We used to teach science knowledge but now we do more about process and enquiry (211005,H)

... yes, things have changed. We used to teach graph like the Korean question style. Now, we follow National Strategy. We used to teach knowledge, facts and details. I think the new strategy has been for the past 3-4 years time (211005,A)

(Eng-23)

We can use plates/sheets to start off with.... What you change, what you don't change, fair test and you have to say 'no, you've got to work out what you have to change' then explain. They have to reason how they are going to change one thing and how they are going to do that: making them make a choice (121005A).

We can use pictorial things. Dictate them. Put them up on the board..... contributing an idea, sharing ideas. Build up from yr7 really, doing any type of investigation. Talking through things, sorting out what we are trying to find out, what we are changing, gradually building up... process starting at yr 7, as a routine. What are we going to change? And keep the same? You keep doing this all the time until you come to respect the nature so that by the time you get to GCSE practical assessments, they just do it automatically (121005C)

I did the 'Scurvy thing' by making groups with each variable. then which one would be a cure or not(211005,P)

(Eng-24)

... In year 7, 8, 9 nearly all of our lessons have some sort of scientific enquiry content every year towards what 's a fair test, How do you plan properly? How do you consider all the criteria in sc1 or just pushing it again to the whole of year 7, 8 and 9 all the way through. Actually what we are doing is putting into year 9 two years of content based preparation one year of application based preparation, the subsequent year they should if we are doing our job properly, do better and better (040705,J)

Pupils are familiar with this type of question because they have been continually taught this way. During lessons, they gradually grasp the meaning of terms. While, they were doing investigations, they were told about the "mark scheme."(211005,P)

If you look at these investigative questions that they've got to answer it is very easy to train them because they are practical science. These are factors and these are variables. Here is method. Here is data. What they have been asked to do: here one word answers and tell them what they have got to write. So as long as you train them on answering the question, if your are training them with questions that are well put, I think these will give you broader ranged children (040705,A)

(Eng-25)

I found this question on a previous paper and this year, I gave it to my current year 9 to do for the first part of the lesson then at the latter part of the lesson, I did the experiment. It worked well. Then we discussed the work, considering the key points and what the questions were asking for (040705, E)

I did the 'Scurvey thing' by making groups with each variable. Then which one would be a cure one (211005, P)

Pupils are familiar with this type of question because they have been continually taught this way. During lessons, they gradually grasp the meaning of terms.

While they were doing investigations, they were told about the mark scheme (211005, p).

(Eng-26)

Because it's(our teaching) driven by SATs we tend to teach POAE type at the moment because we need to know our facts except that a few weeks prior to the exam we teach terminology and investigation through cases using the case terminology and we do PORE type of thing for GCSE. So we teach planning, obtaining evidence, analyzing and evaluating but we only really pick up on this type of question on POAE but not very well and we pick out this in the revision programme and in practice questions before SATs in April (311005,B)

I think our top set would probably... in a couple of month' s time would know what a dependent and independent variable is...The top set would not have a problem with that (121005,C)

As I said, we used to teach this type. We taught knowledge and explain everything and make them get it right in the multiple choice or simple answer format. We can teach B(Korean questions). It is not impossible but it is going to be a hard job to do (211005, A).

(Eng-27)

I think you have to teach technique...you can incorporate that in your science teaching... so they pick up the skills when necessary. I do some practice questions from past papers. I think to build up over the previous papers. In this type of questions, I would make pupils do lots of practice. So they can see the format used and answering the multiple choice (040705,B)

Probably, I will try to teach my pupils the process of elimination. Trying to figure out which ones don't make sense because I think a lot of these will throw pupils off really quickly. Apart from the very very top set.(040705,E)

It has to be built up because with my year 8s, they can do OK with two lines on a graph but it could mean anything. There has to be training because you have to get analysis where graph work.... So we put lots of work into teaching them *to how to read graphs especially as they do incredibly well on the graph questions but then something else has been lost. There got to be a balance (121005,A).*

...you can put that on to that. You can break this down into that and gradually develop it through. So you can use that idea with the brighter pupils and that for the bottom end (311005, D)

When you look at this graph, there is too much information. Only the very very bright pupil will be able to pick up anything from that. They don't know where to look. You could train them. Lots of details.... There is a lot to explain to them step by step (211005, C),

As I said, we used to teach this type. We taught knowledge and explain everything and make them get it right in the multiple-choice or simple answer format. We can teach B(Korean questions). It is not impossible, but it is going to be a hard job (211005, A)

It is almost KS4 questions, which I think these are too difficult for my pupils. Then they are more likely make children recall (121005, B).

...it's a complete change to what we teach and work they'd find really hard. You need to work on the graphs and gradually overlay one on the other. A mix of practical and graphs (121005,D)

When you look at this graph, there is too much information. Only the very very bright pupil will be able to pick up anything from that. They don't know where to look. You could train them. Lots of details. There is a lot to explain to them step by step (211005, C),

(Eng-28)

...this(TIMSS-2003) one is quite straight forward you just give them PACE(311005, A).

I think the way we teach now instead of teaching PACE we prepare for this type of questions even for the younger (311005, B)

It looks like a primary science. Puzzle stuff... It will be a similar way to teach KS3 questions (311005, P).

(Eng-29)

Those (English questions) are process based. I think, we have to teach sc1. Especially, year 7 pupils need to be prepared to write about strange situation and about things, which they may never have heard of. That is a way encouraging pupils to do that sort of thing. We have to step away from traditional experiments... And take something that may be a bit odd like the' rose'. It is not... pupils would have never done (040705, A).

Korean transcripts

(Kor-1)

It looks like a question demanding understanding of a process of enquiry or scientific investigation rather than its result or conclusion. These kinds of questions are being dealt with at Year 10 Curriculum. (160705 C).

...it is scientific investigation question,,, process of science (130805 M)

(Kor-2)

The questions from English KS3 tests look like 'reasoning' or 'open-investigative projects done at primary school although it is here at a higher level. If we train primary pupils do this type of question, they would soon be able to solve them. I don't understand why we have this content- based curriculum at middle school level... Definitely I think, our curriculum is inconsistent in this sense (130805,K and A).

These questions are scientific investigative questions involving a degree of common sense (190705,A)

(Kor-3)

Although our pupils understand the terms such as variables, they would experience difficulty in the process of problem solving and the process of enquiry because our kids do not have much investigative work. Pupils would have difficulty in planning, carrying out and drawing conclusions by themselves. I think, examinations tend to assess pupils' ability in interpreting data. Rather than assessing a comprehensive range of enquiry ability..
(130805, K)

Although our pupils are good at interpreting graphs because we do a lot, they may not be able to create graphs from the tables.
(130805, M)

The pupils are used to solving multiple choice format questions. They are familiar with interpreting data or solving problems with similar content and *context like this (Korean ones) (190705,A)*

(Kor-4)

I also think, teachers would have difficulty in assessing answers to the questions because they do not have one right answer like the Korean ones (160705,K).

I think, if a new type of questions is given such as the English questions, then teachers would take some time to work them out before they integrate them in teaching and assessing... I think teachers would feel it difficulty to assess open-ended questions...(130805 M).

(Kor-5)

Although the questions are quite difficult for pupils, they are getting used to the process of solving problems (190705,B).

Korean questions have lots of mathematical content. Some demand the process of science but more of them demand solving problems mathematically (160705,A)

Pupils cannot get right answers unless they have known all of the content in a question including answers 1-5. Kids have to have enquiry ability, problems solving ability and mathematical ability. Then they keep practising the problem solving process in order to familiarise themselves with how to answer those questions (160705,B).

(Kor-6)

The Korean ones are not different from what we learnt in our schooling (190705,C)

They are also familiar to our kids and us (190705,C)

The Korean ones are mainly in the area of data interpretation rather than in planning or carrying out the process...(130805, K)

(Kor-7)

TIMSS-2003 question is familiar with pupils because of multiple-choice format. And these are being taught in primary science.
Thus, it would not be difficult to solve them (190705 C)

I think, the TIMSS-question is not unfamiliar with children because they have been taught by doing 'open-class' which have no right-wrong answers with various problem solving activities. Then the secondary school curriculum in Korea holds traditional content and seems to go backward from primary science to the traditional content curriculum (130805,A)

(Kor-8)

I think, it would be good idea to start with TIMSS-2003 questions if we have to teach this type of questions (English ones) It is easy to apply in the classroom. If the questions are too difficult, it would take too much time to work out for teachers themselves....(130805,K)

(Kor-9)

These questions are scientific investigative questions involving a degree of common sense (190705,A)

These questions would be useful in applying the 7th National Curriculum in the classroom They are simple and easy but they contain the core of scientific enquiry while pupils do scientific investigations or practical work (160705,K)

(Kor-10)

Questions from TIMSS-2003 and Korean HE are assessed within what kids have already been taught. Thus, kids would get the right answer 60% in TIMSS-2003 and 30-40% in questions from Korean HE. By contrast, questions from English KS3 seem easy but they are not from within the curriculum content. Thus, pupils would not get the right answer (160705,A)

Most of pupils would be able to do in TIMSS-2003. 10-15 out of a class of 40 would get the right answers to the Korean HE questions. But I do not know *how pupils would manage with KS3 questions without any experience. Pupils don't like reading and thinking...(160705,A)*

Questions from KS3 tests demand pupils' ability of enquiry. But my low ability pupils... and even the majority of my pupils would not even know how to even start to solve them...Perhaps, bright or gifted children would try them (160705,C)

(Kor-11)

I think, these questions need to do lots of practical work or investigations. But we don't do much practical work... Mostly, pupils do experimentations to confirm what they have learnt rather than planning or carrying out investigations to find out a new thing. We normally do open investigation once a year. (160704,K)

If we give them some time to think or read the context, the class would be messed up... pupils don't like to think and read... to be honest. Therefore, we tend to avoid giving time to pupils... because we don't want to disturb other class...Consequently, pupils are not familiar in asking how and why,(160705. A)

Pupils are used to do multiple-choice format choosing one out of 4 or 5 examples. Although they understand science knowledge with the multiple-choice format, they may not do well in the question, which demands explanations with the same science knowledge... My pupils would not even try these type of questions 'suggest' or 'explain' or 'why' (130805,M)

(Kor-12)

If we teach the new curriculum (the 7th National Curriculum) properly, those three questions would be able to be dealt with by pupils easily. Through the traditional way, we can train them to solve the questions from Korean HE. Through the enquiry based lessons, we can train them up to solve questions from TIMSS-2003 and English KS3. Once they get used to them, they could work out other similar questions (191705,C)

I think, pupils can work out those questions by training them up easily.

Although kids have not enough experience in open investigative works, they could work out easily as they can solve the Korean questions (160705,A, 190705,C,130805,K)

I think it will take 1 month to train them up to get the right answers (130805,K)

(Kor-13)
I think, if we have to teach the English ones, we have to have sufficient knowledge in order to cope with open answers because the answers can be varied...160705,A)

Assessment would be a crucial matter.. if we teach the KS3 type of questions As the Answers would be varied and in a descriptive form, assessment becomes a real matter to teachers (130805,M)

(Kor-14)
Questions from TIMSS-2003 and Korean HE are assessed within what kids have already been taught. Thus, kids would get the right answer 60% in TIMSS-2003 and 30-40% in questions from Korean HE. By contrast, questions from English KS3 seem easy but they are not from within the curriculum content. pupils would not get the right answer (160705,A)

Most pupils would be able to do in TIMSS-2003. 10-15 out of a class of 40 would get the right answers to the Korean HE questions. But I do not know how kids would manage with KS3 questions without any experience. Kids don't like reading and thinking...(130805, K)

(Kor-15)
As teachers, we cannot separate science lessons in the classroom from assessment. We have typical Korean style questions as we know. We are under pressure to train pupils up to familiarise themselves with the questions. Even though the English questions seems good to enhance scientific enquiry ability and to be consistent with primary science, we cannot teach this way because the examinations demand content knowledge rather than process or method of science such as control variables...(130805, M)

(Kor-16)

I think it is nonsense because the new curriculum recommends us to teach scientific enquiry with more or less similar content in which we were taught in our schooling. The worst thing is the assessment. The examinations are assessed on content knowledge not on the process or the scientific enquiry (130805,A).

Although we all acknowledge that school science should give children various experiences, under assessment driven school curriculum, the focus becomes change (130805 K)

(Kor-17)

A teacher who is not good at teaching may be acceptable but the teacher who fails to assess kids properly such as making a mistake in marking is not acceptable amongst Korean parents and pupils. If I assess the work of scientific investigation and I give 10 marks to one child, 9 marks to another child because he missed one thing out in the process, then the 9 marks child complains about it and I have to explain all about the assessment process. Some of the pupils and parents will not accept what I did. So, I would rather avoid those disputes. To be truthful, we are so used to assessing the knowledge in science because right and wrong answers are without any dispute (130805,M).

(Kor-18)

We have to give lessons, guide pupils extra-curricula activities, to do other paper works and do counselling ... so many things to do ...this kind of questions demands doing more open-investigations... We may have to do feedback after the investigation... it is all about time matter (160705,K).

(Kor-19)

I find difficulty in teaching terms and concepts in science. For example, pupils find it difficult to grasp the meaning of the terms solubility, amount of crystallising, saturated solution and unsaturated solution because pupils have never seen those solutions such as KCl, NaNO3 or KNO3. If I tell them NaCl is Salt, pupils would be surprised. I think the ways we teach lack real sense (160705, C).

(Kor-20)

Not Korean questions... because now we are teaching this way...
I guess TIMSS-2003 and English KS3 tests look a similar type. TIMSS-2003 questions regard as primary science whereas questions from KS3 tests as high school science. Thus, I would say questions from KS3 tests (130805,K)

(Kor-21)

Scientific enquiry does not mean doing practical work. We can encourage pupils to think and stimulate discussions. I also do not think scientific enquiry is everything in science education (130805,M)

Often I feel I have wasted a lesson. I teach one thing with practical work in a lesson expecting kids would understand better. However, I find I have to explain again and again after practical work. Kids tend to remember more as I explain after doing practical work (160705,A).

Pupils are not interested in the aims of practical work. They tend to look at the process and keep asking what the next step is. Only about 25-30% kids pay attention about what they are doing (160705,M)

I encourage pupils to think as a way to apply enquiry based teaching in the classroom. I tell them about the life of famous scientists, interesting apparatus and some history of science which is not found in the textbook in order for pupils to reduce their fear about content outside the National Curriculum (130805,M)

(Kor-22)

I don't agree that the National Curriculum content should be reduced and made easier. In the 7th National Curriculum, some difficult content has gone from the examination papers and the content was reduced considerably. I see the National Curriculum content is limited covering natural phenomena. Nevertheless, I don't think kids' achievement has improved. As the curriculum content level is lowered, pupils' achievements become lowered accordingly. I prefer the previous National Curriculum because pupils were working harder because they had to work out the higher level content (160705,K).

(Kor-23)

I agree that our HE questions concentrate on the area of data interpretations... The questions should be varied in order to assess pupils' various ability... Our test papers tend to be knowledge based.... (130805,K)

I tell them about the life of famous scientists, interesting apparatus and some history of science which is not found in the textbook in order for pupils to reduce their fear about content outside the National Curriculum (130805,M).

(Kor-24)

I think, these ones need lots of practical work or investigations. But we don't do much practical work... Mostly, pupils do experimentations to confirm what they have learnt rather than planning or carrying out investigations to find something new. We normally do open investigation once a year. (160704,K)

(Kor-25)

I explain to pupils the aims, processes and results of an experiment because we don't have enough time .... So pupils expect what would happen as a result. If the results are not the same as in the textbook, pupils would be confused.... As a result of this, I am concerned about the conditions for doing experimentation in order that the results will conform to the results in the textbook. Although I tell pupils not to worry about different results from those in the textbook, they stick to the results in the textbooks (160705,K)

(Kor-26)

I think, we have not enough time to apply various methods even in the 7the national curriculum (130805,M)

I wish I could give pupils enough time to plan and carry out investigations so that pupils could carry out an investigation on their own if only we could have enough time and smaller class sizes (160705,A)

(Kor-27)

Pupils are not interested in the aims of practical work. They tend to look at the process and keep asking what the next step is. Only about 25-30% pupils pay attention to know what they are doing (160705,M)

I encourage pupils to think as a way to apply enquiry based teaching in the classroom. I tell them about the bibliography of famous scientists, interesting apparatus and history of science which are not being found in the textbooks in order for pupils to reduce their fear in the content without the National Curriculum (130805,M)

Often I feel I have wasted my lesson. I teach one thing with practical work with one lesson expecting pupils would understand better. However, I find I have to explain again and again after practical work. Kids tend to remember more as I explain after doing practical work (160705,A).

Scientific enquiry does not mean doing practical work. We can encourage pupils to think and stimulate discussions. I also do not think scientific enquiry is everything in science education (130805,M)

In order to teach Korean questions, teachers need to focus on pupils' understanding science concepts and principles, so called ' academic basis' Unless children don't understand one of questions, then they could not get secure their marks. I think, this would be an advantage to foster pupils to be able to apply what they have learnt to other things(190705,B).

(Kor-28)

I don't agree that the national curriculum content should be reduced and the easier content mode. In the 7th national curriculum, some difficult content has gone in the examination papers and the content was reduced considerably. I see the National content is limited within natural phenomena. Nevertheless, I don't think pupils' achievement has improved. As the curriculum content level is lowered, pupils' achievements become lowered accordingly. I prefer the previous national curriculum because kids were working harder because kids had to work out the higher level content (160705,K).

I think, we have a problem in the national curriculum content because the content is the same as we used to be taught while we were secondary school. Then, the curriculum requires learning scientific enquiry rather than science knowledge. I really don't think, it is going to work out. (130805, A) another problem in the national curriculum is that the content reduction brings fragmented and disintegrated textbook structure. Simple curriculum reduction makes school science bits and pieces. (130805, A)

(Kor-29)

I would explain the terms such as solubility, mixture, saturated solution and so on. Then, I would explain all the details. Then I demonstrate how to solve problems and show the process of solving problems including mathematical processes if necessary. Then, pupils would get familiarized what they have learnt through example questions (160705, A)

I don't think pupils would understand fully some of the assessment content. As we understand certain content with limited comprehension when we were in middle schools, pupils would understand partially and practice the ways in which the problems can be solved. As they move on to high schools, they could understand more about it (160705,C)

I believe that 30% of able pupils can understand the Korean questions. Even if teachers do repetitive training for the context, it would be difficult to get answers right over 50% of pupils. In particular, the amount of crystallized solution would be the most difficult one (160705, K, 160705, B).

(Kor-30)

... the questions from the English KS3 tests and TIMSS-2003 look similar types of questions because they demand knowing control variables....although TIMSS-2003 questions are lower level ... (190705,C)

(Kor-31)

I think, pupils can work out those questions by training them up easily.
Although kids have not enough experience in open investigative works, they could work out easily as they can solve the Korean questions. I would explain terms such as variables and science concepts. Then, I would give pupils to

carry out investigation... Then, get them practice papers to familiarise the pattern.(160705,A, 190705,C,130805,K)

I think it will take 1 month to train them up to get the right answers (130805,K)

There would be two ways to prepare for pupils to get answers the questions. If I have enough time, I would explain terms and principles. Then make pupils to do open investigation doing hypothesising, planning, carrying out experiments and analysis of the results. When pupils get the experiment wrong, I would make them do it again until they are happy about the results. It would be a good way to foster pupils' scientific enquiry ability. If I don't have enough time, I would explain the terms: independent variables and dependent variables. Then I would demonstrate examples and make them more familiar with similar patterns of questions of investigations (160705,C).

Korean questions are found all within the national curriculum. Thus, we train children how to get the results rather than the process. I think, as a teacher, teaching the English curriculum would be easier and child-centred (190705, C)

(Kor-32)

I think, English questions demands high literacy skills which take time to get them and time to plan which would not easily be built up but built up by carrying out investigations (130805,M).