Science and Mathematics Education Centre

Inquiry-Based Strategies: An Investigation into the Extent to which they are Indicated and Employed in the Teaching of Contemporary Science Syllabuses.

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ABSTRACT

The science education literature was examined in order to identify the methodologies that various authors considered to characterise inquiry teaching. On the basis of this examination, a new classroom environment instrument, the *Is This an Inquiring Classroom* or ITIC was developed. The final version of the ITIC contained forty items in five different scales, Freedom in Practical Work, Communication, Interpretation of Data, Science Stories and Uncertainty in Science.

The Actual and Preferred Forms of the ITIC were administered to 2,207 Grade 7-12 students and 65 teachers from 15 different schools. The results of this investigation showed that both students and teachers would prefer there to be higher levels of inquiry behaviours in Tasmanian science classrooms, with teachers indicating a preference for significantly higher levels than students. The perceptions of different sub-groups within the student population were also analysed.

An examination of the Tasmanian curriculum documents showed that they supported the use of inquiry teaching methodologies, as defined by the ITIC scales.

From the above investigations it was concluded that it would be desirable for there to be higher levels of inquiry methodologies in Tasmanian science classes, and that the production of the ITIC provides a means of monitoring and measuring any change.

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1.1 THESIS OVERVIEW

1.1.1 Introduction

In the world of science education, the concept of inquiry as a teaching pedagogy is one which has continued to recur in the literature, weathering peaks and troughs in popularity, but never completely disappearing. As Ronald Anderson (n.d.) from the University of Chicago, wrote,

> Inquiry is a word with a long-standing place of honor in science education circles . . . It is the favored word for describing the essence of good science teaching . . . (Anderson, n.d., ¶ 1).

Specific details of what the literature reveals about inquiry in science teaching will be considered in Chapters 2 and 3 of this thesis. However, at this juncture it seems fair to comment that the heyday of inquiry in science teaching is generally regarded as having been during the 1960s and 1970s. In this era inquiry was widely advocated in courses such as BSCS (Biological Sciences Curriculum Study) Biology, Harvard Project Physics, PSSC (Physical Science Study Curriculum) Physics and CHEMstudy Chemistry. What is interesting is that many of the ideas from these courses seem to have lingered after the term inquiry ceased to be a catchcry of science education. This appears to indicate that there is something about inquiry teaching that is important to the study of science - perhaps it captures something of the essence of science?

This latter precept would seem to be supported by the fact that the concept of inquiry as a desirable science teaching pedagogy has undergone something of a renaissance in recent years. This is particularly evident in the literature that has come from the USA since that country's development and adoption of the *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) More locally, in the Tasmanian context in Australia, there has also been a reemphasis on the use of inquiry teaching pedagogies with the implementation of the new curriculum documents *Essential Learnings Framework 1* and *Essential*

Learnings Framework 2 (Tasmania, Department of Education, 2002, 2003) in all government and many non-government schools. These documents have an emphasis on inquiry which is not confined to the Science curriculum area.

A question which arises, however, is as to whether teachers have ever really come to grips with the use of inquiry teaching strategies on a large scale. If several editorials in relatively recent science teacher journals are anything to judge by, then they have not. In an editorial piece in *The Science Teacher* Gerking (2003) recounted her experiences at recent NSTA (National Science Teachers Association) conventions in the USA where she found that in session after session secondary teachers expressed an interest in becoming inquiry based educators, but also said that they did not have a clear understanding of inquiry. In a guest editorial for *The American Biology Teacher* Leonard and Chandler (2003), elaborated on their starting premise that most popular middle and high school biology curricula contain precious few opportunities to inquire, and went on to detail why they saw this as a potential problem for students. In a similar vein, Bybee (2000) expressed the opinion that science teaching was not then, and never had been, in any significant way, centred in inquiry, regardless of whether inquiry was seen as content or technique. He went on to state that although science educators continue to chant the inquiry mantra, science classrooms have not been transformed by the incantations.

How can the extent to which individual teachers use inquiry strategies in their own classrooms be measured? This research study set out to provide a means of at least partially answering this question, and also considered, perhaps more importantly, whether, given the prevailing educational theories and science curricula, the use of such techniques is appropriate in today's classrooms. Special reference is made to the Tasmanian context in Australia.

The overall aim of this study was to more fully inform science teachers about inquiry as a teaching pedagogy, and about teacher and student attitudes toward inquiry, thus enabling teachers to decide if inquiry is a teaching strategy they should employ to improve the learning outcomes of their students. Whilst the study is directed primarily at the Science curriculum area, conclusions from it may, in fact, be more far reaching.

1.1.2 A Note on the Terms Inquiry and Enquiry

Given the variation that occurs in the literature, and also the argument that is sometimes engendered when the terms are under discussion, a comment on the use of the terms inquiry and enquiry is warranted - so as not to antagonise any readers who believe that they are encountering the terms being used incorrectly or inconsistently! To those of us who have held the view that one is a noun and the other a verb, it comes as something of a revelation to learn that the two are in fact merely interchangeable. Consulting a dictionary (eg *Chambers English Dictionary,* Landau & Ramson, 1988), under ‘enquire’ seems to generally bring about a redirection to ‘inquire’. Partridge (1973) in his book *Usage and Abusage,* explained that en- was originally a French prefix corresponding to the Latin in-. He was of the opinion that inquire and inquiry were etymologically preferable. As ‘inquiry’ seems to be the term most prevalent in the literature, it is the one which will be adopted from here on, although, it should be noted that several significant authors, such as Schwab, have used the term ‘enquiry’, and so when reference is made to their work this form may be used. It is hoped that readers will forgive any lapses which occur - it was not felt necessary to adopt the style of Duschl (1986), who asterisks every usage of the ‘enquiry’ form.

In relation to Schwab's favoured usage of the enquiry form, Westbury and Wilkof (1978) noted that when asked about this Schwab gave as his reason for adopting it the fact that in the years centring on 1958 some educational psychologists used the term inquiry to describe the strategies that children used in solving problems. He wished to ensure that he would not be mistaken for one of these psychologists and therefore took to spelling inquiry with an *e*. Some editors were accepting of this, others not.

1.2 FACTORS INFLUENCING THE RESEARCHER'S PERSPECTIVE

1.2.1 Experiences as a Student

My own interest in inquiry as a science teaching pedagogy began as a Grade 11/12 student in the mid 1970s when I first encountered the idea of open book examinations, whilst studying BSCS Biology and CHEMstudy Chemistry courses at a Tasmanian matriculation college (as the schools that are now known in this state of Australia as senior secondary colleges were then termed). To a student who had come through a traditional high school science teaching program with tests that primarily required the memorisation of large amounts of facts there was something very attractive about the idea of exams where students were free to use textbooks in answering the set questions.

This matriculation experience contrasted sharply with that encountered during the various university courses undertaken as part of a Bachelor of Science degree. To students who had experienced open book examinations and related teaching practices, and were headed toward a career in education (Science and Mathematics teaching in particular) there seemed to be something a little outmoded and inefficient in having to memorise pages of facts in order to meet the requirements of a course. All the information that students were being asked to reproduce in an exam situation was readily available in books, so what was the point of it being in their heads as well? Wouldn't it be more efficient for students to spend their time learning how to source and apply information rather than just committing copious amounts of it to memory - often only to stay there for the duration of the relevant examination or shortly thereafter? It also seemed that achieving high examination results was more an indication of short term memory skills rather than any deep understanding of the underlying concepts and subject matter. As a student it was difficult to understand why the university did not adopt the more ‘enlightened’ educational approach that the matriculation colleges had toward at least some science subjects. In retrospect, with the wisdom of years and personal experience of the personnel, budgetary and other difficulties involved in implementing any change process, the position of universities is much easier to understand.

However, ongoing doubts linger even today. Given the ready access to information provided by the Internet and other electronic communications in the twenty first century, shouldn't teachers be providing students with the skills that allow them to acquire, critique and interpret information and data, rather than only asking them to demonstrate their knowledge by answering recall type questions?

1.2.2 Experiences as a Grade 11/12 Biology and Mathematics Teacher

Returning to the matriculation college environment in the mid 1980s, as a Biology and Mathematics teacher, I found that open book examinations and an inquiry approach (at least in name) were still the hallmarks of Biology teaching. As a teacher, there was a marked contrast in preparing students for pretertiary (accepted by universities for matriculation purposes) Mathematics and Biology HSC (Higher School Certificate) examinations as set by the then Schools Board of Tasmania. The Biology examinations required students to have an understanding of underlying themes and concepts. It was necessary for them to be able to *interpret* a question, and identify the relevant concepts, before they could begin to answer it. Mathematics examinations of that era, on the other hand, included a number of theory questions, allowing students to simply memorise a standard answer and then rewrite it under examination conditions (provided of course that their short term memory was good enough).

Within colleges a friendly rivalry frequently existed between the Biology teachers and their Chemistry/Physics counterparts, with the Chemistry/Physics group maintaining that Biology was an easy subject and that their own subjects contained the true science. However, conversations with students did not indicate that even more able students saw this as being the case. Students found the Biology examinations to be at least as challenging as those in the physical sciences area. It would probably be true to say that the subject matter of Biology was more readily accessible to a larger student cohort (in terms of academic ability), than was the subject matter of Chemistry or Physics but students of lesser academic ability frequently could not deal with the nature of questions asked in Biology examinations, as these questions frequently emphasised interpretation rather than factual recall of information. While being able to take textbooks into examinations provided students with a metaphorical crutch, the instruction given to them by teachers was that if they were to be successful in their examination endeavours they should rarely have to open their books in order to answer examination questions. (Around this time Chemistry also had open book examinations, but the type of questions contained in these examinations did not reflect the same interpretative approach that was required in Biology examinations).

1.2.3 Biology - Open or Closed Book Exams?

A downside that emerged to the open book nature of the Biology syllabus examinations was that some teachers felt that the syllabus did not spell out precisely enough what it was that they had to teach students. Biology syllabuses with an inquiry type intent have existed in various iterations in the Tasmanian situation, but during the early 1990s syllabus documents began to no longer specify a particular textbook, but rather gave individual schools/teachers the freedom to choose for themselves the text that they felt most suited the needs of them and their students. It was particularly around this juncture that some teachers seemed to become a little uncomfortable with the requirements of preparing students for the open book Biology examinations.

The movement of more new teachers into what had tended to be a fairly stable teaching cohort, and the increasing importance of examination scores as university entrance became more competitive, may also have been important factors contributing to this feeling amongst some teachers. While the exact influence of each of these potential factors is unlikely to ever be known, the end effect was that the Grade 11/12 Biology syllabus which at one stage had been the most open and flexible of the Grade 11/12 science syllabuses (with the stated intent of allowing schools to adopt a teaching focus that most suited their students - whether it be marine, human, general or other) became the syllabus which seemed to most rigidly define what students should and should not be taught. Despite this, the basic nature of the Biology examination did not really change - up to the current day the intent remains that students be required to have a deep understanding and be able to apply their knowledge.

As a proponent of open book examinations and related teaching methodologies, it was interesting - and at times indeed rather frustrating - for me to participate in numerous Biology subject meetings and workshops where some teachers proposed that Biology examinations revert to a closed book format. The main argument in favour of this was that it would then be possible to ask more recall type questions, and teachers would therefore have more idea as to exactly what the examination might contain, and could hence better prepare students for it.

In hindsight, the underlying problems may have originated with some Biology examination questions that could be said to have not been written and critiqued adequately - allowing the setting examiner to stray too far from the intent of the syllabus and requiring an unreasonable level of theoretical knowledge. Alternatively, it may have been a reflection on the changing economical climate in Australia which meant that more and more students were completing Grades 11 and 12, which had not been, and indeed still are not, compulsory years of education in Tasmania (although requiring students to remain at school until age 17 is to be implemented for students entering Grade 7 in 2004). Previously, many of these students would have entered the job market rather than attending a college. Their attendance at colleges frequently meant that students who were less academically inclined than had previously been the norm were attempting pretertiary courses. In the end, however, open book examinations prevailed - although whether this was because more teachers saw them as being desirable, or because their proponents were more vocal is perhaps a vexed question - and such examinations are still in use in current Grade 11/12 Biology courses.

Similar arguments occurred in physical sciences subject meetings of that era, although these debates seemed to lack the passion of the Biology discussions.

1.2.4 Refinement of the Research Questions

The various meetings where the pros and cons of open and closed book examinations were argued led to me developing a deeper interest in this area. Were open book exams really a better approach? Given the level of collegial opposition that existed it was not possible to unequivocally hold the opinion that they were.

How could this be tested through research? The question certainly did not lend itself to the traditional scientifically controlled experiment, as there were far too many variables that were difficult to control. In analysing my own motivation more I concluded that my real interest lay in whether or not an inquiry approach (whatever this may actually be) was being used in classrooms, and in whether or not teachers and students valued such an approach. The significant consideration then became not so much whether or not particular subjects had open book exams, but rather whether they adopted the type of pedagogies that such examinations should encourage - namely inquiry ones.

Hence the current research project was born.

1.3 RESEARCH OBJECTIVES

The research outlined here aimed to examine the relevant literature, and from this to:

1. formulate a description of what is meant by inquiry-based teaching and learning, particularly considering the methodologies that would be obvious to observers and participants in an inquiry orientated classroom

2. use the description from Objective 1 to develop an instrument to measure the extent to which teachers and students both perceived and preferred that an inquiry-based approach is (or should) be used

3. determine the validity and reliability of this instrument as a measure of science classroom environment

4. use the instrument that was developed to assess the extent to which inquiry methodologies were being used in Tasmanian high school and senior secondary college science classes - as perceived by both students and teachers

5. compare the extent to which inquiry methodologies were currently being used with the extent to which both students and teachers would prefer that they be used in Tasmanian high schools and senior secondary college science classes

6. analyse Tasmanian high school and senior secondary college curriculum documents in order to ascertain the extent to which they indicated/dictated the use of an inquiry-based approach in presenting science courses. Specifically, two sets of documents were examined, as detailed below.

7. use the results from the instrument that was developed to make a judgement as to whether or not the inquiry teaching and learning that was occurring in Tasmanian high school and college science classrooms was in line, firstly, with the stated intent of the appropriate contemporary syllabus documents, and, secondly, with the beliefs of teachers and the preferences of their students.

Hence, this research investigated the appropriateness of using what have been termed inquiry-based teaching strategies in order to achieve the stated aims of contemporary Tasmanian science syllabus documents. The research findings can be used to make recommendations to science teachers, and to teacher training institutions, about the extent to which they should employ, and instruct about, such teaching strategies in meeting the aims of their courses - with a view to maximizing student learning outcomes.

In the case of Research Objective 6, two sets of documents were examined:

- The Grade 9-12 science TCE syllabuses accredited by the Tasmanian Secondary Assessment Board, TASSAB, (or from 2004 by the Tasmanian Qualifications Authority, TQA) for high school and college pretertiary science classes. For Grades 9 and 10 the syllabus designated as *Science* was examined, whilst for Grades 11/12 the pretertiary syllabuses designated as *Biology*, *Chemistry*, *Physical Sciences*, and *Physics* were examined in the first instance.

- The *Essential Learnings Framework* documents (Tasmania, Department of Education, 2002, 2003) that from 2005 form the basis for curriculum development and teaching for all year groups in Tasmanian government schools up until the end of Grade 10.

The ongoing references to inquiry teaching in the literature, combined with personal experiences, made inquiry in science teaching a topic worthy of this investigation - perhaps, inquiry was a trend which was ahead of its time, or perhaps it should be regarded as a strategy that has outlived its time.

1.4 SIGNIFICANCE OF THIS RESEARCH

In completing this research, a new instrument has been developed which takes into account current trends in learning environment research. The *Is This an Inquiring Classroom?* questionnaire (ITIC) presented has been refined and validated and will now be available to other teachers and researchers to investigate issues such as the following:

- To what extent are inquiry methods being used in classrooms in a particular school, state, country or syllabus? (This could be assessed from teacher and student actual forms of the questionnaire.)
- Do students prefer inquiry-based learning or more traditional forms? (Using student preferred form of questionnaire. This is not to say that student preference should necessarily determine the manner in which they are taught - some students may prefer traditional methods because they find it easier to get high marks under such a system.)

- To what extent do teachers think that they should be using inquiry methods? (Using teacher preferred form of questionnaire.)

- How do the beliefs and perceptions of students and teachers match with the stated intent of their syllabus documents? (The scales included in the questionnaire could be used in analysing curriculum documents.)

- What is the impact on inquiry teaching of curriculum innovations which may occur? (Give questionnaires before and after the innovations.)

- What modifications do teachers need to make in order to achieve their desired classroom environment - with respect to inquiry teaching? (Look at which scales teachers or their students rank their classroom environment low on.)

The above represent important research questions, particularly if teachers and/or schools have tended to disregard inquiry as a teaching strategy appropriate to today's classrooms.

1.5 SCIENCE EDUCATION IN TASMANIA - SOME BACKGROUND

1.5.1 Grades 7-12 Education in Tasmania

Historically, secondary education in Tasmania has been separated to what is termed high school, meaning Grades 7 to 10, and what is termed college, meaning Grades 11 and 12. There are currently eight senior secondary colleges in the state, and these operate independently of any high schools, with separate buildings and their own teaching staff. In some rural areas high schools have Grade 11/12 tops, but it would generally be true to state that more able students, particularly those with university aspirations, are more likely to move away from home so as to attend one of the city based colleges rather than to continue to attend their local high school whilst completing Grades 11 and 12.

At Grade 11/12 level students choose between pretertiary and non-pretertiary subjects. Whilst all pretertiary courses are of a standard that is accepted for university entrance, there is huge variation in the non-pretertiary courses offered, with colleges being free to develop and offer courses that are certificated by the college. The colleges were originally set up as matriculation colleges with the primary function of providing a pathway to university. As employment has become more difficult in Australia attendance at senior secondary colleges has increased, so that a commonly quoted statistic is that only 30% of college students study pretertiary subjects (although the source of this statistic remains elusive).

1.5.2 Grade 7-10 Science Education in Tasmania

In the majority of Tasmanian secondary schools, science has traditionally been compulsory for all students in Grades 7 to 10, with students also having had the option of studying a subject known as Science Extended in either Grade 9 or 10. However, over the last decade this situation has tended to change with a number of high schools making science optional in Grades 9 and 10. Whilst there is a feeling in some quarters that this is, at least in part, a response geared to dealing with a shortage of science teachers there is no actual evidence to support this contention. It is nonetheless an interesting contention, particularly in light of a report by Strauss (2004) that the Californian Curriculum Commission recommended new criteria for K-8 textbooks that allowed for a maximum of 20 to 25 percent of hands-on material - in an attempt to balance the need for a comprehensive science curriculum with the limited science background of many K-8 teachers. Although the commission's recommendation was subsequently vetoed, it seems significant that it was ever made.

Students enter Grade 7 with widely varying experiences as to the quantity and nature of science education which they have encountered during their primary school education. To some extent, they leave Grade 10 with similar wide variations in the science content knowledge they have encountered, but hopefully with a similar grounding in the processes of science.

Grades 7 and 8 syllabuses have always been school based and it has been entirely up to individual schools what they teach in these courses. Grades 9 and 10 syllabuses have traditionally been written, accredited and certificated under the auspices of TASSAB (see Tasmanian Secondary Assessment Board 1998a, 1998b). It should be noted that this situation changed from 2005, with neither TASSAB nor the organisation that replaced it, the Tasmanian Qualifications Authority (TQA) now having any input into Grade 9 and 10 syllabuses. All government school syllabuses, from entry level up to the end of Grade 10 are now determined by schools around the *Essential Learnings Framework* curriculum documents.

1.5.3 Grade 11/12 Science Education in Tasmania

From high school, students can opt to study science subjects at Grade 11 and 12 level. At this level, science tends to be taught as separate disciplines, rather than as a general course, particularly in the case of students who are studying at a pretertiary level. The science subjects offered at pretertiary level have been Biology, Chemistry, Environmental Science, Physical Sciences and Physics. From 2004 a new pretertiary subject, titled *Science of Natural Resource*s also become available to Grade 11/12 students. Tasmanian students have the option of studying pretertiary subjects in Grade 11 or Grade 12 or both. Except for Chemistry and Physics, which have Physical Science as a prerequisite, students who have achieved appropriate top level results in Grade 10 are free to attempt pretertiary science subjects in Grade 11 - although, for reasons that probably relate largely to retention of students into Grade 12, restrictions do apply as to how many Grade 11 results will be used in calculating a student’s tertiary entrance (TE) score.

In the current research Grade 7 to 10 Science and pretertiary Biology, Chemistry, Physical Science and Physics classes were surveyed. Non-pretertiary college courses were not considered as they did not provide as obvious an incremental pathway in terms of content and processes.

1.5.4 Accreditation of Science Syllabuses in Tasmania

For Grades 9-12, Science syllabuses, together with those for all other subjects, were traditionally written, accredited and certified by a body known as TASSAB (Tasmanian Secondary Assessment Board), formerly the Schools Board of Tasmania. A new body, the TQA, or Tasmanian Qualifications Authority came into existence on 1st January 2004 (Tasmanian Qualifications Authority, 2004a), and took over this role from TASSAB.

From 2005, neither TASSAB, nor its replacement body the TQA, will accredit or certificate Grade 9 and 10 subjects. Whilst this does not impact directly on the current research the processes leading up to, and repercussions of this decision, have impacted on all curriculum areas, including science, in Tasmanian government schools. This is particularly the case as coincident with, and probably acting as a catalyst for, the above change has been the development of a new guiding curriculum intended to cover the years from birth to the end of compulsory schooling (Currently age 16 or completion of Grade 10, but to become age 17). This new curriculum is known as the *Essential Learnings Framework* and will be considered more in later sections of this thesis. The introduction of the *Essential Learnings Framework* and associated documentation, occurred at around the same time as the *Is this an Inquiring Classroom*? Questionnaire (ITIC) had been developed and approval gained for research involving it to be conducted in Tasmanian schools.

As the *Essential Learnings Framework* documents are the new guiding curriculum documents up to Grade 10 across all curriculum areas, it became important that this study consider these documents, in addition to the traditional science syllabus ones.

1.5.5 A Brief Historical Perspective of Science Courses in Tasmania

For many years, Tasmanian science syllabuses gave teachers few instructions with regard to assessment - so long as teachers were able to come up with a final numerical assessment, which was then converted to an award of credit, higher pass, pass, lower pass or fail, and so long as schools did not seem to have an abnormal number of any one of these awards at a particular level of study, the requirement for assessing students had been met. Grade 11/12 pretertiary subjects had a formal examination to provide the external component of their assessment, but teachers were given little guidance as to what should constitute the internal component. They were simply asked to provide a single numerical value as their assessment. At this stage Grade 7-10 course were referred to as School Certificate and Grade 11/12 courses as Higher School Certificate (HSC).

During these years there was, in reality, an emphasis on knowledge-based assessment, in at least the majority of science syllabuses offered. At Grades 11 and 12, in particular, there was a feeling that whilst teachers were expected to provide an internal assessment which could and should incorporate numerous skills, (such as carrying out and writing up practical work, or researching a topic of current scientific interest) they were criticised if there was not a correlation between this internal assessment and their students' performance on the external, often knowledge based, exam. To some extent, fear of this criticism may have been more perceived than real, and a result of correlation coefficients provided on computerised result sheets, but nonetheless it existed.

The advent, in 1992, of the Tasmanian Certificate of Education (TCE) courses which are currently used in Grades 11 and 12, and which were used in Grades 9 and 10 up to the end of 2004, saw a much greater emphasis on process rather than content. (According to Tasmanian Qualifications Authority (2004b) the philosophy of the TCE aimed to promote students power to learn, and ultimately to learn independently of instruction and guidance.) This emphasis was carried through into the assessment of these courses, with criterion based assessment being adopted, and the criteria to be assessed being specified in each syllabus document.

Whilst some teachers were extremely critical of the Grades 9 and 10 TCE science syllabuses on the basis that they incorporated only one knowledge criterion (out of a total of 8 criteria in the syllabuses most recently used for these grades), there was at least general agreement that these TCE syllabuses were successful in making explicit many of those things which teachers had always professed to incorporate as part of good science teaching. Despite the criteria being specified, the nature of both the Grade 9 and 10 Science syllabuses allowed for huge variation in what was taught and how material was presented to students.

The Grade 11/12 science syllabuses incorporated a greater number of knowledge - as opposed to process - criteria than did the Grade 9-10 syllabuses, and thus attracted less criticism in this regard.

1.6 THESIS STRUCTURE

This thesis consists of the following components:

Chapter 1 -	contains background information on how the current research project was developed, along with a brief perspective on science education in Tasmania.
Chapter 2 -	documents the history of inquiry in science curriculum development, including the work of Henry Armstrong in the late 19th Century, that of John Dewey in the early part of the 20th Century, the reform movements of the 1960s, the work of Joseph Schwab, Project 2061 and the development of the National Science Education Standards in the USA.
Chapter 3 -	investigates the nature of inquiry teaching, including what is inquiry, why do proponents consider inquiry to be a desirable strategy, what might inhibit the use of inquiry and the relationship between inquiry teaching and constructivism.
Chapter 4 -	looks at the stages in the development of the preliminary questionnaire including choice of scales, item writing and critiquing, ethical considerations and validation of the questionnaire.
Chapter 5 -	documents the development of the final version of the student *Is this an inquiring classroom?* (ITIC) questionnaire, following analysis of the preliminary data. It includes the considerations and methodology used in developing and administering the final student version.

Chapter 6 - gives details of the data obtained from the ITIC student questionnaire, and the interpretation of this data.

Chapter 7 - documents the development of the teacher version of the *Is this an inquiring classroom?* questionnaire, and includes the interpretation of the teacher questionnaire results.

Chapter 8 - is an analysis of the Tasmanian science curriculum documents in use at the time that the ITIC was administered, carried out in order to determine how the concept of inquiry teaching sits within them.

Chapter 9 - is an analysis of the new Tasmanian Grade 11/12 science syllabus documents, that came into effect following the administration of the ITIC.

Chapter 10 - is an analysis of the new Tasmanian *Essential Learnings* syllabus documents, that came into effect following the administration of the ITIC.

Chapter 11 - Overall discussion of, and concluding comments for, the ITIC research study.

Following Chapter 11 are the References and Appendices. These include the preliminary and final versions of the *Is this an inquiring classroom?* questionnaire (ITIC). For the final version of the questionnaire both student and teacher versions are included.

CHAPTER 2 - HISTORICAL BACKGROUND TO INQUIRY PEDAGOGY IN SCIENCE CURRICULUM DEVELOPMENT

CHAPTER OVERVIEW

This chapter considers the ideas and influence of the major proponents of inquiry teaching in science. Although the true origin of inquiry teaching, or even the origin of the term *heuristic*, must be regarded as being lost in the mists of time the authors who have championed the teaching of science as inquiry can be more easily identified, as can the various educational reports and concerns that have impacted on the use of inquiry pedagogies in science classrooms.

The chapter commences by considering the work of Henry Armstrong in the United Kingdom and John Dewey in the USA, before moving on to look at the various science curriculum reforms of the 1960s, including the influence of Joseph Schwab. Whilst the 1960s are often regarded as having been the heyday of inquiry teaching in science, a search of the literature reveals that inquiry teaching continued to have its proponents through the 1970s and 1980s despite there being debate over its effectiveness. The late 1980s and 1990s saw a renewed call for curriculum reform, with the publication of the Project 2061 reports *Science for all Americans* and *Benchmarks for Scientific Literacy*, followed by the release of the *National Science Education Standards* documents in the USA in 1996. These latter documents promote an inquiry approach to science teaching and have had considerable influence, so that by the early 2000s the term inquiry was extremely common in the titles of many articles published in relation to science teaching.

2.1 THE LATE 19TH AND EARLY 20TH CENTURIES - HENRY E. ARMSTRONG ADVOCATES HEURISTIC TEACHING METHODS IN THE UNITED KINGDOM

Inquiry teaching is a construct which continues to recur in the literature relating to science curriculum development and reform. Although many educators seem to accept that the emphasis on teaching science as inquiry had its origins in the late 1950s and early 1960s, a little research reveals that inquiry as a science teaching pedagogy can be traced back much earlier than this.

It is difficult to assign the origins of inquiry pedagogy to any one author, rather the ideas that it represents seem to have grown and recurred over time. Solomon (1994) considered that the first attack on traditional didactic approaches to science teaching, which can be regarded as the antithesis of inquiry pedagogies, was made by H. E. Armstrong at the turn of the century (19th to 20th centuries), with Armstrong's development of heuristic methods of teaching. Hence, Solomon appears to credit Armstrong with the development of heuristic science teaching methodologies.

However, Armstrong himself, writing in the preface to a collection of his works (Armstrong, 1903), stated that he was responsible neither for developing the ideas behind heuristic teaching principles, nor for the introduction of the word heuristic. He considered that the heuristic method is as old as the hills and that it is the method of nature. Brock (1973) gave examples to support this contention, noting such advocates as Locke and Rousseau, Erasmus Darwin (writing in *Female Education*), Thomas Day (writing in *Sandford and Merton*) and Richard Lovell Edgeworth (writing in *Practical Education*). Although the origins of the term heurism may be somewhat obscure, it is undoubtedly the pedagogy under which Armstrong's methods, along with all those that have come to be termed inquiry methods, can be categorised.

Armstrong stated that he first came across the term heuristic in a paper given by Professor Meiklejohn at the International Conference on Education, which was held in conjunction with the Health Exhibition at South Kensington in 1884. Whilst Armstrong did not provide any further details of Professor Meiklejohn, Brock (1973), writing in the introduction to his collection of Armstrong's works, noted that

Professor John Miller Dow Meiklejohn held the Chair of the Theory, History and Practice of Education at St Andrew's University in Scotland, that he was one of the most prolific of Victorian school textbook writers and that he gave a paper titled *Professorships and Lectureships on Education* at the South Kensington conference. Brock considered that Armstrong found this paper eminently suggestive as it reinforced his own conclusions about pupil-centred learning. Armstrong stated that Meiklejohn contended that the permanent and universal condition of all method in education is that it be heuristic. He quoted Meiklejohn as saying that the heuristic method was the only method to be applied in the pure sciences and the best method of teaching of the applied sciences. Therefore, Meiklejohn - and potentially others - had promoted inquiry type science teaching pedagogies around the time of, if not before, Armstrong.

A point of Meiklejohns that Armstrong considered worth citing was that Edmund Burke was probably the greatest constructive thinker that ever lived. The British statesman Burke (1729-1797) offered a view of education that would seem to be very much in agreement with Armstrong's ideas.

> A definition may be very exact, and yet go but a very little way towards informing us of the nature of the thing defined; but let the virtue of a definition be what it will, in the order of things, it seems rather to follow than to precede our inquiry, of which it ought to be considered as the result. It must be acknowledged, that the methods of disquisition and teaching may be sometimes different, and on very good reason undoubtedly; but, for my part, I am convinced that the method of teaching which approaches most nearly to the method of investigation is incomparably the best; since, not content with serving up a few barren and lifeless truths, it leads to the stock on which they grew; it tends to set the reader himself in the track of invention, and to direct him into those paths in which the author has made his own discoveries, if he should be so happy as to have made any that are valuable. [Burke, 1756, ¶ 3].

Reading through Armstrong's works it soon becomes evident that this quote from Burke could equally have been written by Armstrong as an introduction to his own methodologies, for it contains the essence of Armstrong's heuristic methods of teaching - letting the student take the position of the investigator in acquiring new knowledge. Burke's writings are further evidence that inquiry teaching methodologies predate Armstrong - although they may have previously lacked the practical trials and detail that Armstrong provided, and may not have related to science teaching to the extent that Armstrong's work did.

Brock (1973) offered some further insights into the origins of the term heuristic, noting that Meiklejohn used it in an 1860 lecture as if it were familiar to his audience, that the term heuristical was used in an 1848 teachers' manual, that Armstrong said that the term had still not reached the dictionary in 1898 and that it was Armstrong's Special Report, *The heuristic method of teaching or the art of making children discover things for themselves*, for the Board of Education in 1898 that gave the term wide currency. Brock noted that by the time of Meiklejohn's death in 1902 *heurism* was recognised as the war-cry of those who believed all teaching should be by means of carefully directed inquiry. Given this information, it seems reasonable to conclude that it was Armstrong who was the main proponent of heurism in science teaching and who brought it to the forefront in Britain during his lifetime (1848 - 1937). This view is supported by Armstrong (1924) describing himself as its (heurism's) most militant modern exponent.

In the aforementioned report, *The heuristic method of teaching or the art of making children discover things for themselves,* Armstrong (1898) offered the opinion that the value of mere knowledge is immensely over-rated, and voiced support for heuristic methods of teaching - methods that involve placing students, as far as possible, in the attitude of the discoverer , and which involve their *finding out* instead of merely being told about things. The term heurism is currently included in dictionaries, with the 1988 edition of the *Chambers English Dictionary* (Landau & Ramson, 1988) defining it as the method in education by which the pupil is set to find out things for himself and the 2002 edition of *The Compact Oxford English Dictionary* (Soanes, 2002) defining heuristic as enabling a person to discover or learn something for themselves.

Solomon (1994) equated Armstrong with Baden-Powell, commenting that whilst the latter was trying to stimulate initiative and self-reliance in the young by his invention of Scouting, Armstrong was trying to instil the same spirit into the conduct of school experiments. Solomon quoted the following from Armstrong, suggesting that it sounds as fresh today as on the day it was written:

> Let it be realised that an experiment is something altogether different from a demonstration or verification, just as a trial is very different from an execution . . . The one involves prolonged mental activity, the other mere mechanical obedience. In schools generally the work done is scarcely ever proper experimental work but merely work involving practical demonstrations or verifications - executions not trials. Much nonsense is talked by trainers of teachers and by not a few teachers who ought to know better about the impossibility of children doing ‘original work’; it is forgotten that every conscious act done in ignorance of its consequences but with a distinct object of ascertaining what will happen is an act involving original enquiry. (Solomon, 1994, p. 9, who cited from Van Praagh, 1973).

A detailed account of Armstrong's career in both chemistry and science education and the influences on the development of his educational thinking, including the extent to which his ideas were adopted, was given by Brock (1973) in his introduction to a collection of Armstrong's works. Interestingly, Van Praagh (1973) edited a collection of Armstrong's works in the same year, and in the introduction to this volume gave a much briefer account of Armstrong's career than did Brock, but went on to link Armstrong's views on science education to current (circa 1973) thinking in science education.

As the influence of Armstrong appears to have been a, or perhaps the, major one in the development of heuristic, and subsequently inquiry, science teaching methods, particularly in Britain, it is worth considering the development of Armstrong's ideas in some detail.

According to the account given by Brock (1973), Henry Edward Armstrong studied at the Royal College of Chemistry in Oxford St. Given the opportunity to attend some classes given by the biologist T. H. Huxley, Armstrong offered the criticism that one learned Huxley's opinions about an issue, but not how to form opinions of your own. This would suggest that from a relatively early age Armstrong was not tolerant of traditional methods of science teaching. The writings of Armstrong (1898) supported this contention stating that as a student he had every desire to learn, but that didactic teaching seemed always to produce a sense of irritation, and that practical work was intensely interesting but only too often done on obedience to orders without the underlying philosophical motive being clear.

From the Royal College of Chemistry Armstrong moved on to work with the chemist Edward Frankland, in his private laboratory, and then on to work with Herman Kolbe (who first synthesised salicylic acid - the basis of aspirin) in Germany. Brock considered that it was Frankland and Kolbe who made Armstrong a critical and passionate believer in self-education through laboratory research - long before the terms inquiry or discovery teaching had been coined in science education. Brock added that Armstrong himself said that his interest in the practice of scientific method was originally sparked by the writings of Richard Chenevix Tench, a poet, Professor of Divinity and Archbishop of Dublin who demonstrated a thorough questioning of evidence in his work. Armstrong was reportedly also greatly impressed by the stringent examination and cross-examination that he experienced during a patent appeal court case. He felt that this represented the acme of scientific treatment, and realised how far short of it scientists generally fell in their ordinary treatment of problems. Brock summarised Armstrong's feelings as:

- scientific training taught him to examine evidence and to ask questions about causes
- Tench caused him to worry about meaning
- the patent action made him alive to the need of a searching cross-examination and judicial consideration of every fact for and against a proposition.

Armstrong used the term *scientific method* for the methodical logical use of information, and this term has become incorporated into the language of science education. Brock reported that in an 1867 report commissioned by the British Association for the Advancement of Science a committee composed of the Harrow teacher Farrar, the physicist Tyndall, the biologist Huxley and the clergyman Wilson distinguished scientific *information* from scientific *training*. Brock considered that this distinction was the antecedent of Armstrong's distinction between scientific *facts* and scientific *method*. As such this report could be suggested to have been influential in the development of inquiry methodologies, even though that may not have been the intent of its authors.

At the end of 1870 Armstrong was appointed to the London Institute. His previous teaching experience had been with medical students who had to be prepared for examinations. At the London Institute Armstrong was no longer tied by examinations and began to devise different methods of teaching, encouraging students to tackle problems experimentally in the institution laboratory. In 1879 Armstrong was appointed to the Applied Chemistry lectureship at the newly established City and Guilds of London Institute, where he planned what Brock describes as a new kind of chemistry course, illustrated by experiments. Moving on to work at the again newly formed Central Institution of the City and Guilds of London Institute Armstrong found that the chemistry students who were taught by his heuristic methods had a high failure rate when sitting London University examinations - due to the nature of the exams and his emphasis on practical, as opposed to bookwork. However, in terms of research output and honours gained by his former students, his department had more prestige than any other chemistry department in London. The dilemma produced by this situation represents an ongoing one in the use of inquiry methods in science teaching when preparing students who must sit a final examination that may not necessarily be designed to test those skills that an inquiry course most strongly develops. Good examples of this in the Australian context have been many of the Grade11/12 exams that students must complete in order to obtain a tertiary entrance score and thus entrance to a university course. In Armstrong's case the end result was, perhaps not surprisingly, that his chemistry department was abolished when the Central Institution merged to form the Imperial College of Science and Technology in 1907. This scenario perhaps explains why many science teachers have argued against the use of inquiry methods in courses where students must be prepared for externally set examinations.

Armstrong produced many works relating to his thoughts on teaching science. He considered (Armstrong, 1903) that the germ of all his subsequent work could be found in his maiden essay, *On the teaching of natural science as a part of the* *ordinary school course and on the method of teaching chemistry in the introductory course in science classes, schools and colleges* (Armstrong, 1884), and that the gradual development of the method - which came to be known as the heuristical method - could be seen by comparing this essay with his later ones. The 1884 essay was delivered to the *International Conference on Education* in London, and in it Armstrong indicated that he saw observing and reasoning from observation and experiment as being the principles that should underlie the development of science courses. He considered that in reality using these methods is only building on the fact that children are always putting questions, and that they have the desire to know the why and wherefore of everything they see. He commented that it is a lamentable result of the present school system that the natural spirit of inquiry is stunted instead of its growth being carefully developed and properly directed.

Brock reported that whilst conference participants seemed pleased by Armstrong's ideas they felt that the current (circa 1884) system of payment by results made Armstrong's methods unworkable. However, apparently Armstrong himself never saw examinations as a great barrier to the wider adoption of his heuristic methods - he simply believed that the examination system should be changed to accommodate his ideas (eg Armstrong, 1898).

In his works, variously presented as lectures, writings and reports, Armstrong (1903) advocated the introduction of *Science for everyday life* for all students into schools, specifically advocating the teaching of scientific method. It seems to have been a consequence of these ideas that laboratory work became common in British schools - with Brock noting that until the 1960s most school laboratories resembled their ancestral forms at schools that Armstrong had had a close involvement with. Armstrong further advocated that teachers generally should have mastered the experimental method and be able to assume the attitude of the investigator. He wrote in the preface to his 1903 collected works that the teacher who acts merely as the mouthpiece of others is only fit to train parrots and that man is by nature a reasoning being and needs to be treated as such, adding that in schools this fact has been honoured more in the breach than in the observance. Armstrong also expressed concern that no organised effort had been made to put youth in possession of the new knowledge of scientists such as Black, Cavendish, Dalton, Darwin, Faraday, Lavoisier, Liebig and many others who in modern (sic) times had made the world of today what it is.

Both Solomon (1994) and Brock (1973) reported that in 1896 the Oxford and Cambridge Examination Board gave approval to a school science syllabus which had largely been designed by Armstrong, and which he published an account of under the title *Heuristic Method of Teaching or the Art of Making Children Discover Things for Themselves.* In this 1898 special report to the Board of Education Armstrong asserted that the recent progress which had been made in education was unquestionably due to the introduction of heuristic methods and exercises (of which he had been one of the chief advocates). He went on to explain that heuristic methods are those that place students, as far as possible, in the attitude of the discoverer - methods which involve their finding out instead of merely being told about things. He continued on to say that the value of mere knowledge is immensely over-rated and its possession over-praised and over-rewarded. He praised the British Association Scheme for recommending a heuristic form of science course which was based on his methods, noting that in 1897 it was in use in over 40 of the London Board schools.

Judging from the available accounts (Armstrong, Brock, Van Praagh, Solomon), Armstrong was a passionate believer in his heuristic teaching methods. He was interested in science education at all levels, working with elementary through university level courses and students, and running courses for science teachers (Brock reported that nearly 200 teachers attended the first two Saturday morning sessions that Armstrong held at the Central Institution). He prepared detailed science syllabuses (eg Armstrong 1889, 1890) to demonstrate how his ideas could be put into practice, and himself worked with classes. Whilst he was influential in having heuristic methods, in particular experimental work, adopted in British schools, he was not without his detractors. This may have been due to his reported proneness toward a sharp tongue and a critical attitude as much as to genuine disagreement with his ideas. Brock reported that Armstrong's invective made him many enemies, and even a cursory reading of Armstrong's writings (eg Armstrong, 1903) provides an insight as to why he may have been seen in this light.

Brock noted that the trade depressions of the 1880s demonstrated to many scientists that an industrial war could only be won if British industry and education altered radically. Armstrong's opinion on this (Armstrong, 1896, 1901) was that it was a lack of research in industry that held British industry back, and that this lack of research was a reflection on school science teaching, which in Armstrong's opinion placed too little emphasis on training students in the scientific method.

Brock also noted that a letter from the Association of Public School Science Masters (APSSM) appeared in *The Times* on 2 February 1916, blaming the state of the war on the neglect of science in British education, and resulting in the formation of *The Neglect of Science Committee*. The pamphlet *Science for All* which originated from this and subsequent committees was evidently somewhat opposed to heurism as a science teaching methodology. There was apparently a belief that heurism needed to be tempered with a more informative approach, and also that the preference for experiments by the class - to encourage the spirit of inquiry - to demonstration experiments led to a great waste of time, limiting the scope of science courses. Brock noted that some of the comments relating to heurism made in the compilation of reports that were presented in this era (1919) were in fact a caricature or misinterpretation of Armstrong's intentions - but that the reports had influence. Armstrong's ideals were also at times misinterpreted in schools - reportedly being often debased to a heavy emphasis on physical measurement and the physical sciences.

Brock stated that it must be admitted that by the time of Armstrong's death in 1937 the heuristic method, as originally conceived, had vanished, killed by the examination system and the collective criticisms of the new psychology, the general science movement and brilliant opposed writers, together with another war closing the 1930s. With the associated need for fresh stringent economies, some teachers again questioned the British emphasis on laboratory teaching. However, Brock went on to note that by the end of the 19th Century Armstrong had reshaped British science teaching, and that science teaching in Great Britain had been coloured by Armstrong's viewpoints since the 1890s. Brock also pointed out that Armstrong was bound to attract criticism as he attacked every conceivable area of science education.

Solomon's writings supported Brock's description of Armstrong's influence, voicing the opinion that by 1925 Armstrong’s method began to fall from favour, but that his initiative never quite lost its appeal, and that when the educational system was ripe for another revolution it was ideas very similar to his which rose to the challenge.

Brock commented that it is difficult to judge how far Armstrong is responsible for the modern (circa 1973) use of discovery methods, as undoubtedly American systems that owed nothing to Armstrong were influential on curricula such as Nuffield. He also said that it is salutary to see how much of what Armstrong preached was being said in the early 1970s in the different but still pioneering language of *experience learning*, *child-centred learning*, *integrated subjects*, *curriculum development* and *discovery methods*. Kuslan and Stone (1968) commented that much of what Armstrong asserted was fully supported by modern (sic) theory in science education, and that whilst Armstrong made no impression in the USA, and hardly more than a disturbance in England, the fresh note that he struck in the education of children had survived.

Armstrong's comment (1924) was that he had lived to see the attempt to develop the experimental method in schools a practical failure.

Regardless of whether either Armstrong or other authors saw his attempts to introduce heuristic teaching methodologies as a failure, Armstrong must be regarded as a very strong influence in introducing educators, particularly science ones, to inquiry teaching methodologies. Armstrong may have been particularly influential to those educators who knew of his work because of the hands-on approach that he seems to have adopted, actually working with groups of students in schools.

2.2 JOHN DEWEY ADVOCATES REFLECTIVE THINKING IN THE USA

Although Armstrong's work seems to have had little impact in the USA, at least at the time that he was active, very similar sentiments to his were being expressed in the USA by John Dewey. John Dewey has been described as being, in his own lifetime, America's best known and most influential philosopher (Skilbeck, 1970). In writing about Dewey, Skilbeck commented that Dewey's prolix method of writing made it difficult at times to be clear whether Dewey was expounding and criticising a position or developing his own ideas on a subject. This tendency meant that Dewey's writings were not always readily accessible to a general audience, but this notwithstanding, Skilbeck commented that Dewey's thinking was to affect generations of teachers and educational theorists, not only in America but throughout the world.

The core of Dewey's thinking on education is expressed in a 1909 address to the American Association for the Advancement of Science (Dewey, 1910a). Here he stated the position that everyone with an interest in the sciences having an appropriate place in education must feel a certain amount of disappointment at the results attained to date. He singled out an influential reason for this as being that science had been taught too much as an accumulation of ready-made material with which students were to be made familiar and not enough as a method of thinking and an attitude of mind. This becomes a theme throughout Dewey's writings and seems very similar to the thoughts and sentiments being expressed by Armstrong in the United Kingdom around the same era.

Dewey identified a possible reason for the prevailing method of science teaching as being the number of sciences that existed and the indefinite bulk of material in each. He cited the case of the discussions of college faculties over the last 25 years concerning entrance requirements in science, with alternative calls for a little of a great many sciences and a good deal (comparatively) of one biological and one exact science. Dewey pointed out what he saw as the absurdity of what schools attempt to do in science education by drawing a comparison with languages. He said imagine a curriculum where each of the three terms of the year was devoted to a language. In the first year Latin, Greek and Sanskrit were covered, in the next year, French, German and Italian and the last year was given to review with Hebrew and Spanish as optional studies. Unfortunately, Dewey's analogy has something of a ring of truth even for today's school science courses.

In his address Dewey went on to reveal that his preferred position was one where science is presented as an effective method of inquiry into any subject matter. He said that if there is any knowledge which is of most worth it must surely be the knowledge of the ways in which something comes to be entitled to be called knowledge, rather than opinion, guess work or dogma. He said that such knowledge is a mode of intelligent practice, a habitual disposition of mind, and that only by taking a hand in the making of knowledge, the transferring of guess and opinion into belief authorised by inquiry does one ever get a knowledge of the method of knowing. Dewey considered that it was because science had not provided such opportunities to students that it had not accomplished in education what was predicted for it. He also considered that *only by pressing the courtesy of language beyond what is decent* could we term the acquisition of information which is ready made, without active experimenting and testing, science. He identified a particularly pressing problem as being turning laboratory technique to intellectual account. His meaning here was that students should be required to do more than just follow recipe book type laboratory procedures, where they simply learnt to use scientific equipment.

In a continuation of this theme Dewey (1945 republication of 1916 article) saw science as knowledge at its best, but considered that something was lost if it was not taught so students acquired a sense of what gives it its superiority. Dewey was of the opinion that elementary science education is critical, with there being a need for teachers at this level to give students a first hand acquaintance with a fair area of natural facts to arouse their interest in the discovery of causes, dynamic processes and operating forces - as opposed to merely making observations and recordings.

Like Armstrong, Dewey saw scientific education as being valuable for all students, not just those who were going to work in the field of science (Dewey, 1910a, 1945). He considered that the great majority of those who leave school should have some idea of the kind of evidence required to substantiate given types of belief, and that they should have a lively interest in the ways in which knowledge is improved and a marked distaste for all conclusions reached in disharmony with the methods of scientific inquiry. Dewey felt that the real measure of effective science education was to be found in the extent to which the public at large adopted and was guided by the methods of scientific thinking in all things - not by the number of scientists produced, nor by the increasing mastery of nature.

Expounding on these views, Dewey (1916) stated that because the mass of pupils were never going to become scientific specialists it was much more important that they got some insights into what scientific method meant than that they should copy at long range and second hand the results that scientific men had reached. He added that the few who do go on to become scientific experts will also have had a better preparation than if they had been swamped with a large mass of purely technical and symbolically stated data. He considered that those who do become successful men of science are those who manage to avoid the pitfalls of a traditional scholastic introduction into it - an indication of the lack of faith that Dewey placed in contemporary science education.

Dewey went even further than claiming that science education for all was desirable, stating that he believed that the future of our civilisation depended upon the widening spread and deepening hold of the scientific habit of mind. He said that scientific method represented the only method of thinking that had proved fruitful in any subject. Skilbeck (1970) noted that Dewey's faith in scientific method as a universal cure to social malaise remained unshaken through two world wars, the careers of fascism and communism, economic depression and the cold war. Dewey saw the cycle of scientific method as a standard to which all forms of thinking should strive to reach, with all beliefs being held provisionally, subject to further inquiry.

The influence of Dewey can be gauged by the comment of Rudolph (2003) that nearly all the recommendations of the science education establishment made during the first half of the twentieth century bear the mark of Dewey's thought in one form or another. It can also be gauged as Rudolph pointed out by the wholesale adoption of his book *How We Think* by the teacher training institutes in the USA as a guide for teaching the scientific method. This volume was published in 1910 and again as an extensively revised edition in 1933.

In *How We* Think Dewey (1910b), who had experience as a teacher, described a process of inquiry he termed reflective thinking in which students began with a perplexing situation, formulated a tentative interpretation or hypothesis, tested the hypothesis to arrive at a solution and acted upon (or tested) the solution. In *How We Think* Dewey identified the phases of reflective thought as:

- suggestion
- intellectualisation - problem identification
- hypothesis
- reasoning
- testing.

These were the processes that he saw as basic to scientific thought and which should become part of every student's education. Dewey made it clear that instruction in scientific thinking rather than science per se should be the primary aim of the science teacher, with reflective thinking forming the basis of an inquiry pedagogy. Dewey saw reflective thinking as being an appropriate reform not just for science education, but for education in general. He started from the premise that some principle that makes for simplification of what goes on in schools was needed and gave as his tenet the conviction that the needed steadying and centralising factor was to be found in adopting as the end of endeavour that attitude of mind, that habit of thought which we call scientific. He said that his book represented the conviction that the naïve and unspoiled attitude of childhood, marked by ardent curiosity, fertile imagination and love of experimental inquiry was very near to the attitude of the scientific mind. In this regard, Dewey's thoughts mirror those of Armstrong who saw children as always putting questions and having the desire to know the why and wherefore of everything.

Dewey defined and promoted reflective thinking as an

> active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends (Dewey, 1933, p. 9)

and contended that application of this principle would lead to individual happiness and the reduction of social waste. Dewey considered that to be genuinely thoughtful humans must maintain a state of doubt, not accepting an idea until justifying reasons have been found.

An ongoing theme in Dewey's work is that the aim of schools often seems to be the amassing of knowledge, covering ground and making students a *cyclopedia of useless information*. Whilst acknowledging that thinking cannot go on in a vacuum, with suggestions and inferences only occurring to a mind that possesses factual information Dewey remained convinced that too much knowledge accumulation was happening in schools, with students frequently being immersed in mere details, their minds loaded with disconnected piecemeal statements of facts and laws. He considered that only deduction or reasoning brought out and emphasised consecutive relationships and that only when relationships were held in view did learning become more than a miscellaneous scrap bag.

Dewey wrote that thinking is inquiry - investigation, turning over, probing or delving so as to find something new or to see what is already known in a different light, that in short it is *questioning*.

Despite the acknowledged influence of Dewey the inquiry teaching methods that he advocated do not seem to have become widespread in the USA in his era. Comments made by Dewey in the introduction to a republication of one of his 1916 articles (Dewey, 1945) support this interpretation of history. In this introduction Dewey wrote that the course of events over the last thirty years have reinforced what is basic to the article, the two main points being firstly that science should be seen as the primary method of intelligence, and secondly that education in scientific thinking is important for all students. These thoughts indicate that by 1945 science education had not changed to accommodate Dewey's way of thinking.

2.3 INQUIRY IN OFFICIAL REPORTS 1918 - 1947

Some examples provided by Driver (1983) indicate that methods very similar to those of both Armstrong and Dewey, and which may be regarded as representing an inquiry approach, continued to be mentioned in official reports well into the 1900s. Driver was of the opinion that for as long as science had had a place in the school curriculum there had been a tension between the acquisition of knowledge and the use of pupils' own inquiries in the pursuit of further knowledge. She considered that over the last 100 years documents on the role of science in general education had reflected this tension. In this regard, the experiences of Armstrong in the United Kingdom and Dewey in the USA were no exception.

Driver quoted the following passage about science from the Report of the Committee on the Position of Natural Science in the Educational System of Great Britain, titled *Natural Science in Education*, which was published in 1918:

> It can arouse and satisfy the element of wonder in our natures. As an intellectual exercise it disciplines our powers of mind. Its utility and applicability are obvious. It quickens and cultivates directly the faculty of observation. It teaches the learner to reason from facts which come under his own notice. By it, the power of rapid and accurate generalisation is strengthened, without it, there is a real danger of the mental habit of method and arrangement never being acquired. (Driver, 1983, p. 74)

Driver then quoted from a 1936 report by the Science Masters' Association, *The Teaching of General Science*, which listed three main contributions that science made to general education. These were:

1. utilitarian or vocational: it helps the pupil in their everyday life, or may be necessary in their future occupations
2. disciplinarian: it teaches them to think; it sharpens their minds
3. cultural: its inclusion is desirable because it forms an essential part of our social heritage (Driver, 1983, p. 74).

Hence, the idea that science helps to develop important skills as well as providing knowledge continued to be recognised. The development of process skills such as the thinking ones referred to above call for the use of inquiry methodologies, so inquiry can be regarded as being an ongoing theme up to this time.

Similar concerns about the state of science teaching were evident in American publications of this era. Hurd (1969) noted three significant ones:

1. In 1938 The Progressive Education Association published a document *Science in General Education* describing a program emphasising the inquiry and social aspects of science.

2. In 1945 a Harvard University Committee reporting in *General Education in a Free Society* recommended the teaching of high school science using broad integrative elements and scientific modes of inquiry set within cultural, historical and philosophical contexts.

3. In a series of 1947 reports on the effectiveness of science instruction the President's Scientific Research Board deplored the conditions where students were taught science as a *world of natural laws, or orderly cause and effect* not *a world of chance or arbitrary action*. This committee noted the lack of student interest in the physical sciences and suggested that much more use could be made of the history of science, its adventures and dramatic action, to appeal to young people's interests and arouse their imagination.

2.4 INTO THE 1960S - THE IMPACT OF THE SPUTNIK LAUNCHES

Although the preceding discussion shows that the importance of the thinking skills developed by science have long been acknowledged, it seems to have been the Soviet launch of Sputnik on October 4 1957 which provided the impetus to bring about major changes to the way in which science was taught in American schools, and the further development - and subsequent naming - of inquiry methods.

The NASA website, (Sputnik and the dawn of the space age, n.d.), states that as a technical achievement, Sputnik caught the American public off-guard, and that the public feared that the Soviets' ability to launch satellites also translated into the capability to launch ballistic missiles that could carry nuclear weapons from Europe to the USA. It goes on to say that the Soviets struck again, when on November 3, Sputnik II was launched, carrying a much heavier payload, including a dog named Laika. The Sputnik launches led directly to the creation of the National Aeronautics and Space Administration (NASA), and also, indirectly, had far reaching effects on science education.

Collette (1973) said that Americans were embarrassed because of the progress the Russians made in their space program. Nagalski (1980) described them as being stung by what was perceived as the growing Russian edge in space and technology, whilst Solomon (1994) considered that there was not so much an educational revolution as a public convulsion at the state of science teaching - sparked off by the colossal affront to U.S. national pride of the Soviet launching. School and college science teaching was singled out as the public scapegoat for this humiliation, making, to use Solomon's phrase, 'the time ripe for another revolution' and being the push behind the next round of major changes in how science was taught.

Consequent to the outcry over the Sputnik launches, both the National Science Foundation and the National Academy of Science began curriculum reform projects in America. Shymansky, Kyle, and Alport (1983) noted that the curriculum reform movement had a gradual beginning with the formal organisation of the Physical Science Study Committee late in 1956, as a result of a 1954 recommendation of the Division of Physical Science of the National Academy of Science encouraging professional physicists to work with high school, and college instructors to develop new courses. Although this indicates that work on new curricular had started prior to the launch of Sputnik it seems to have been that launch that added momentum to this curriculum development - to the extent that Collette (1973) commented that some of the most innovative, and spectacular changes ever to occur in American public school education took place in the area of science around this time.

Collette (1973) reported that many new approaches were produced by national curriculum groups up to 1965, with all these approaches attempting to lead students through a series of experiments which encouraged the creative process, and to bring them to a point where they conceptualised the scientific knowledge they obtained. Although they may not have been either recognised or acknowledged as such at the time these courses were advocating Armstrong's ideas, and inquiry teaching.

What has been described as a prophetic lecture by Joseph Schwab in 1961 is said to have heralded the movement for inquiry methods in science education, although Lucas (1971) also listed Suchman as ‘one of the two major proponents of inquiry teaching’, and Shulman and Tamir (1973) noted that, discovery and inquiry were significant ideas in the book *The Process of Education* written by Jerome Bruner (1962) as a result of the National Academy of Sciences conference at Woods Hole. The most likely scenario would seem to be that all authors had an influence on a renewed call for inquiry science teaching methodologies and hence on the term inquiry becoming entrenched in the science education literature.

As the Woods Hole conference occurred first chronologically its influence on inquiry teaching in science education will be considered first.

2.5 THE WOODS HOLE CONFERENCE

The Woods Hole Conference was held at Woods Hole on Cape Cod in September 1959. Over 10 days this conference brought together 35 scientists, scholars and educators to discuss how education might be improved in USA primary and secondary schools - examining the fundamental processes involved in imparting to young students a sense of the substance and method of science. Jerome Bruner was the Chairman of the Woods Hole Conference, and as such attempted to synthesise a report of what were, in his opinion, the major themes, principal conjectures and most striking tentative conclusions of the conference. He prepared the report *The Process of Education* (Bruner, 1962) in consultation with the other conference participants.

Bruner (1962) reported that at this time a number of major efforts in curriculum design had already been launched by leading physicists, mathematicians, biologists and chemists. He cited the Physical Science Study Committee, PSSC, and Biological Sciences Curriculum Study, BSCS, as two examples, and added that similar projects were in prospect in other fields of scientific endeavour.

Bruner further added that various learned societies were searching for and finding ways of establishing contact between leading scholars and educators and that educators and psychologists were examining anew the nature of teaching methods and curricular and were becoming increasingly ready to examine fresh approaches. This made the time ripe for an overall appraisal of the situation - resulting in the Woods Hole Conference, which Bruner described as unique in bringing together scientists, psychologists, professional educators and historians (included with a view to comparing the issues involved in science teaching to those in a more humanistic field).

In the introduction to his volume Bruner commented that what was emerging as a trademark of his generation was a widespread renewal of concern for the quality and intellectual aims of education, with a considerable portion of the population having become interested in the question *What shall we teach and to what end?* He noted that this trend is accentuated by what

> is almost certain to be a long-range crisis in national security, a crisis whose resolution will depend upon a well-educated citizenry (Bruner, 1962, p.1).

Bruner's interpretation of the situation mirrors the comments cited previously re the soviet launches. He went on to say that if all students were helped to the full utilisation of their intellectual powers we would have a better chance of surviving as a democracy - thought processes that again have the flavour of Dewey and Armstrong about them.

Bruner identified four major themes from the conference. The first of these was the role of structure in learning and how it may be made more central in teaching. The premise here was that students have a limited exposure to the materials they are to learn, so how can this exposure be made to count in their thinking for the rest of their lives? The dominant view was that the answer to this question lay in giving students an understanding of the fundamental structure of subjects - rather than simply the mastery of facts and techniques. Non-specific transfer (or the transfer of principles and attitudes) is said to be at the heart of the educational process, consisting of initially learning not a skill but a general idea - which can then be used as a basis for recognising subsequent problems as special cases of the idea originally mastered. It was argued at Woods Hole that it might be wise to assess what attitudes or heuristic devices are most pervasive and useful, and to then make an effort to teach children a rudimentary version of these that could be further refined as they progressed through school. Bruner commented that too little is known about how to teach fundamental structure effectively or how to provide learning conditions that foster it. Much discussion at the conference centred around this question reportedly had to do with ways and means of achieving such teaching, and of the kinds of research needed to help in preparing curricular with emphasis on structure.

The second theme of the conference identified by Bruner related to readiness for learning. The proposition here was that the foundations of any subject may be taught to anybody at any age in some form; that the basic ideas that lie at the heart of all science (and mathematics) are as simple as they are powerful. To be in command of these basic ideas, to use them effectively, requires a continual deepening of one's understanding of them that comes from learning to use them in progressively more complex forms. Bruner stated that it is only when such ideas are put in formalised terms as equations or elaborated verbal concepts that they are out of reach of the young child.

Bruner also noted a central conviction, that intellectual activity anywhere is the same, whether at the frontier of knowledge or in the third grade. What a scientist does at his desk or in his laboratory, what a literary critic does in reading a poem, are of the same order as what anybody else does when engaged in like activities - if they are to achieve understanding. The difference is in degree, not in kind - the schoolboy learning physics *is* a physicist and it is easiest for him to learn physics behaving like a physicist than doing something else. (The something else came to be called 'middle language' at Woods Hole - classroom discussions and textbooks that talk about the conclusions in a field of intellectual inquiry rather than centring upon the inquiry itself).

The third theme of the Woods Hole conference related to intuitive thinking. Participants saw this as something to be valued and noted that it was an objective of many of the most highly regarded teachers in mathematics and science, but were unclear how it could be specifically taught. One suggestion was that teachers might be able to model it by guessing at answers to questions asked by their class and then subjecting these guesses to critical analysis. It was thought that maybe it is better for students to guess at an answer rather than be struck dumb - as very often in science and in life we are forced to act on the basis of incomplete knowledge.

The fourth conference theme had fewer implications for inquiry teaching, relating to motives for learning. In summary motives for learning must be based as much as possible upon the arousal of interest in what there is to be learned. The quest identified was to devise materials that challenged the superior student whilst not destroying the confidence of others.

Given the above themes, it is easy to see why *The Process of Education* is regarded as having discovery and inquiry as significant ideas. However, as these themes arose out of group discussions, it seems that no particular individual was credited with their inception. Further, no single individual from the group seems to have emerged as continuing to foster these ideas and so help entrench them as part of the psyche of science educators.

2.6 JOSEPH SCHWAB CHAMPIONS INQUIRY TEACHING

Given the lack of follow up by members of the Woods Hole conference, it seems to have fallen to Joseph Schwab to be the champion of inquiry teaching in science education. Although, Westbury and Wilkof (1978) considered that much of Schwab's writing had been uncertain in its impact, as the character of his thought and the medium of publication that he used (largely essays written from the viewpoint of an engaged intellectual) made it difficult for many readers to comprehend the totality of his concerns, Schwab's influence can still be regarded as the single most influential one in introducing the concept of inquiry teaching to science educators.

Westbury and Wilkof described Schwab's essays as invitations to enquiry - perhaps something that Schwab would have seen as fitting. They also commented that during the late 1950s, as Schwab sought to work with teachers and faculty of schools of education, and as he was at his most productive intellectually and receiving widespread recognition as a theoretician, his writing was seen as puzzling and enigmatic (probably particularly to those who had never known the general education movement) and more often than not was misunderstood. It is interesting that two profound believers in the value of inquiry pedagogies, Schwab and Dewey both wrote in a style that was rather inaccessible to teachers at large.

Reid (1999) agreed with Westbury and Wilkof's assessment of Schwab's writings, commenting that in spite of his prominence in the literature of curriculum Schwab's ideas were hard to categorise and could, therefore, be hard to understand. Reid described Schwab as a writer of 'practical' papers which practitioners often found incomprehensible. An interesting comment that Reid made was that Schwab was notable for his promotion of conversation over content, and that Schwab identified this as a marker of his quarrel with the mainstream of thinking on curriculum.

Westbury and Wilkof (1978) noted that Joseph J. Schwab worked in the University of Chicago for nearly fifty years, entering the university at age fifteen, graduating in 1930 with a baccalaureate in English literature and physics, completing a doctorate in genetics, in 1938 becoming an instructor and examiner in biology and retiring from the university in 1974 as Professor of Education and William Rainey Harper Professor of Natural Sciences. During 1937 he accepted a fellowship in science education at Teachers College, Colombia University. Thus, Schwab worked in the University of Chicago's undergraduate program during a time of curriculum reform there and was greatly influenced by the collegiality, forms of thought and practices of that period. He favoured the idea of a general education that was informed by the disciplines or ways of knowing, introduced discussion teaching methods into the undergraduate program, believed in the tractability of science for general education and was passionately concerned with the relationships between science, values and education. As part of the reform of the undergraduate course at the University of Chicago a one year integrative capstone for the whole course, titled Observation, Integration and Interpretation (OII) was introduced in order to explore the various fields of knowledge studied previously. Westbury and Wilkof believed that this was an important influence on his later intellectual development.

Westbury and Wilkof (1978) considered that Schwab's thoughts on science were significantly influenced by Dewey's philosophical work, but where Schwab parted company with Dewey, according to Rudolph (2003) was in the degree to which he believed that methods of inquiry could operate independently of disciplinary content. Dewey claimed that the methods of science were ultimately applicable across any domain, whilst Schwab argued that the methods of science were discipline specific.

At the time of his aforementioned 1961 lecture Joseph Schwab was a professor of natural sciences and education at the University of Chicago. Although it may have been the 1961 lecture that brought inquiry teaching methodologies to the public (or at least educators') eye, Schwab had written about his ideas before this. In 1958, whilst Harper Professor of Natural Sciences and also Professor in the Department of Education at the University of Chicago Schwab authored an article titled *The teaching of science as inquiry*. The editorial paragraph, which introduced the author of each article, described him as a pioneer in new educational methods in the teaching of science at the general level to college students.

Schwab (1958) stated that the formal reason for a change in the present methods of teaching science lay in the fact that science itself had changed. In particular, he considered that three properties of emerging scientific knowledge distinguished it from nineteenth century science, and listed these as:

- the special reference of science knowledge
- its revisionary nature
- its plural character.

Schwab described nineteenth century science as being supposed to seek and find inalterable truths and that the education appropriate to such a view was clearly mastery of the facts so discovered. Hence, in the nineteenth century a clear, unequivocal, coherent organisation and presentation of the known - in other words a rhetoric of conclusions - was the most appropriate method of teaching science. No need was seen for evidence, interpretation, doubt or debate and students were to learn and remember the material that they were given. Schwab stated that a dogmatic education embodied in authoritative lecture and textbook, inflexible laboratory instructions, and exercises presenting no problems of choice and application was the education appropriate to the nineteenth century view of science (although authors of the era, such as Armstrong would surely have disagreed with him on this point). He went on to add that it was shockingly clear that this was also the science education purveyed by most American schools today (referring to the time of his writing).

He added that four reasons were given for this situation:

- that the time allotted to education would permit a view of inquiry only at the expense of coverage
- that students would merely be confused by discussion of doubts and alternatives
- urgencies, such as a shortage of engineers, are appealed to as a reason to follow the traditional course
- that a class of journeymen engineers and pedestrian teachers maintained and regulated by a scientific elite is a necessary economic measure.

Schwab, however, did not accept any of these reasons as being sound ones, and went on to explain what he saw as being a better science curriculum.

Schwab explained that the teaching of science as inquiry had two senses, firstly that science is presented as inquiry, and secondly, that students undertake inquiries as a means of learning material. He said that the traditional classroom and laboratory can be converted by means such as:

- Laboratory sessions become occasions for partial or miniature inquiries and are much more permissive and open, with problems being posed to which students do not know the 'right' solution.

- Situations may be set in which students find and formulate a problem as well as planning and carrying out procedures to investigate it.

- Students are called upon to exercise judgement and choice concerning the parameters to be chosen for study and the interpretation of the data obtained.

- Students are called upon to dissect the records of a scientific inquiry in order to distinguish its constituent concepts, assumption, data etc and thus come to understand their roles. Schwab described four different ways in which actual scientific research and discoveries could be presented as inquiry.

In an article first published in October 1960, but reprinted as Schwab (2000), he summarised his thoughts on the problems then facing science teachers. He considered that the problems stemmed from two roots, firstly, a national need of high and urgent priority, and, secondly, a change in the character of science itself - from a literal-minded empiricism to a complex in which conceptual invention plays a vast role. The implication of this for science education, according to Schwab, was that expertise - authoritative possession of a body of knowledge about a subject matter - was no longer enough to qualify men as the best teachers of science. He continued on to add that time hallowed instruments of instruction, such as the lecture, the textbook and the test, would be inadequate or even inappropriate for much science teaching. Schwab considered that a dual clientele for science education existed within schools, those who were potential consumers of scientific knowledge and those who were possible makers of that knowledge. He concluded by saying that whilst the first impulse may be to view enquiry as something for very few, for the top five or ten percent of students, he did not believe that this should be the case. Again, Schwab's ideas echo those that had been espoused by Armstrong and Dewey.

Schwab expanded on these thoughts on science education in the lecture titled *The Teaching of Science as Enquiry*, which he delivered as the 1961 Inglis Lecture (Schwab, 1966). In this lecture, Schwab stated that after years of indifference or disdain for educational problems large numbers of scientists had come out of their laboratories and become involved, either directly or indirectly, in curriculum matters. The Woods Hole Conference is evidence that Schwab was correct in this regard. Schwab summarised this situation as having been brought about by the need to maintain and support a mode of scientific enquiry which had never before been so urgently required, so visible to the naked, public eye, and understood so little by so few. Schwab went on to state that this need could be filled simply by teaching science as science, and that what was required was that in the very near future a significant section of the public become cognizant of science as a product of fluid enquiry.

The three publications mentioned above seem to have been the foundations for presenting Schwab's ideas to the science education community.

Westbury and Wilkof considered that during the early 1960s, when the concerns of American schoolmen centred on the content of high school science, Schwab was seen as a spokesman for the importance of discipline-based teaching of science in the schools, with several of his writings becoming basic texts for the structuralists in the schools and colleges of education. They said that Schwab's primary commitment was always with science as a *habit of enquiry*, and that he was particularly interested in the description and analysis of why a particular science chooses at a particular time to emphasise one conception or verification over another.

It would seem that by 1974 Schwab felt that some progress had been made in this area, as he commented (Schwab, 1974) that the teaching of science was no longer merely the imparting of a special body of knowledge, but now included the effort to impart competencies and attitudes: competencies to inquire in one way or another; attitudes and values concerning evidence and argument, certainty and uncertainty. He added that this shift imparts to the teaching of science much that is common to the teaching of literature and of the social studies – and that at the same time these areas have become much more scientific. He also added that the effectiveness of any means of teaching any body of knowledge was in part a function of what was happening to those students in other areas/parts of the curriculum (including the expectations, habits and attitudes generated in other curriculum areas).

Schwab related these ideas to what he saw as the then current problems of inflation, unbridled consumption of irreplaceable natural resources and the deterioration of the environment, stating the view that the American people and their leaders were reluctant and unequipped to make decisions and choices. He saw too much effort going into giving attention to each part in isolation with a failure to provide adequate means of communication and collaboration amongst experts. He suggested that whilst the schools alone could not set this situation right, it could not be rectified without the schools, who must begin to teach the young what a seriously formulated practical problem looks like and also to give them a beginning idea of what a good solution entails. Whilst Schwab did not mention inquiry teaching as such in this discussion it would obviously be the basis of such work in schools. He proposed that the natural sciences, social studies and humanities in every school cut their time and coverage of their own subject matter by one third, and that this time be used to convey the disciplines of treatment of practical problems. He gave as an example the fact that the energy crisis would not be solved by an engineer who worked merely with the matter of solar capture, whilst a political scientist studied the political side of the matter and an economist the economics. In other words, he was noting the existence of a synergy between these groups, leading to a refinement of his earlier ideas on the teaching of science as inquiry, with the inquiries that students undertake now moving beyond the field of science. He added that teachers would not know how to teach this and that there was no recognisable group of men to train them, but that we should make a start anyway. Schwab could have just as easily written this about the implementation of the Essential Learnings curriculum in Tasmania over the period 2001-2005. This curriculum will be mentioned more later on, but it is interesting to note that the aims and problems are similar.

As Schwab was particularly influential/active in the area of teaching science as inquiry, his ideas will be examined more fully in the next chapter.

2.7 AN OVERVIEW OF THE 1960S

Suchman (1961) cited the work of Bruner in making his own comments on the use of discovery methods. Suchman's work referred to a variety of curricular, not just in the field of science. He considered that discovery was a powerful educational tool and stated that around the time of his writing a growing number of educators had been motivated to capitalise on the intense motivation and deep insight that seemed to accrue from the discovery approach to concept attainment. He described the results of using independent discovery methods in mathematics and physics, in particular, as dramatic. Suchman summarised the research of Bruner and other researchers as saying that concepts are most meaningful when the learner actively gathers and processes the data from which these concepts emerge. He considered that this was true because:

a) The experience of data gathering (exploration, manipulation, experimentation etc) was intrinsically rewarding.

b) Discovery strengthened the child's faith in the regularity of the universe which enables them to pursue causal relationships under highly frustrating conditions.

c) Discovery built self-confidence which encourages the child to make creative intuitive leaps.

d) Practice in the use of the logical inductive processes involved in discovery strengthened and extended these cognitive skills.

Suchman wrote that the educational practices of the time made children less autonomous and less empirical in their search for understanding as they moved up the elementary grades. It would be reassuring to be able to assert that in the education system of the twenty first century this is no longer the case, but examination of current practices would still seem to support it! Suchman stated that instead of children devoting their efforts to storing information and recalling it on demand they should be developing the cognitive functions needed to seek out and organise information in a way that would be most productive of new concepts. He emphasised that the educator should be concerned above all with the child's process of thinking - trusting that the growth of knowledge will follow in the wake of inquiry. He went on to describe the *Discovery through Inquiry* program that he had collaboratively designed for elementary schools, and which was designed to let children acquire the attitudes, skills and strategies that are fundamental to the scientist's approach to research. He proposed this inquiry training not as a new way of teaching science, but as a way of teaching basic cognitive skills, which he suggested are just as important to the intellectual development of the child as reading and arithmetic. Again, the thoughts of Dewey seem to recur.

Hence, Suchman saw inquiry teaching as being important both within and beyond science education.

Some of the important and well known American curriculum projects which appeared during, or grew out of, the 1960s era include BSCS (Biological Sciences Curriculum Study), Harvard Project Physics, PSSC(Physical Science Study Curriculum) and CHEMstudy. Joseph Schwab was himself the author of some of these texts (eg Schwab, 1963 - *Biology Teachers' Handbook*). To give an idea of the uptake of these courses, the PSSC course was in 1964-1965 in one form or another being taught to approximately half of the high school students in the USA who were enrolled in physics courses, and the PSSC subsidised the in-service training of approximately eight thousand high school teachers in summer institutes (Kuslan & Stone, 1968).

In England Nuffield Science Projects were making considerable resources available for the production of curriculum materials at around this time. In his comments on Armstrong's work, Brock (1973) described Armstrong's heuristic methods together with the American project methods as being the indirect antecedents of the Nuffield Foundation's science teaching projects of the 1950s. Solomon (1994) reported that the Nuffield Project concluded with the following as the characteristics of the kind of science teaching which they wished to promote:

- a well-grounded understanding of science (or a branch of science), not a knowledge of disconnected facts
- encouragement of children to think freely and courageously about science in the way practising scientists do
- experimental and practical enquiry for children as a means of awakening original thought.

The abovementioned projects, whilst well known, were by no means the only curriculum projects of the era. Shulman and Tamir (1973) described the changes of this time as nothing short of revolutionary, and cited evidence that by 1967 there were over 70 curriculum projects in science alone. The various American projects previously listed, together with Nuffield, are often looked on as being flagships for inquiry teaching. A comparison which Solomon (1994) made between the two countries, was that in England the role of the teacher was to radiate enthusiasm and encouragement, whilst in the USA the teacher was to rally to the national call and carry out the behests of educationalists. Regardless of the difference, both the American and English projects became well known and strong support was, and can still be, found for their ideals. For example, Gagné (1963) considered that the idea of inquiry was one of the most important and interesting ideas to be given emphasis in recent discussions of science education, and that there appeared to be very widespread agreement that inquiry was a worthwhile objective.

It seems that once inquiry based methodologies were given a name they soon became popular in science teaching and curriculum design. For example, Kuslan and Stone (1968) produced a volume to introduce pre-service and in-service elementary teachers to teaching science by inquiry. They commented that the new currents in science teaching stressed the importance of deriving learning from direct experiences with scientific phenomena, an approach that they said was modelled after the investigative processes of scientists and which was called the inquiry or discovery approach. They devoted the first chapter of their book to a description of what they termed the tactics and strategies of science and proposed a model of scientific endeavour in terms of its characteristics and processes. They acknowledged that although they strongly emphasised the value of inquiry procedures in science instruction there was no large body of experimental knowledge that testified to the effectiveness of inquiry in leading children to a more coherent and deeper knowledge of science content, principles and theories.

Perhaps this lack of formal research was an inhibiting factor in inquiry teaching methods being more readily and widely accepted.

Hurd (1969) opened by referring to the energetic efforts of the past decade to reform science teaching at the secondary school level, noting that hundreds of conferences had been held, millions of dollars invested and thousands of teachers, educators, scientists and laymen called upon to change the traditional science curriculum. He considered that the American science curriculum had, with few exceptions, remained conservative, being more suited to an agrarian rather than a scientific-technological-industrialised society, and that there was a need to develop science courses more suited to understanding the nature of the scientific enterprise and its meaning for modern America.

Hurd commented that the theme of a symposium to celebrate the dedication of a new university science building was once *The greatest threat to education - knowledge* and noted that the amount of knowledge held in every field of science was staggering and increasing at an accelerated rate. He said that the amount of knowledge doubled by the time children in first grade reached high school and that older science concepts, such as the atom and photosynthesis encompassed more meaning each year. He also said that the production of new knowledge in science and its applications in technology was changing the entire pattern of vocations and career advancement. He considered that a major problem in career development was that it was no longer possible to prepare a person for a lifelong career, as knowledge requirements changed and many jobs became obsolete - and that this was a problem for not only those with limited education, but those with a Ph.D. in science as they could expect the significant knowledge in their field to change two or three times during their career. Hurd wrote that these conditions suggested that an education in science must prepare young people to learn on their own and to expect to learn more after leaving school and added that this is one reason for the emphasis in education today (sic) on learning to learn, inquiry and discovery methods.

All of these comments are interesting in light of the fact that Hurd's work was published in 1969 and very similar philosophies are being espoused in education today, some thirty five years later. Hurd further suggested that means for improving traditional science curriculum, as reflected in the new curricula, were: placing a greater emphasis on rational thinking as a course outcome; using the discipline as a criterion for the selection of instructional materials; organising the curriculum with both a concept and an inquiry sequence; and shifting more responsibility for learning to the student. Hurd considered that in science there is more new knowledge than old and that this imbalance was not evident in other teaching fields. Hurd also considered that the conditions outlined above meant that if we could not change then we would always be educating youth for a world that no longer exists, and that this was why there had been so much criticism of science courses with a fixed body of content, rote learning and out of context with the inquiry processes that generated the knowledge. He said that traditional courses had treated the mind of the student as a storehouse to be filled with information rather than as an instrument for thinking. Hurd continued on to point out that the sciences are particularly suited to an education built upon reasoning, problem solving and change and that it is only within a framework of evolving concepts, probabilities and investigation that science can be learned in an honest fashion.

Hurd said that the most we knew about the future world was that it would be different, complex and changing, that individuals would have responsibilities for which they had not had specific training and that they would be expected to act creatively in fostering change and innovation. These comments seem to imply that all individuals would benefit from an inquiry type curriculum, regardless of whether or not they went into science careers.

Hurd reported that when the science curriculum reform of the last decade (the 1960s) was examined it was found that most of the pressure for change came from scientists who questioned whether high school science courses were truly representative of science as it was known to scientists. The comment of one scientist was that high school teachers were so busy teaching biology, chemistry and physics that they forget to teach the science of their subjects. Hurd went on to add that being well informed about science was not the same as *knowing* science; that science was an intellectual activity that arose from personal experience and took place in the minds of men (pre politically correct language). He considered that science was simply a way of using human intelligence to achieve a better understanding of nature and nature's laws, but that this was not the spirit in which it was taught in conventional science courses, and it was this which disturbed curriculum reformers.

With respect to commonalities between the new science courses Hurd commented that the best correlation was found in the emphasis upon the nature of scientific inquiry - that while it was not planned as a curriculum theme it did appear in each of the new course projects. He added that one may speculate that in the long run the inquiry processes may be a more effective theme for integrating science courses than concepts from biology, physics, chemistry and the earth sciences.

As can be seen from the above account of Hurd's ideas, Schwab was by no means alone in promoting the teaching of science as inquiry.

2.8 THE 1970S

Shymansky, Kyle, and Alport (1983) noted that by 1970, after a decade and a half of curriculum development and implementation the United States had apparently established a pre-eminence in science education to match its status in basic scientific research, and that the hundreds of millions of dollars spent were generally felt to be a good investment. They added that unfortunately many people now felt that the job had been accomplished and that by the mid 1970s nationally funded curriculum efforts began to slow down rapidly, despite the efforts of a small group claiming that only part of the job had been completed.

Hurd (1970) stated that the influences of science upon the economy, international politics and other fields of inquiry were not obvious to most people. He described the educational rationale underlying the, then, recent curriculum reform projects, as *being like a scientist*, and considered that young people acquired the impression that science has no meaning except for the professional sciences. He suggested that a science education should enable people to appreciate the worthiness of the scientific enterprise, and to use it to attack contemporary problems. This, in fact, sounds much like what Schwab envisaged - or indeed Armstrong or Dewey - with Brock (1973) making the comment that it was salutary to see how much of what Armstrong said was being said today (where today is circa 1970). It indicates that by 1970 the original idea of inquiry either had not had time to be implemented, or had to some extent lost its way. At this stage the former would perhaps have tended to have more influence, as in reality there would have been insufficient time for students taught using the new enquiry methods to complete their schooling. Shulman and Tamir (1973) would seem to agree with this position, writing that although claims had been made as to the failure of the new curriculum reforms, these claims were premature, and that judgements would have to be long-term and multidimensional.

Herron (1971) noted that an objective cited almost without exception in new materials was that of bringing students to some understanding of scientific inquiry, but that notions concerning the nature of scientific inquiry were both numerous and varied. He went on to say that by scientific inquiry we mean that disciplined form of human curiosity which involves scientists in ongoing, self-correcting and revisionary processes which results in bodies of currently warranted fact and theory - part of which he acknowledged borrowing from Schwab.

From the comments of the above authors it would seem that by the early 1970s the idea of inquiry had been embraced by education, although no standard definition of what the term meant seemed to be in use. This premise is supported by Shulman and Tamir (1973) who noted that the notions of discovery and inquiry had been recurring themes in science education in the sixties, and that the concept of discovery had been replete with ambiguity. Lucas (1971) noted that in the literature there is a great overlap in usage of the terms ‘discovery’ and ‘inquiry’, and that authors tended to slip from the use of one term to the other. Lucas commented that when many curriculum projects are competing for government money it is perhaps understandable that different terms are coined to describe essentially similar teaching techniques, but that this makes it easy for teachers to become lost in a semantic fog. This should be taken as a warning that when reading materials which refer to inquiry or discovery methods researchers should be wary of simply using their own interpretations of these terms.

In summary, by the 1970s there seemed to be debate over the term inquiry, the term discovery had been introduced and the success of inquiry teaching reforms was being questioned.

2.9 THE 1980S

The continued importance into the 1980s of the concept of inquiry as an aspect of science teaching is illustrated by the six aims which the 1981 policy statement of the Association for Science Education, *Education through Science* listed. These were summarised by Driver (1983) as:

1. understanding of scientific concepts
2. the development of cognitive and psycho-motor skills
3. the ability to undertake inquiries
4. understanding the nature of the scientific enterprise
5. understanding the relationship between science and society
6. the development of a sense of personal worth.

In addition to the concept of inquiry being important the idea of preparing students for life in a different world continued into the 1980s, with Kyle (1980) asserting that the students currently being educated would spend half their adult lives in the 21st century, a world of unknown dimensions. He asserted that a major goal of education should be to prepare the majority of students - those who would not enter a career with a science focus - with a general awareness of and appreciation for science and the processes of science. He commented that the new science curricular (such as those mentioned previously) sought to create laboratory experiences that presented genuine problems of investigation for students of all levels, with an emphasis on increasing students' critical thinking and giving them some understanding of science.

However, the extent to which change had actually been effected in science classrooms was still open to question at this time, as is evidenced by the comments of several authors. Hurd, Bybee, Kahle, and Yager (1980) evaluated the status of biology education in the secondary schools of the USA. They did this using a number of studies which had been carried out, in the light of 20 years having elapsed since the beginning of what they refer to as the curriculum improvement program. They noted that these years had been marked by changes in the disciplines of biology, in science as an enterprise, in the social milieu, in concepts of appropriate knowledge and in the conditions of schooling; and go onto state that throughout the history of biology education, goals and purposes had been continually reevaluated, but that changes were slow - the rate of scientific and social change had been greater than the rate at which science programs had been updated and revised. Although these authors' work was published in 1980 it must be presumed that much of what they refer to actually took place in the 1970s.

With regard to the methods employed in biology teaching, Hurd et al. noted that little evidence existed that inquiry was being used, and that scant data supported the contention that students in biology attained an understanding of scientific inquiry, or that they could use the skills of inquiry. Regardless of this an examination of the goals of middle and junior high school life science courses showed that they included:

- acquainting students with scientific methods
- students acquiring *personal scientific attitudes* such as curiosity, respect for reliable information, thinking critically, acceptance of being wrong, appreciation of science and of living things
- students acquiring skills associated with inquiry development.

Hurd et al. commented that the goal of acquainting students with scientific methods should include information processing skills such as holistic understanding of problems, multicausal relationships, systemic thinking, qualitative methods of investigation, and methods of future research. One of the twelve recommendations which Hurd et al. made was to emphasise human uniqueness, social problems, an enlarged view of scientific methods, ethics decision-making and careers in textbooks and curriculum materials. Overall, what seems to become evident from the comments of Hurd et al. is that, at least up to the time of their writing, inquiry methods had not been fully adopted by teachers. Their comments re the lack of inquiry being incorporated into biology courses are particularly interesting in the light of Schwab's influence, his writing in the area of biology teaching and his commitment to inquiry as a teaching methodology. However, looking at the various goals and recommendations which Hurd et al. mentioned it would seem that there was still a perceived need for the methods inherent in inquiry teaching.

In an article titled *Why inquiry must hold its ground* Nagalski (1980) commented that the inquiry method itself was being called into question, that a push for 'back-to-basics' was emerging, and, in attempting to define what inquiry was, noted that there were widely varying definitions. Nagalski stated that the inquiry approach had received high marks from USA educators over the years, as evidenced by the still widespread adoption of inquiry-oriented texts and methods, but went on to cite evidence that

> today's science curricula are becoming more textbook dominated, a factor ... discouraging to use of inquiry (Nagalsaki, 1980, p. 27).

Nagalski reiterated what seems to have been stated at least from the time of Dewey, that at the present rate of technological change today's basic knowledge would be obsolete tomorrow, and that if students were to survive and adapt in such a swiftly changing world they must have the ability to analyse information, to arrive at logical conclusions, and to act wisely based on these conclusions.

These examples highlight that, after nearly twenty years of so-called reform, confusion still remained over what the term inquiry meant, and debate as to its merits continued to occur.

This interpretation is supported by Tamir (1983), who wrote that the role of inquiry in science education had been one of the most controversial issues in the last twenty years, and that it has not by and large received prominence in most classrooms. He was of the opinion that there was now strong empirical evidence for the promotion of inquiry in science teaching, and advocated a reform in teacher education programs as a means of more successful implementation of inquiry methods.

The question of how effective inquiry programs had been was examined in a meta-analysis reported on by Shymansky, Kyle, and Alport (1983). As part of a larger meta-analysis project initiated at the University of Colorado under the direction of Ronald Anderson, Shymansky et al. summarised the results of 105 experimental studies carried out over 25 years, involving 45,626 students, dealing with the effects of new science curricula on student achievement. Their study was initiated as part of a broad meta-analysis project. Shymansky et al. noted that since 1955, and particularly in the 1960s and early 1970s, elementary, junior high and secondary school science curricula experienced considerable growth and substantial change - which they believed could only be described as phenomenal (they stated that within 15 years of the historic Sputnik launch dozens of such curricula were developed). They added that a comprehensive set of goals and objectives was never thoroughly articulated for these new curricula, but that they came to be associated with process goals where learning how to learn science was stressed. They stated that after 25 years and over five billion dollars invested from both public and private funds the question *How effective were new science curricula in enhancing student performance?* was still unanswered, and their research attempted to address this issue. For the purpose of their study, new science curricula were defined as those courses or curricula projects which:

- were developed after 1955 (with either public or private funds)
- emphasised the nature, structure and process of science
- integrated laboratory activities as an integral part of the class routine
- emphasised higher cognitive skills and appreciation of science.

By way of contrast, traditional curricula were defined as those courses or programs which:

- were developed or patterned after a program developed prior to 1955
- emphasised knowledge of scientific facts, laws, theories and applications
- used laboratory activities as verification exercises or as secondary applications of concepts previously covered in class.

In categorising courses Shymansky et al. noted that the level of treatment fidelity was difficult to establish as new curricula may have been used in traditional ways and vice versa. They considered only studies involving USA samples, as they felt that modifications are often made when curricular are adopted for international use.

Their results indicated that the new curricula had a positive impact on student performance for each of the 18 performance criteria measured, except for student self-concept. They noted that the results for general achievement were especially interesting, as much of the criticism re the new science curricula had focussed on the apparent decline of general science knowledge among students exposed to the new programs, and that the results of their study indicated that students exposed to new science curricula achieved 0.43 standard deviations above their traditional curriculum counterparts. Their overall conclusion was that there was a substantial body of research literature which collectively pointed to the new science curricula as a successful attempt to improve science education.

Shymansky, Hedges, and Woodworth (1990) conducted a resynthessis of the data from the above study, using a refined statistical procedure. The results of the resynthesis generally supported the conclusions drawn in the earlier meta-analysis - that the new science curricula of the 60s and 70s were more effective in enhancing student performance than traditional textbook-based programs of the time - although there were some differences, with fewer significant effects and smaller margins.

A study by Lott (1983) on another aspect of the University of Colorado project has a promising title in *The effect of inquiry teaching and advance organizers upon student learning outcomes*, but in fact seems to contribute little useful information to the debate on inquiry techniques. Lott (1983) looked at the effect of inductive versus deductive teaching on student outcomes. He categorised educational experiences in which examples or observations were provided to students prior to formalising generalisations as inductive (and presumably equated these to inquiry teaching) and those where generalisations were formalised prior to any illustrative examples as deductive. Using the aggregate measure he found essentially no difference between the two teaching approaches, but pointed out that 60% of the studies considered used a level of inquiry only slightly different from the deductive measure.

Anderson (1983) wrote an article directed at consolidating the information reported in all the University of Colorado meta-analyses. In this article he commented that the meta-analysis project focussed on the research questions receiving the most attention in the extant science education literature. The fact that inquiry was a feature of the meta-analyses confirms that it had been receiving considerable attention as a topic. Anderson commented that inquiry, whilst defined in various ways, had been a prevalent theme in the literature of the last twenty five years. In summarising the information from the meta-analyses he considered that *in general* it pointed to a positive vote for inquiry.

However, Costenson, and Lawson (1986) cited the results of the above meta-analyses as providing *impressive* evidence of the superiority of lab-oriented inquiry teaching methods - in terms of student attitudes, interest, learning and intellectual development - particularly in the biological sciences. They went on to say that they believed that if the modern goals of instruction were to be met, then inquiry must be incorporated into the classroom.

Duschl (1986) noted that recent proposals continued to endorse the inquiry approach, despite negative reactions from teachers, and went on to advocate the use of old textbooks as a suitable mechanism for inquiry teaching. If this negative reaction of teachers is common, then the comment of Germann (1989) that inquiry is not being taught effectively in American schools is hardly surprising. Germann suggested that a more directed approach may provide better results for concrete operational students, but did not suggest dropping inquiry methods completely.

Thus, by the end of the 1980s, inquiry still had its advocates and was being looked at from a research point of view. Some doubt still existed as to whether even those courses that purported to do so were really being taught as inquiry. That the seemingly ongoing crisis in science education had not been resolved, at least in the American context, is evidenced by the comments of Yager and Penick (1987), who, whilst not referring to inquiry methodologies in particular, noted that nearly everyone was ready to agree that there was a critical problem in the USA relative to science education. Yager and Penick echoed the belief of earlier authors that science education should be for all students, not only those likely to make a career in science.

A major curriculum development project, Project 2061 began in the USA in the latter part of the 1980s. This project and its implications will be considered in some detail, but in the interests of continuity several works unrelated to this development will be considered first.

2.10 THE EARLY 1990S

Tobin, Kahle, and Fraser (1990) worked in Australia on issues that they identified as being of international importance and concern. Their research suggested that teachers were placing more emphasis on knowledge than on higher order skills, with higher-order questions being directed only to a few selected students in the class. Tobin et al. commented that the evidence suggested that there was something of a crisis in science education, with many programs which purported to being inquiry based showing little evidence of inquiry, and failing to provide children with the intellectual tools for the 21st century. One cannot help but be struck by a sense of déjà vu here - this is a reiteration of what was being said at the time of the Sputnik launch. Thus the idea of science education not adequately preparing students for the future continues through to the literature of the 1990s, a fact which is not really surprising given the rapid technological change which has characterised these times. Perhaps, further evidence of Australian teachers not sufficiently valuing an inquiry approach is given by the findings of Rosier and Long (1991) that teachers of year 12 students gave the application of scientific knowledge and methods a lower rating than attitudes and manual skills in the conduct of experiments.

Although Songer and Linn (1991) did not use the term inquiry teaching, the conclusions of their work really seem to be advocating such an approach. They talked about the danger of focussing science instruction too narrowly on facts or isolated pieces of scientific knowledge, and stated that unless students have sufficient opportunity to understand the knowledge generation process they are unlikely to become participants in the process in the future. They noted that the Harvard Project Physics curriculum emphasised a historical perspective, and that students responded favourably to this approach, but that it had not received widespread acceptance in textbooks.

Tobin et al. (1990) made the point that from a constuctivist perspective, the major curriculum challenge for teachers was to focus on student learning with understanding rather than to stress content coverage only. And so, it seems that a new theme - that of constructivism - entered the debate which surrounded the use of inquiry methodologies. This theme will be considered further in a later section.

Linn (1992) commented that the science education community was united in calling for reform in science instruction, yet divided as to what the reform should be. This is the situation which seems to have prevailed since at least the time of Schwab - perhaps it is just the normal state of affairs in science education that everyone wants things to be better, but cannot agree on how to achieve this. Linn also brings the ideas of constructivism into play, emphasising that students must construct meaning, integrating their own observations of the natural world with additional information. Again the idea of the future needs of society arises, with Linn making the comment that we do not retain enough students in science courses for the needs of the 21st century.

Shymansky and Kyle (1992) were in agreement with the ideas of Linn, noting that science educators had now been searching for the *wonder drug* for at least 30 years. They considered that presently there was widespread international recognition of the need to reform science education, in order to prepare citizens for the 21st Century. They noted that even if the curriculum reforms of the past had accomplished their ends curriculum reform would still have been necessary to address current issues and concerns.

Griffiths and Barman (1993) mentioned that the national statement on science being developed by the Australian Education Council explicated the importance of students' understanding of the nature of science, and that it said, for example, that students should be helped to understand how knowledge is gained, classified, tested and validated. There seems to be more than a hint of Schwab's original inquiry ideals in here. As Australian states went on to use this national statement and the associated profiles (Curriculum Corporation, 1994a, 1994b), albeit in differing ways and to differing extents, perhaps more widespread usage of inquiry methods would be expected to have occurred in Australian science classrooms.

2.11 PROJECT 2061 - THE *SCIENCE FOR ALL AMERICANS* AND *BENCHMARKS* PUBLICATIONS

Project 2061 was a national development in science education in the USA, so named because Halleys Comet was visible at the time of its development (1985) and it was realised that the students whom the innovations were aimed at would be alive to see the return of the comet in 2061. Project 2061 set out to identify what it was most important for the next generation to know and to be able to do in science, mathematics and technology, in other words, what would make them scientifically literate.

The final recommendations of Project 2061 were integrated into the publication *Science for all Americans* (American Association for the Advancement of Science, 1989). *Science for all Americans* (*SFAA*) defines science literacy and lays out some principles for effective learning and teaching. According to the American Association for the Advancement of Science (AAAS) Project 2061 website (Science for all Americans, n.d.) *Science for all Americans* serves as the foundation for current efforts to reform science education in the USA and abroad. The AAAS website goes on to say that *Science for all Americans* serves as a basis for discussions of the skills and knowledge that students should have. Whilst the website of the authoring body should not be regarded as an unbiased source of such information, subsequent developments in science education tend to support these claims.

It is stated in *SFAA*, that most Americans are not science-literate, and that the present science textbooks and methods of instruction often impede progress towards science literacy. *SFAA* took a broad view of science literacy, specifically including having a capacity for scientific ways of thinking in the definition. Contemporary curricula in both science and mathematics were profiled as being overstuffed and undernourished, with particular problems identified as including an emphasis on:

- the learning of answers rather than the exploration of questions
- memory at the expense of critical thought
- bits and pieces of information instead of understandings in context

- recitation over argument
- reading in lieu of doing.

SFAA emphasised that the teaching of science should be consistent with the nature of scientific inquiry, stating that whilst scientific inquiry is not easily described, there being no fixed set of steps that scientists always follow, there are certain features of science that give it a distinctive flavour as a mode of inquiry, and which everyone can exercise in thinking scientifically about many matters of interest in everyday life. These were listed as:

- Science demands evidence.
- Science is a blend of logic and imagination.
- Science explains and predicts.
- Scientists try to identify and avoid bias.
- Science is not authoritarian.

SFAA went on to state that whilst the document emphasises what students should learn, it was recognised that how science is taught is equally important, and that teaching should be consistent with the nature of scientific inquiry. *SFAA* considered that in order to understand science as a way of thinking and doing, and not as just a body of knowledge, students should have some experience with the kinds of thought and action that are typical of it as a field, stating that teachers should do the following:

- start with questions about nature
- engage students actively
- concentrate on the collection and use of evidence
- provide historical perspectives
- insist on clear expression

- use a team approach
- not separate knowledge from finding out
- deemphasise the memorisation of technical vocabulary
- welcome curiosity
- reward creativity
- encourage a spirit of healthy questioning
- avoid dogmatism
- promote aesthetic responses.

Science for All Americans acknowledged that, as the nation discovered after Sputnik, enduring educational reform is not easily achieved, but considered that there was now a public consensus on the need for reform in science, mathematics and technology education. It considered that most of the educational reports of the 1980s that pointed to the need for such improvement had been motivated by two growing public concerns, firstly, America's seeming economic decline and secondly, trends in USA public education such as low test scores, students' avoidance of science and mathematics, a demoralised and weakening teaching staff in many schools, low learning expectations relative to other technologically advanced nations and being ranked near the bottom in international studies of students' knowledge of science and mathematics.

SFAA considered that there was now a clear national consensus in the USA that all elementary and secondary school children needed to become better educated in science. As is outlined above it sees the way forward as being consistent with what has been termed inquiry teaching.

In reading through the *Science for All Americans* materials it is not possible to avoid noting the similarities between it and the ideas of earlier reformers. It seems that what can reasonably be regarded as the major science education initiative of the 1980s was reiterating and emphasising points that had been made in earlier writings.

A subsequent Project 2061 publication *Benchmarks for Scientific Literacy*, (American Association for the Advancement of Science, 1993) was the Project 2061 statement of what all students should know and be able to do in science, mathematics and technology by the end of each of grades 2, 5, 8 and 12. Whilst *Benchmarks*, as this publication is commonly known, did not advocate any particular teaching methods or curriculum design, it did state that when people know how scientists go about their work and reach scientific conclusions, and what the limitations of such conclusions are, they are more likely to react thoughtfully to scientific claims and less likely to reject them out of hand or accept them uncritically. *Benchmarks* emphasised that students should be encouraged to ask 'How do we know that is true?', and stated that the history of science has an important place. It further stated that imagination and inventiveness are more important in science than is generally realised, and suggested that by the end of high school students should have designed and carried out at least one major investigation.

Hence, many of the ideas of Project 2061 can be linked to those of Schwab and the inquiry movement. Maor and Taylor (1995) supported this contention, expressing the opinion that according to *Project 2061* the teaching of science should be consistent with the spirit and character of scientific inquiry. Lopez and Tuomi (1995) considered that a national consensus was evolving around what constituted effective science education and that it was reflected in the *Science for all Americans* and *Benchmarks* documents, together with the *National Science Education Standards* (NRC, 1996). They said that one of the two common convictions shared by these documents was that all students needed to learn scientific skills such as observation and analysis (the second was a less is more philosophy). Lopez and Tuomi called for active, hands-on, student-centered inquiry to be at the core of science education and considered that both teachers and administrators needed to understand that the statement *I don't know but maybe we can find out* is the starting point for all inquiry.

However, the new curriculum reform movements represented by the Project 2061 materials do not appear to have won everyone over. Dawson (1994) stated that currently (and presumably in Australia at least) there seemed to be a tension between a back-to-basics movement and a more liberal attitude recommending constructivist learning approaches. Dawson suggested that historically back-to-basics is a common position taken in times of economic adversity, and which advocates learning fundamental scientific content and skills in a rather traditional manner,

Germann (1994) noted that in 1990 there was a further call for U.S. students to be first in the world at science and mathematics by the year 2000 - a repetition of events of an earlier time . . . He said that one of the major goals being advocated in science education was to help students construct knowledge concerning scientific phenomena and, at the same time, help them to reason, think critically, and to solve problems. A suggested vehicle for this was inquiry-based laboratories.

Thus, it would seem that in the literature the push for reform based on inquiry has changed to a push for reform based on constructivism. However, the techniques of these two strategies appear to be similar and complementary in nature. Maor and Taylor (1995) discussed elements of both these strategies against a background of students using a computerised learning environment to develop higher-level thinking skills associated with scientific inquiry. They concluded that a teacher's constructivist-oriented pedagogy enabled the majority of students to develop higher-level thinking skills such as thinking critically, asking creative questions, and undertaking inquiry-oriented problem solving, whilst a transmissionist epistemology was likely to subvert the aims of inquiry-based teaching.

Strage and Bol (1996) wrote about high school biology courses in particular, but it seems unlikely that their conclusions cannot be extended to science courses in general. They considered that the past decade had seen unprecedented increases in attention paid to science and science education in both the public media and academic circles. This is an interesting statement in light of all the public attention science education seems to have received in the 1960s, but nonetheless, this comment serves to reinforce the fact that the development of suitable science curricula was still seen as having a high profile.

Strage and Bol also stated that science educators had begun to see their role as preparing all students for life in a world of rapid scientific and technological change, rather than preparing a small minority of students for highly specialised, often exclusive careers, again reiterating an ongoing theme from the literature. Strage and Bol then stated that current reconceptualisations of curricular frameworks reflected the goal of helping students integrate what they learn in the science classroom into their daily lives, by placing the curriculum content in more ecologically valid contexts, making it more inquiry-based, and urging the adoption of outcomes assessment measures which tap students' ability to engage in guided discovery activities rather than their memory for content per se. They also said that greater emphasis was now placed on the need to develop students' critical thinking and problem-solving skills. From the comments of Strage and Bol, it would seem that inquiry methods were still being proposed toward the close of the twentieth century.

2.12 THE NATIONAL SCIENCE EDUCATION STANDARDS

Of all the writings and authors that have been considered to date, America's *National Science Education Standards* (*NSES*) have perhaps the greatest potential to actually bring about change in how science is taught in that nation's classrooms and possibly beyond - the easy availability of the standards and related documents via the Internet means that their ideas are readily accessible to virtually any interested party. As inquiry is seen as being a cornerstone of these standards the *NSES* are important in the current discussion.

The National Research Council released the *National Science Education Standards* in December of 1995 (National Research Council, 1996). Basically, these standards defined the science content that all students in the USA should know and be able to do. In addition they provided guidelines relating to teaching, assessment, professional development, programs of study and education systems. The standards represented an attempt to improve science education programs for all students in the USA, with the *Call to Action* at the beginning of the standards spelling out a vision for science education intended to make scientific literacy for all a reality in the 21st Century.

The *National Science Education Standards* had their origins in 1991, when the president of the National Science Teachers Association (NSTA) asked the National Research Council (NRC) to coordinate efforts to develop national standards for science education in the USA. Between 1991 and 1995 groups that included teachers, scientists, administrators and teacher educators produced several drafts of the Standards, which were submitted to extensive review by others in similar roles, resulting in the *NSES* document, which is now regarded as the driving force behind improving science education in the USA.

The Center for Science, Mathematics and Engineering Education, CSMEE, (1997) considered that the national consensus that resulted from the process in which the *NSES* were developed gave them a special credibility. Ellis (2003) elaborated on this, noting that the National Research Council, NRC, brought together the reform efforts of the American Association for the Advancement of Science (Project 2061) and the National Science Teachers Association (NSTA). He considered that the release of *A Nation at Risk* by the National Commission on Excellence in Education in 1983 initiated the process of consensus building between the scientific and educational communities and also the public. Ellis noted that during the past two decades more than 300 reports had been published that analysed and commented on the need for a revised vision for science education. He cited examples of the science education community being involved in defining science literacy and engaging in curriculum development for at least a decade prior to the release of the *NSES* - although as the preceding sections of the current dissertation indicate this is in fact a discussion that has been going on for much longer than a decade.

The standards are based on the premise that science is something that students do, not something that is done to them. They are seen not as prescribing a specific curriculum, but as providing criteria that can be used to design a curriculum framework. The standards themselves state that they are premised on a conviction that all students deserve and must have the opportunity to become scientifically literate, and that they look towards a future in which all Americans will be familiar with basic scientific ideas and processes, and so have fuller and more productive lives. The *NSES* see inquiry as being central to science learning, with students engaging in describing objects and events, asking questions, constructing explanations, testing those explanations against current scientific knowledge and communicating their ideas to others. They also identify their assumptions, use critical and logical thinking and consider alternative explanations, hence actively developing their understanding of science by combining scientific knowledge with reasoning and thinking skills. These would seem to be processes that the greatest proponents of inquiry teaching considered so far, Armstrong, Dewey and Schwab, would have been in concordance with.

The definition of science literacy used in the standards would also have been applauded by the above authors, being defined as:

> Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. (National Research Council, 1996, p. 22)

This is elaborated to explain that people who are scientifically literate can ask, find, or determine answers to questions about everyday experiences. They are able to describe, explain, and predict natural phenomena. The standards also state that scientific literacy has different degrees and forms, and that it expands and deepens over a lifetime, not just during the years in school. The Standards outline a broad base of knowledge and skills for a lifetime of continued development in scientific literacy for every citizen, as well as provide a foundation for those aspiring to scientific careers.

Science as Inquiry is one of the eight content standards of the *National Science Education Standards.* This standard is seen as incorporating the abilities necessary to do scientific inquiry and understandings about scientific inquiry. A further content standard, *History and Nature of Science,* considers science as a human endeavour, the nature of science and the nature of scientific knowledge. Although categorised here as content standards, these two standards reflect the flavour of what has been termed inquiry teaching.

The *NSES* specifically state that inquiry is a step beyond 'science as a process', in which students learn skills, such as observation, inference, and experimentation, as the *NSES* include the 'processes of science' and require that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. The *NSES* state that engaging students in inquiry helps them to develop:

- an understanding of scientific concepts

- an appreciation of 'how we know' what we know in science
- an understanding of the nature of science
- the skills necessary to become independent inquirers about the natural world
- the dispositions to use the skills, abilities, and attitudes associated with science.

In looking at what teachers of science do, the *NSES* documents stated that they *plan an inquiry-based science program*, with individual teachers being encouraged to give less emphasis to fact-based programs and greater emphasis to inquiry-based programs that engage students in an in-depth study of fewer topics. The *NSES* also called for teachers to have the opportunity to learn science through inquiry themselves.

The *NSES* saw science as being a mind-on as well as hands-on process, with students being involved in inquiry-oriented investigations in which they interacted with their teachers and peers, establishing connections between their current knowledge and scientific knowledge found in many sources, applying science content to new questions, engaging in problem solving, planning, decision making and group discussions.

The *NSES* emphasised that science education needed to gives students three kinds of scientific skills and understandings. Students need to:

- learn the principles and concepts of science
- acquire the reasoning and procedural skills of scientists
- understand the nature of science as a particular form of human endeavour.

CSMEE (1997) stated that an important way in which the *NSES* differed from the *Benchmarks* document was that the *Standards* placed greater emphasis on inquiry, including it as important science content as well as a means of teaching and learning. Bybee (2000) considered that it was the emphasis on cognitive processes and critical thinking that differentiated the NSES from traditional materials. Lederman and Flick (2002) considered that what makes current reform efforts different to those of the past was the stress on students learning *about* inquiry. Whilst both Benchmarks and the *NSES* agreed on the importance of students learning *about* inquiry, one area where they differed was in respect to the *NSES* stressing the view that students should *do* inquiry.

One reason for the emphasis on inquiry in the *National Science Education Standards* may have been that which has received ongoing citation in the literature, the rate at which knowledge is currently accumulating. This is recognised well beyond the confines of science education. For example, Erickson (2001) commented in relation to the emphasis that some courses still put on the memorisation of a body of facts, that the information base in our world is challenging the best of microchips.

2.13 THE IMPACT OF THE NATIONAL SCIENCE EDUCATION STANDARDS, 1996 AND BEYOND

Following the release of the *National Science Education Standards*, and presumably because of them, the terms inquiry and science began to commonly occur together in the science education literature once again.

For example, Chiapetta (1997) commented that upon entering a science classroom one should be able to observe an exciting learning environment in which students were wondering why and finding out, asking questions, resolving discrepancies, figuring out patterns, representing ideas, discussing information and solving problems, and that this vision of science teaching was associated with the term inquiry. Chiapetta went on to revisit the ideas of teaching science by inquiry and teaching science as inquiry and suggested strategies and techniques by which this could occur.

The proliferation of articles and books which mentioned inquiry in some way following the release of the *NSES* is evidence that the introduction of the *NSES* in the USA has given inquiry teaching in science yet another new lease of life. To give an idea of this proliferation some titles are listed below:

- Criteria of excellence for geological inquiry: the necessity for ambiguity (Ault, 1998).
- What are the relative effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry classes? (Johnson & Lawson, 1998).
- Content and science inquiry (Hinman, 1998), which considers the need to distinguish scientific and general inquiry.
- *Nurturing Inquiry* (Pearce, 1999), a book which seeks to show elementary teachers how to teach inquiry science in their classrooms.
- Inquiry investigation (Hand & Keys, 1999), which develops a tool called the Science Writing Heuristic to help teachers incorporate more thoughtful inquiry into their curricula.
- Managing the inquiry classroom (Lawson, 2000), describes and suggests possible solutions to some of the classroom management problems associated with inquiry teaching.
- The art of asking questions: Using directed inquiry in the classroom (Goodman & Berntson, 2000), which suggests using questions as an integral component of a science curriculum, thus making inquiry the context rather than the method for science teaching.
- What should the inquiry experience be for the learner? (Windschitl & Buttemer, 2000), which describes a model of inquiry learning that ties together the processes of seeking, identifying and substantiating knowledge.
- Salting the oats: Using inquiry to engage learners at risk (Lynch, 2001).
- Inquiry in kindergarten: Learning literacy through science (Shamlin, 2001), which found that engaging in scientific inquiry created a need for literacy.
- Using inquiry-based science to help gifted students become more self-directed (Schillereff, 2001).

- Tell-tale signs of the inquiry-oriented classroom (Drayton & Falk, 2001), which describes the features that characterise student and teacher roles and tasks in a classroom that is representative of a culture of inquiry.

- Standardising the language of inquiry (Misiti, 2001), which considers the issue of incorrect use of inquiry leading to confusion and suggesting precise definitions.

- Literacy learning and scientific inquiry: Children respond (Ruggiano Schmidt, Gillen, Colabufo Zollo, & Stone, 2002) which examined how six students with literacy learning needs responded to inquiry teaching in science.

- Helping English learners increase achievement through inquiry-based science instruction (Maia Amaral, Garrison, & Klentschy, 2002).

- Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science (Khishfe & Abd-El-Khalick, 2002).

- Defining inquiry (Martin-Hansen, 2002), which considers the different types of inquiry referred to in teaching resources and literature.

- The inquiry "I": A tool for learning scientific inquiry (Phillips & Germann, 2002).

- Rethinking laboratories (Volkmann & Abell, 2003), which offers an inquiry analysis tool and adaptation principles to help teachers evaluate and adapt traditional cookbook laboratories to be more inquiry oriented.

If a search is made of the NSTA (National Science Teachers Association) journals, which are written specifically for a classroom teacher audience, the number of articles which contained inquiry as part of their title or abstract are too numerous to list. Examples include Thacker, Eunsook, Trefz, and Lea (2003), Espinoza (2003), Barrow and Krantz (2003), Lunsford (2003),Bodzin and Cates (2003), DiPasquale, Mason, and Kolkhorst (2003), Rapp (2003), Bernstein (2003), Goodnough and Cahsion (2003), Leonard (2003), Marshall (2003), Harwood (2003), Stiles (2003), Chiapetta and Adams (2004), Ereckson (2004), Deming and Cracolice (2004). Some articles (eg Timmons, 2003) are starting to refer to the *NSES* standards when stating what their ideas are covering.

Whilst the introduction of the *NSES* seems to have had a considerable impact on the literature and teaching methodologies in the USA, the comments of Driver, Newton, and Osborne (2000) seemed to indicate that the same had not been true in the United Kingdom. They commented that the central premise of their study was that science education, as currently practised, reflected a basically positivist view of science in which the book of nature is read by observation, and experiment, with an emphasis on factual recall, and confirmatory experiments. They contended that it was necessary to reconceptualise the practices of science teaching so as to portray scientific knowledge as socially constructed, and see discursive practices such as argument as requiring greater prominence.

The book *Inquiry, and the National Science Education Standards* (National Research Council, 2000), and similar guides began to discuss variation in models of classroom inquiry that might help science educators have a more expanded understanding of classroom inquiry. The authors presented suggestions of how a particular inquiry feature could be implemented in classrooms in different ways, depending on the amount of structure, and ownership imposed by the teacher, and the amount of ownership assumed by students. Songer, Lee, and McDonald (2003) considered that whilst there is a great deal of work still needed to transform the NRC recommendations into activities that promote in-depth inquiry activities among a range of students the guide presented a compelling first step dialogue towards the kinds of expanded understandings of inquiry science that they advocated.

In the foreword to *Inquiry and the National Science Education Standards* (National Research Council, 2000), Bruce Alberts, writing as President of the National Academy of Sciences, was of the opinion that teaching science through inquiry allowed students to conceptualise a question and then seek possible explanations that responded to that question. He also commented that a more familiar style of teaching - that where teachers provide their students with sets of science facts and with technical words to describe those facts - remained depressingly common today. Alberts considered that science classes of this type treated science as if it were preparation for a quiz show or a game of trivial pursuit, and that this led to many problems as students did not see themselves as quiz show participants, failed to see how this type of knowledge would be useful to them in the future and therefore lacked motivation for this kind of learning. More important still, he said, was the fact that this kind of teaching missed the opportunity to give all students the problem-solving, thinking and communication skills that they would need to be effective workers and citizens in the 21st Century. He said that the *NSES* provided valuable insights into the ways that teachers might sustain the curiosity of students and help them develop the sets of abilities associated with scientific inquiry. Alberts saw the challenge for everyone who wanted to improve education as being to create an educational system that exploited the natural curiosity of children, so that they maintain their curiosity for learning throughout life. This leads to something of a sense of déjà vu once again, when one considers the comments of Armstrong and Dewey.

Songer, Lee, and McDonald (2003) were of the opinion that few K-12 science education programs had proven successful in meeting the high standard set by the *NSES*, with educators needing to explore how new curricular approaches, models of enactment and innovative school practices might promote meaningful science learning for the range of learners prevalent in today's classrooms. They considered that inquiry was at the heart of what it means to be scientifically literate, but that much of the research that had explored classroom based inquiry science drew from privileged classroom settings. They were supported by other researchers, as will be outlined more fully in the next chapter.

In summarising a workshop held to consider what the influence of the *NSES* had been Hollweg and Hill (2003) concluded that a cursory view of the literature suggested that the standards had achieved at least part of their aim. Some of the key presenters at the workshop included Horizon Research, Anderson and Ellis.

Horizon Research (2003) found that among teachers who indicated familiarity with the standards, approximately two-thirds at every grade range reported agreeing or strongly agreeing with the vision of science education described in the *NSES*. Secondary teachers were more likely than elementary teachers to be familiar with the *NSES*.

In looking at how science is being taught across the USA the Horizon team concluded that little had actually changed since the introduction of the *NSES*, although there had been a reduction in the number of students reading science textbooks during class and a slight reduction in lecture and the use of textbook and worksheet problems. Little to no change was found in the use of hands-on or inquiry activities.

Horizon Research concluded that overall science teaching had undergone little change since before the *NSES*. Although, a majority of teachers reported agreement with the vision of science education in the *NSES* it was not clear if the teachers were referring to the content or pedagogy or both. The Horizon team identified stresses due to the amount of content included in the standards - despite the standards espousing a less is more philosophy - plus externally mandated test requirements.

Anderson (2003) pointed out that there was a tendency to think of the *NSES* as a set of rules or guidelines to follow and that if teachers followed those rules, student achievement would improve. He noted that things were not so simple, and that teachers are unlikely to be able to adhere to the practices advocated in standards unless they had increases in funding for school science programs.

Ellis (2003) cited the results of the *National Survey of the Status of Science and Mathematics Education* as finding that two thirds of the teachers in grades 5-12 and 46% of the teachers in grades K-4 gave heavy emphasis to science inquiry. This is an impressive statistic if it was really happening. Perhaps unfortunately, from the point of view of an inquiry pedagogy, one of the *NSES* content standards receiving least attention was the history of science one.

It is interesting to note that as the idea of inquiry recurred once again there was divergence of opinion, not so much as to whether or not it is desirable, but as to the extent to which inquiry teaching was being put into practice in science courses. The amount of attention which inquiry has and is receiving indicates that there is ample justification for continuing to investigate the use of inquiry pedagogies, and that consequently the development of an instrument to assess the degree to which inquiry methods are used in science classrooms is justified - and would in fact assist in settling the dispute over the extent to which inquiry is used.

The continuing importance of the notion of inquiry in science education is commented on by Llewellyn (2005), who noted that scientific inquiry is one of the most talked about topics in science education today, and that whether science literacy, standards, instructional techniques or assessment are being discussed the phrase scientific inquiry is likely to work its way into the conversation.

Horizon Research wrote that a major question that remained was what science was actually being taught in classrooms, with no comprehensive picture of the science content that was actually delivered to students existing. They noted that this lack of information on what science was being taught in classrooms, both before the *NSES* and since, made it very difficult to assess the extent of the influence of the *NSES* on teaching practice. The development of an instrument to assess the extent to which inquiry is being used in classrooms would allow the collection of at least baseline data.

2.14 CHAPTER SUMMARY

In ending this historical review, it is worth noting that a major change that had occurred by the end of the twentieth century was the ease of communication around the world brought about by the ready availability of electronic means of communication and the World Wide Web. Consequent to the development of the Internet, documents such as *Science for All Americans, Benchmarks* and the *National Science Education Standards* became freely available to any interested parties. Because of this ease of communication it is unlikely that major developments in science education (or any other field) in one part of the world will go unnoticed for very long. This is in contrast to the situation that is likely to have existed at the time of Armstrong, Dewey or even Schwab.

This chapter has examined the literature that exists relating to the use of inquiry pedagogies being advocated in science teaching. The next chapter will further examine the literature with a view to defining exactly what inquiry teaching is - or is not.

CHAPTER 3 - THE NATURE OF INQUIRY TEACHING, INCLUDING CONTRIBUTING AND INHIBITING FACTORS

CHAPTER OVERVIEW

Whilst the preceding chapter gave some consideration to what has been meant by the term inquiry when it has been used in the literature, this chapter will endeavour to distil the ideas of the various authors as to what constitutes - or does not constitute - an inquiry approach. This will be done with a view to using their thoughts to formulate a questionnaire that can be used to assess the extent to which an inquiry approach is being adopted in individual classrooms.

3.1 WHAT IS INQUIRY TEACHING, AND WHY HAS IT BEEN CONSIDERED DESIRABLE?

Joseph Schwab’s 1961 lecture would have to be regarded as a - if not the - key document in this regard. As the lecture was fairly detailed, and Schwab has authored a number of works, aimed at biology teachers in particular, one could be excused for wondering why there is so much disagreement as to what an inquiry approach should look like. This notwithstanding, it could well seem to a casual surveyor of the literature that the only thing there is agreement about is the lack of agreement as to what constitutes inquiry.

Unfortunately, as DuVall (2001a) reminded us, the word inquiry has been used so routinely in the world of education that it is in danger of losing its true meaning. He considered that it was easier to pin down what inquiry wasn't rather than what it was, adding that it was usually fairly obvious when a classroom was not inquiry-based, but that it was not always obvious whether an active classroom was truly inquiry-based or not. Lederman and Flick (2002) agreed that confusion about the meaning of inquiry and its appearance in the classroom continued to exist among classroom teachers and teacher educators, with one source of this confusion stemming from the nature of science instruction that current science teachers and teacher educators themselves received.

Barman (2002) in a guest editorial commented that if you are struggling to define what inquiry means you are not alone and, whilst giving his own thoughts, urged teachers to spend time discussing what they considered student inquiry to be with their colleagues. Perhaps there is considerable merit in the contention of Bruce Alberts (in the foreword to National Research Council, 2000) that inquiry is in part a state of mind - that of inquisitiveness - and that it comes naturally to most young children who care enough to ask why and how, although adults often dismiss their incessant questions as silly and uninteresting. This view would not be out of line with those of two major proponents of inquiry discussed in Chapter 2, Henry Armstrong and John Dewey.

To illustrate his thought, Alberts gave the example of the effect that the father of the Nobel Prize winning physicist Richard Feynman had on Feynman's development as a scientist. Feynman recalled a conversation with his father whilst observing a bird:

> See that bird? It’s a Spencer's warbler" (I knew that he didn't know the real name). "You can know the name of that bird in all the languages of the world, but when you're finished, you'll know absolutely nothing whatever about the bird. You'll only know about humans in different places and what they call the bird. So let's look at the bird and see what its doing - that’s what counts. (National Research Council, 2000, p. xiv)

As Schwab’s 1961 Inglis lecture seems to be generally regarded as having been particularly influential it is worth looking at in some detail when trying to define the nature of inquiry in science teaching. Schwab (1966) considered that it was necessary that people understood that science is a mode of investigation which rests on conceptual innovation, proceeds through uncertainty and failure, and eventuates in knowledge which is contingent, dubitable, and hard to come by. Schwab added that this would require a virtual revolution in the teaching and learning posture which had characterised American science education, and continued on to further make the point that it was no longer sufficient to teach science as fact - it needed to be taught as interpretation of the knowledge which was available at that point in time. In support of this, Schwab offered the example that physicists of that time put the life expectancy of a body of knowledge in small-particle physics at no more than four years. Schwab distinguished between *stable enquiry*, which he considered to be *constructing an edifice* of scientific knowledge, rather than questioning its plan, and *fluid enquiry*, whose task he considered it to be to study the failure of stable enquiries in order to discover what was lacking in the principles that guided them. He considered that the background of the problems in science education at that time reflected the emergence from obscurity to prominence of the fluid component of scientific enquiry, whilst education continued to present science as a nearly unmitigated rhetoric of conclusions.

Schwab listed three reasons for converting school science *from the dogmatic to the enquiring*. He added that in happier and more peaceful times the individual's own happiness and satisfaction may have been sufficient reason, but that it was now a matter *concerning our welfare as a polity*. Perhaps the post September 11 2001 (bombing of the World Trade Centre buildings in New York) environment that now exists serves to reinforce this notion for today's world. The three reasons then listed by Schwab are:

1. the special need for scientists
2. the need for an informed political leadership
3. the need for an informed public.

In the latter part of his lecture, Schwab considered means for bringing about an enquiring curriculum. In summary, he considered that the following features contributed to such a science curriculum:

1. the laboratory - practical work should lead rather than lag theory, and include a tangible experience of the difficulties of acquiring data, such as unresolved debates, diversity of problems and methods, and continuing differences in concept and interpretation

2. a doubt component - an honest statement of ignorance, uncertainty and dubiety, illustrating the complexity of the problems which science dares to solve

3. an enquiring classroom - with science being shown as enquiry, and also ‘teaching as enquiry’, instructing students in how to learn for themselves, and using methods which show that there is room for alternative interpretation

4. use of original scientific papers as curriculum materials - at least with 11th and 12th grade students

5. use of idiomatic translations - to convey the character of enquiries

6. use of papers as interludes of depth - to provide a balance between depth, and the breadth which many courses appear to strive for

7. use of narrative of enquiry - using a problem seen and a research plan produced by a scientist, and then letting the student adopt the position of the scientist

8. use of invitations to enquiry - individual problems of controllable length and difficulty, which make use of what the text has taught.

Lucas (1971) quoted an account from Schwab of what a classroom where inquiry techniques were being used would be like:

> . . . Once alternative possibilities have presented themselves, discussion ensues. The feasibility and validity of different problems are debated. Ways and means must be discussed. Techniques are devised and criticised, assumptions are unveiled and identified. Then there must be consensus and a division of responsibilities. Finally, at the end, when research reports are written, circulated and read by different teams, there are discrepancies to be checked or accounted for in the interests of further consensus. (Lucas, 1971, p. 189)

Schwab (1963) stated that science as enquiry was one of the most radical ways in which the BSCS texts departed from conventional ones, and that the essence of teaching science as enquiry would be to show some of the conclusions of science in the framework of the way they arose and were tested, and that this would mean to tell the students about the problems posed and the experiments performed, to indicate the data thus found, and to follow the interpretation by which these data were converted to scientific knowledge, including a treatment of the doubts and incompleteness. In these statements, Schwab provided us with some evidences which can be looked for fairly readily in classrooms. He identified the problems with teaching science as a rhetoric of conclusions as relating to the fact that so doing fails to show that scientific knowledge is more than a simple report of things observed, and fails to show that scientists are capable of error. A side effect of this is that as people find the science they were taught at school no longer holds true they doubt their teachers and science itself.

Having considered the thoughts of Schwab, some ideas from other authors will be considered in historical sequence.

Gagné (1963) saw inquiry as perhaps the most critical kind of activity that the scientist engages in. He judged that inquiry was a set of activities characterised by a problem-solving approach, and that its objectives were most clearly achieved when a student was able to adapt the procedures of scientific inquiry in response to any new unsolved problems encountered.

Bruner (1968) tended to use the term discovery, but was of the opinion that he had never seen anybody improve in the art and technique of inquiry by any means other than engaging in inquiry, the significance of this presumably being that if people are not trained in the art of inquiry they will not make practising scientists.

In his book *Inquiry Techniques for Teaching Science* Romey (1968) made mention of his own experience of graduate courses which emphasised recall, and then having to work on a thesis where he had to discover even the problems themselves. He compared asking a student to learn science from a book or a set of lectures to asking a music student to learn notes before having been taught to play the instrument. Other contributors to Romey’s book make a number of suggestions about the nature and value of inquiry teaching. Samples (1968) was of the opinion that what we really want is for students to become confident in the use of their own minds, and considered that there is too little time *not* to teach by inquiry. Samples provided examples of inquiry activities, as did Berger (1968), who considered that the activity he outlined, using a historical example, gave students valuable and vital insights into the process of science as seen in a real problem, including how data could be misinterpreted because of insufficient information. Farre (1968) believed that inquiry showed that facts do not speak for themselves, that scientific facts are interpretations of the data, and that interpretation of data reflects a certain way of looking at the world. Rutherford (1968) stated that when it came to the teaching of science, science teachers, science educators and scientist are all opposed to the rote memorisation of mere facts, and stood for the teaching of the scientific method, critical thinking, the scientific attitude, the problem-solving approach, the discovery method and the inquiry method. Whilst the literature does not really seem to support Rutherford's claim for all of the groups mentioned, it is still possible to appreciate the points he is making about inquiry teaching. Rutherford added that to separate scientific content from scientific inquiry is to make it highly probable that the student will understand neither.

Collette (1973) said that science is necessarily a dynamic changing enterprise, and should be presented as such in science teaching, so as to allow young people to expect change, have positive attitudes towards change, and to prepare them for the future. He added that hopefully teaching science as inquiry would not only let students better understand science, but make it possible for them to acquire certain intellectual skills, which would then make it possible for them to organise their thinking, recognise and use relevant information, and in general, perform as rational and intelligent human beings. Renner and Stafford (1972) seemed to agree with this idea, stating that inquiry is the teaching methodology to encourage intellectual development, pointing out that schools cannot provide students with all the knowledge which they will need in their lifetimes, and that it is therefore necessary to teach them how to learn. They added that inquiry learning had the potential to do this, and that it is best accomplished through exploration, invention and discovery. Before we get too carried away with all this though, perhaps we should also heed the cautionary note that Renner and Stafford sounded, that for inquiry teaching to be as successful as possible the learner must *want* to develop an understanding - a predisposition which many teachers are not always fortunate enough to find in their science course students.

In a similar vein to the above Sund and Trowbridge (1973) claimed that there was evidence that inquiry-oriented teaching methods helped students to make self-discoveries about their various talents. They said that the essence of inquiry teaching was arranging the learning environment to facilitate student-centred instruction and giving sufficient guidance to ensure direction and success in discovering scientific concepts and principles. They considered that an inquiry-oriented teacher seldom tells but often questions, and went into considerable detail about both questioning and discussion in inquiry teaching. With regard to laboratory work, Sund and Trowbridge considered that open-ended investigations with a minimum of explicit instructions should be used.

Connelly, Wahlstrom, Finegold and Elbaz (1977) advocated a guided discussion approach to inquiry teaching, and said that whilst teachers personal styles may be very different from one another they may still be consistent with the purpose of inquiry discussion. During these guided discussions teachers do not normally judge the correctness of students' answers, but comment critically on the soundness of their arguments.

Nagalski (1980) highlighted the need for critical thinking in tomorrow's world, and considered that through inquiry students were conditioned to think critically and creatively, and to generate their own conclusions based on observations which they themselves collected.

Kyle (1980) noted that the use of inquiry methods in the science classroom had been justified in as many different ways as there were meanings and connotations associated with the term. He went on to summarise some of what he termed the multifarious connotations associated with inquiry and pointed out that scientific inquiry should not be construed as being synonymous with investigative methods of science teaching, experimental methods of science teaching, discovery methods of science teaching, self-instructional learning techniques or open-ended learning techniques - all of which he contended are learning techniques that it had become fashionable for educators to equate with scientific inquiry. He considered that the actual learning process was not scientific inquiry, but a prerequisite to scientific inquiry, and that the time had come for science educators to limit the use of the term scientific inquiry to that which constituted scientific inquiry from the scientist's point of view. He said that the ability to scientifically inquire was the personal, internalised ability of an individual to synthesise knowledge which had been obtained through the learning of basic process skills and competencies that enabled a person to rationally inquire, and to solve problems by means of unrestrained inductive thinking. As part of his article Kyle cited his own research, stating that it was interesting to note the relatively small amount of time that students in college science laboratories actually spend experimenting in the laboratory and concluded that even at the college level students were performing what he termed cookbookish laboratories as opposed to any form of real scientific inquiry. Kyle defined scientific inquiry as a systematic and investigative performance ability which incorporated unrestrained inductive thinking capabilities after a person had acquired a broad and critical knowledge of the particular subject matter through formal learning processes. He went on to comment that it was necessary to distinguish between inquiry in general and scientific inquiry, and for high school students to be cognizant of this distinction.

Tamir and Lunetta (1981) used their Task Analysis Inventory to analyse laboratory handbooks, using fourteen items to determine the extent to which books fostered an inquiry approach. They noted that the inquiry skills which were fostered in biology were different from those of physics or chemistry, and that even within a discipline significant differences existed in certain important inquiry skills. Their task inventory included items relating to the planning and design of investigations, performance carrying out the investigation, analysis and interpretation of data and application of the results obtained.

An article by Tamir (1983) set out to clarify the notion of inquiry. He found that the image of inquiry that a group of practising teachers held was, by and large, one of a systematic step by step process based on observations and experiments which give results that are to be interpreted and which lead to conclusions and scientific laws.

Tamir (1985) presented a content analysis scheme consisting of 22 items, which aimed to allow teachers to identify which components of inquiry were included in textbooks. These items can, therefore, be taken as helping to define what inquiry is.

The effect of process-oriented science on problem-solving ability was examined by Shaw (1983), in light of the call by the back to basics movement to de-emphasise the teaching of such skills. Shaw found that problem-solving skills which students were taught were applied to new content areas, and from this concluded that problem-solving skills may also transfer to other academic areas. This lends support to those who have argued for the use of inquiry techniques on the basis that they develop skills which can be applied more generally.

Yager (1986) listed the features of a science program approaching excellence as a model of inquiry as having the following characteristics:

1. Teachers value inquiry, encourage such an orientation, and possess such personal skills.

2. Classrooms use science objects and events where students focus on investigation.

3. Curricula and units of instruction give attention to science processes, the nature of inquiry, and necessary attitudes and values.

4. Teachers act as role models in debating issues, admitting errors, examining values and confronting their own ignorance.

5. Instruction focuses on exploration rather than coverage.

Sutton (1989) blamed textbooks for dominating people’s experiences of science, leaving them with the image that it was just stores of facts. Sutton’s opinion seems to be in line with that of other supporters of inquiry, that the history of science should be shown in more detail, so as to reveal the revolutions in thought which have occurred.

In discussing desired reforms in science education, Shymansky and Kyle (1992) stated that if we want citizens who are creative, reflective, critical thinkers and problem solvers, schools must enhance the ability of all students to become active learners capable of learning how to learn. Whilst they did not espouse a philosophy of inquiry teaching the qualities being sought sound very like ones which inquiry teaching professes to develop.

Roth and Roychoudhury (1993) found that students developed higher-order process skills through nontraditional laboratory experiences that provided students with the freedom to perform experiments of personal relevance in authentic contexts. Sutton (1994) considered that expecting students to interpret what was happening in practical work was a tall order, given that scientists may have struggled with the same phenomenon for centuries, and said that science lessons should be the study of what people have said and thought about nature. McRobbie and English (1993) noted that many recent reports had called for the development of higher-order thinking skills, and suggested that *science as argument* may be a useful metaphor to work with to significantly improve science education.

As has been noted in the preceding chapter, inquiry is a cornerstone of the National Science Education Standards (*NSES).* The term inquiry was used in two different ways in the *NSES* (National Research Council, 2000, Bybee, 2000). Firstly, it referred to the *abilities* students should develop to be able to design and conduct scientific investigations and to the *understandings* they should gain about scientific inquiry. Secondly, it referred to the teaching and learning strategies that enable scientific concepts to be mastered through investigations. The National Research Council stated that the *NSES* aimed to draw connections between learning science, learning to do science and learning about science.

The chapter of the *NSES* devoted to principles and definitions gives the following definition and explanation of scientific inquiry:

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (National Research Council, 1996)

The standards document goes on to consider in some detail what inquiry might look like in classrooms of each of a range of grade levels, K-4, 5-8 and 9-12. The Science as Inquiry content standard is divided to two parts:

- Abilities necessary to do scientific inquiry.
- Understandings about scientific inquiry.

The range of activities that each of these encompasses and hence what they might look like in a classroom situation is summarised by the two tables, Table 3.1 and Table 3.2, below, which are reproduced from National Research Council (2000).

The *NSES* explain that they aim to go beyond process skills such as observation, inference and experimentation, requiring students to mesh such processes with scientific knowledge, as they use scientific reasoning and critical thinking to develop their understanding of science. This encourages students to participate in the evaluation of scientific knowledge by asking questions such as "What counts?", "What data do we keep?", "What patterns exist in the data?", "What explanations account for these patterns?", "Is one explanation better than another?" (National Research Council, 1996).

The *NSES* explain that understandings of scientific inquiry (as opposed to abilities to do scientific inquiry) represent how and why scientific knowledge changes in response to new evidence, logical analysis and modified explanations debated within a community of scientists.

Table 3.1

Content Standard for Science as Inquiry: Fundamental Abilities Necessary to Do Scientific Inquiry. Reproduced from National Research Council (2000).

Grades K-4

- Ask a question about objects, organisms, and events in the environment.
- Plan and conduct a simple investigation.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data to construct a reasonable explanation.
- Communicate investigations and explanations.

Grades 5–8

- Identify questions that can be answered through scientific investigations.
- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Communicate scientific procedures and explanations.
- Use mathematics in all aspects of scientific inquiry.

Grades 9–12

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Communicate and defend a scientific argument.

Table 3.2

Content Standard for Science as Inquiry: Fundamental Understandings about Scientific Inquiry. Reproduced from National Research Council (2000) Inquiry and the NSES.

Grades K-4

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
- Scientists use different kinds of investigations depending on the questions they are trying to answer.
- Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge).
- Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations.
- Scientists review and ask questions about the results of other scientists' work.

Grades 5–8

- Different kinds of questions suggest different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations.
- Mathematics is important in all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- Science advances through legitimate skepticism.
- Scientific investigation sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data.

Grades 9–12

- Scientists usually inquire how physical, living, or designed systems function.
- Scientists conduct investigations for a wide variety of reasons.

- Scientists rely on technology to enhance the gathering and manipulation of data.
- Mathematics is essential in scientific inquiry.
- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions an possible modification; and it must be based on historical and current scientific knowledge.
- Results of scientific inquiry — new knowledge and methods — emerge from different types of investigations and public communication among scientists.

According to the *NSES* (National Research Council, 1996) inquiry teaching and learning have five essential features:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to **evidence,** which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate **explanations** from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations.

With the advent of the NSES, and their detailed descriptions of what inquiry is, debate in the literature seems to have shifted from what inquiry might be to a focus on what inquiry might look like in classrooms.

The *NSES* emphasised that at all stages teachers should guide, focus, challenge and encourage student learning. The standards emphasised that teachers continually create opportunities, make strategic use of questioning, encourage oral and written discourse and employ a collaborative group structure. They stated that the understandings and abilities described by the standards cannot be achieved by any single approach to science teaching, and that teachers should use different strategies to develop the knowledge, understandings, and abilities described in the content standards. They reminded readers that conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry.

Crawford (2000) studied the class of one high school ecology course with a view to being able to list what made up the day to day running of an inquiry based classroom. She considered that although her case study involved one setting, one teacher and one school, assertions about this teacher's teaching may enable others to sharpen their focus on what it means to teach about scientific inquiry in school classrooms. She listed these assertions as:

- Inquiry is situated in context.
- Teachers need to embrace inquiry as a content and a pedagogy.
- Collaboration between teacher and students enhances inquiry.
- Teacher and student roles are complex and changing.
- Greater levels of involvement are required by teachers than in traditional teaching.

Kashmanian Oates (2002) considered inquiry teaching in the college context and described how an inquiry-based science curriculum supported the seven principles for best practice in undergraduate education, listing these as:

- encourages student/faculty contact
- encourages cooperation among students
- encourages active learning
- gives prompt feedback
- emphasises time on task
- communicates high expectations
- respects diverse talents and ways of learning.

She said that through original research not only are students engaged in the science, but many who will not go on to become scientists receive a clearer explanation of what science is about.

Chinn and Malhotra (2002) contrasted the cognitive processes that were needed in authentic scientific inquiry with the processes that were needed in simple inquiry tasks, listing the cognitive processes involved as:

- generating research questions
- designing studies, including selecting variables, planning procedures, controlling variables, planning measures
- making observations
- explaining results, including transforming observations, finding flaws, indirect reasoning, generalisations, types of reasoning
- developing theories, including level of theory and coordinating results from multiple studies
- studying research reports.

Bybee (2002) wrote of using the term *scientific inquiry* in three distinct, but complementary, ways: as science content that should be understood; as a set of cognitive abilities that students should develop; and as teaching methods that science teachers could use. Commenting on the perspectives presented at an international symposium that aimed to shed light on issues associated with the enactment of inquiry, Duschl noted that the six papers presented revealed the variety of meanings associated with the term inquiry. (Abd-El-Khalick et al., 2004).

It is interesting to note that there seems to be a surprising degree of consistency in the aims of reformers, but lack of agreement over how to achieve the desired ends. From the comments of the above authors, it is possible to draw out a number of common themes. These will be used, together with ideas about why inquiry has not been used more widely, in the development of an instrument to assess the degree to which inquiry is used in classrooms.

3.2 FACTORS INHIBITING THE USE OF INQUIRY AS A SCIENCE TEACHING PEDAGOGY

Before taking the above analysis of what inquiry teaching is and what it involves and using this to develop a questionnaire, there would seem to be merit in considering the factors that have been seen as inhibiting the wider use of inquiry pedagogies. These factors may also offer insight into items that should be incorporated into the questionnaire.

It is not really surprising that for as long as inquiry methodologies have had their proponents they have also had their protagonists. As the 1960s are regarded as having been the heyday of inquiry (at least pre the development of the *National Science Education Standards*), criticisms from this era seem a good place to start considerations. Kuslan and Stone (1968) considered some of the arguments which had been made against inquiry by authors whom they termed knowledgeable educators and psychologists. These counter arguments included that:

- young children lack the incentive to tackle problems and are unable to narrow problems sufficiently for success
- a rich background in the subject matter is a precondition for discovery learning
- failure at inquiry may dampen students' enthusiasm
- there has not yet been a conclusive demonstration that discovery transfers across the various disciplines.

Hurd (1969) considered that the subject matter of the new courses for the most part lacked humanistic, social and historical perspectives. This may have been a factor in teachers choosing not to adopt/continue using these courses - and hence omitting inquiry as a byproduct of not using the new courses rather than through any deliberate decision. Hurd listed other criticisms of the new courses, such as teachers not teaching the course in a manner consistent with the stated goals and the courses being too long.

In their analysis of biology education, Hurd et al. (1980) commented that biology was the most frequently offered science, and that it was the only science discipline in which significant numbers of teachers chose to use one of the new programs of the 1960s. The fact that they also commented that although 50% of teachers had attended NSF (National Science Foundation) institutes they did not feel competent to teach using inquiry methods, with less than 50% of teachers using inquiry activities in their teaching, did not seem to augur well for these methods. Hurd et al. noted that there were probably many reasons why inquiry had not been fully implemented, and listed several. These were: biology teachers were not educated in research methodologies, so they were not model inquirers for their students - not understanding inquiry either as a scientific process, or as a teaching method; biology teachers lectured more than 75% of the time, so there was little time left for inquiry; biology teachers felt that only highly motivated, gifted students could benefit from inquiry teaching; secondary school curriculum and instruction was determined almost entirely by textbooks.

Costenson and Lawson (1986) interviewed teachers, and came up with a table of ten top reasons why inquiry was not used. This is reproduced below as Table 3.3. Costenson and Lawson went on to refute each of these reasons, but their refutations do not change the fact that teachers were not using inquiry due to the reasons listed.

Hofstein and Lunetta (1982, 2003) carried out critical reviews of the research on school science laboratories. In the most recent review they listed four factors that continued to inhibit learning in the school science laboratory. The last of these related to the incorporation of inquiry-type activities into school science being inhibited by limitations in resources and by lack of sufficient time for teachers to become informed and to develop and implement appropriate science curricula. In addition, they listed large classes, inflexible scheduling of laboratory facilities and the perceived foci of external exams as issues.

Table 3.3

Ten Reasons Why Inquiry is Not Used by Teachers. From Costenson and Lawson (1980).

1. Time and Energy	Too much time must be devoted to developing good inquiry materials. Too much energy must be expended to maintain level of enthusiasm through five classes each day.
2. Too slow	We have district curricula and must cover all the material. The class will not cover all they need to know.
3. Reading too difficult	The students cannot read the inquiry book.
4. Risk is too high	The administration will not understand what is going on and think I am doing a poor job. I am not sure how each unit will turn out.
5. Tracking	There are no formal thinkers left in regular biology.
6. Student immaturity	Students are too immature. Students waste too much time and, therefore, will not learn enough.
7. Teaching habits	I’ve been teaching this way for 15 years, and I cannot change now.
8. Sequential material	Inquiry methods lock you into the order of the book. I cannot skip labs because there is too much new material in each.
9. Discomfort	I feel uncomfortable not being in control of what is going on in my classroom. Students feel too much discomfort.
10. Too expensive	My lab is not equipped for inquiry. My district will not buy materials needed to maintain an inquiry approach.

A more general perusal of the literature seems to reveal five major limitations which have been proposed as restricting the use of inquiry teaching methods. These may be summarised as:

1. inquiry teaching takes longer
2. inquiry teaching is too confusing, or just does not work for most students
3. teachers are not sufficiently educated in the use of inquiry methods
4. there is a dearth of suitable and readily available teaching resources
5. assessment methods work against an inquiry approach.

3.2.1 Inquiry Teaching Takes Longer

The contention that that inquiry methods take too long, and prevent the course content from being covered was acknowledged by Schwab in his 1961 lecture. However, he was of the opinion that it was a serious question as to whether the many topics commonly covered in traditional high school science courses were necessary or even desirable. The emergence of this problem even earlier is noted by Solomon 1994) who writes that Armstong's inquiry methods were too slow for covering Higher School Certificate examinations. Herron (1971) stated that one thing we could be sure of was that enquiring laboratory activities took longer. Connelly et al. (1977) supported this, noting that it may be necessary to sacrifice some content coverage in using inquiry methods. Schneider, Krajcik, Marx and Soloway (2002) noted that there were concerns that movement away from teacher-disseminated coverage of content would limit the amount of science content to which students were exposed and given opportunities to learn, leaving them at a disadvantage in large scale achievement tests. They sought to obtain empirical evidence that linked inquiry-based instruction with success on science achievement tests, and studied a high school that had restructured its science program to address reform recommendations through the use of project based learning. The study found that project based learning students scored favourably on national tests compared to the national average and concluded that educators need not fear that students in inquiry-based courses will be disadvantaged on large scale achievement tests. Despite these findings an ongoing theme in the literature seems to have been that some teachers/schools see inquiry-based instruction as potentially disadvantaging their students.

It is worth noting at this stage that a theme in the implementation of Tasmania's new *Essential Learnings* curriculum is that teachers should teach in less breadth, but in more depth. As the *Essential Learnings* advocate an inquiry approach across the curriculum, this is a means of addressing teacher concerns.

A problem identified by Horizon Research (2003) related to a number of factors, including the time required for inquiry teaching. The Horizon team considered that a problem is that the content standards themselves are too daunting and that it is not possible to teach all of the content embedded in the *NSES* or the *Benchmarks* in the 13 years available to the school system, using the pedagogies recommended by the *NSES*.

3.2.2 Inquiry Teaching is too Confusing, or Just Does Not Work for Most Students

The idea that inquiry teaching is too confusing was evident in the work of Gagné (1963) when he stated that although it was possible, it was not necessarily desirable to extend invitation to inquiry activities to secondary and primary schools. He argued that practicing inquiry too soon and without a suitable background of knowledge could have a narrowing and cramping effect on the individual’s development of independent thinking. Driver (1983) considered that *I do and I am even more confused* may be a more appropriate ending than the traditional *I do and I understand* to the slogan commonly used in support of practical work. Songer and Linn (1991) seemed to support this idea with the finding that children rarely spontaneously integrate new information. Germann (1989) found that many teachers found conventional inquiry instruction ineffective for most students, and suggested the use of a more directed approach for concrete operational students.

Kyle (1980) listed as claims that had been made against the new inquiry based curricular: that they were best suited to bright students; that they were too abstract for the average student; that they had failed to alleviate the declining enrolment in science courses; that many of the laboratory exercises could be classified at the lowest levels of the discovery hierarchy and that they had given students and many secondary teachers a false impression of scientific inquiry. He said that prior to engaging in a successful, productive and useful scientific inquiry a person must acquire a broad and critical knowledge of the subject matter, which is acquired through the learning of basic competencies. Kyle stated that these competencies would include number computation, spatial and manipulative skills, and the capabilities of observing, classifying, measuring, describing, inferring and model conceptualisation (he considered that these skills were equally valuable to those students who did not become scientists). This is an interesting list, as it would seem unlikely that teachers would try to teach inquiry without developing such skills. However, it seems quite possible that criticisms such as these have influenced teachers/schools to either not adopt or drop inquiry techniques.

Kyle went on to add that not all high school students had the desire or the ability to synthesise scientific knowledge and to undergo the unrestrained, inductive, intellectual responses required of a person in order to inquire scientifically. Kyle considered that many science teachers frustrate students by forcing them to inquire, and added that some authors seem to imply that certain methods of instruction and learning are most efficient for all students - and that this is not the case.

3.2.3 Teachers are Not Sufficiently Educated in the Use of Inquiry Methods

The issue of teachers not being trained to teach science as inquiry must be regarded as a significant one, particularly in today’s science classrooms, where, more and, more there is a tendency for untrained teachers to be given science classes. This is a situation that exists, for example, in a number of Tasmanian high schools that have adopted a middle school program.

Hurd (1969) noted that the reaction of teachers to criticism over the way in which they taught high school science was that they were teaching what they were taught in their pre-service training and that in that training very little if any time was devoted to learning about science as science. Add to this Hurd's comment that the assignment of teachers outside their subject is widespread, with a sizeable fraction of the science teachers in America being science teachers by administrative decision rather than by training, and lack of teacher training could well be regarded as a significant barrier to inquiry.

Connelly et al. (1977) acknowledged the importance of teacher knowledge in using their discussion methods to teach science as inquiry, stating that the influence of the teacher is critical in determining instructional outcomes of these discussions. Welch, Klopfer, Aikenhead and Robinson 1981) reported that many teachers were ill-prepared, in their own eyes and in the eyes of others to guide students in inquiry learning, a finding that Eltinge and Roberts (1993) considered that a number of authors supported. Welch et al. elaborated on their conclusion in noting that there appears to be a discrepancy between existing general statements about the importance of inquiry and the attention given it in practice. Although teachers made positive statements about the value of inquiry they often felt more responsible for teaching facts, things which show up on tests. Hurd et al. (1980) stated with respect to biology teaching, that teachers did not learn how to present biological topics in an inquiry-based interdisciplinary way. In a similar vein to Hurd et al. (1980), Tamir (1983) acknowledged that the notion of inquiry caused a great deal of confusion among teachers, and in both that article and Tamir (1989) made some suggestions about training teachers to teach effectively in the laboratory.

Lopez and Tuomi (1995) considered that the reason well designed hands-on teaching kits didn't work in the reforms of the 1960s and early 1970s was that the kits were in most cases simply turned over to teachers and that in general elementary teachers have an inadequate science background and so felt uncomfortable with the materials. Additionally student inquiry meant a lot of noise and mess and materials didn't work as expected or were used up. While this could be regarded as a particular problem for elementary teaching, comments by authors such as Uno (1990) have suggested that it extends to college teaching. Uno reported that in his experiences leading workshops at American Institute of Biological Sciences annual meetings few attendees had used inquiry. He identified the reason for this as being because their own undergraduate programs had not offered adequate classes to prepare them to teach in this manner.

Crawford (2000) started from the premise that there is a paucity of research on how to design instructional environments to promote students' understandings of scientific inquiry. She considered that orchestrating non-traditional inquiry instruction is complex and that many teachers had not embraced the essence of this mode of learning. She added that details of day to day events in the real world of classroom life are left to the imagination, and often frustration, of the classroom teacher striving to use inquiry-based strategies. She studied the way that one teacher implemented inquiry in his high school ecology course, with a view to making the principles available to other teachers. Crawford found that students' opinions were frequently solicited in the class, and that six key characteristics of this ecology classroom were:

1. situating instruction in authentic problems
2. grappling with data
3. collaboration of students and teacher
4. connection with society
5. teacher modelling behaviours of a scientist
6. fostering student ownership.

Crawford considered that the teacher took on the same six roles that have been suggested for teachers using constructivist approaches plus some additional ones, giving ten roles:

1. motivator
2. diagnostician
3. guide
4. innovator

5. experimenter
6. researcher
7. modeller
8. mentor
9. collaborator
10. learner.

Crawford considered that a teacher's work in an inquiry-based classroom required taking on a myriad of roles - and that these roles demanded a high level of expertise. The classroom studied also involved students taking on non-traditional roles, some usually reserved for the teacher. In conclusion, Crawford said that her study represented a model of collaborative inquiry that required the teacher to take on more active and demanding roles than traditionally depicted, including the teacher modelling the work of scientists. These roles were constantly changing and demanded more active and complex participation by the teacher.

If this is the case, then the precept of Lederman and Niess (2000) that science teachers, by virtue of the nature of the science courses in their backgrounds, do not necessarily possess adequate understandings about inquiry would be a real reason for inquiry teaching not to be used. Lederman and Niess stated:

> We can think of no better way to foster students appreciation for science and mathematics than to have them develop understandings about inquiry, problem-solving and reasoning. We can think of no better way to alleviate the mystery, confusion and apprehension students often have about mathematics and science . . . (Lederman & Niess, p. 15-16).

They then went on to state that none of this would occur without a strong initiative of professional development related to knowledge of subject matter, process skills and pedagogy - indicating that they saw lack of teacher expertise as a major inhibitor to inquiry.

In addition to having an adequate science background, DuVall (2001b) saw teachers as being confronted with the additional challenges of learning how to teach in the zone of proximal development, learning how to be quiet and learning how to promote meaningful discussions and collaboration.

Keys and Bryan (2001) strongly advocated the need for more research along the lines of that of Crawford, saying that this was necessary in order to elucidate the knowledge base that was required for inquiry teaching, so that it could be used to inform teacher education programs. They considered that such studies, on the roles and knowledge of teachers in implementing inquiry in the classroom, would have a broad impact as they would reflect what may realistically be accomplished on a large scale, especially in diverse settings with respect to factors such as student ability and motivation, ethnic background, literacy levels, sex and special needs students. They considered that data was needed to show what kinds of inquiry-based science may reasonably be carried out in ordinary classrooms, and what kinds of student learning outcomes could be reasonably expected. They commented that only then, when the voices of researchers were in resonance with those of teachers, could we begin to create harmonised reform-based instruction that is enduring.

Windschitl (2002) considered that it was unreasonable to assume that individuals who had not conducted a single inquiry in which they developed a question of interest and designed an investigation to answer that question would spontaneously embrace the idea of using open inquiry in their classrooms - or feel capable of managing such complex instruction. Windschitl found that the sole common condition across participants who used inquiry regularly in their classrooms was that they had previous long term research experience in which they played significant roles in authentic investigations. Whilst acknowledging his small sample size (six preservice teachers in a program dedicated to producing graduates who would assume leadership roles in their schools as well as be exemplary teachers) Windschitl still concluded that teacher education programs should promote some authentic science research experiences. Eick and Reed (2002) seemed to agree with this, noting the role of learners' personal histories on their teaching identity development and the implications of this for preparing inquiry-based science teachers, and concluding that traditional institutions needed to implement more supervised teaching experiences using structured inquiry before students enter teacher education.

Windschitl also pointed out that the deceptively minor differences between structured, guided and open inquiry had monumental implications in the classroom for what students actually did, pointing out that guided inquiry was far more intellectually challenging for learners and pedagogically complex for teachers to manage than was structured inquiry. Independent or open inquiry was still more challenging for both learners and teachers.

Horizon Research (2003), in looking at the influence of the *NSES* on teachers and teaching practice, concluded that the preparedness of teachers for standards-based science instruction was a major issue, with areas of concern including inadequate content preparedness and inadequate preparation to select and use instructional strategies for standards-based science instruction. As inquiry is a focus of the *NSES* it can reasonably be concluded that inadequate preparation is likely to include this area.

If the somewhat sobering assertion of Sandler (2003) - that nearly one fifth of high school science teachers lack even a minor in their main teaching field, and that 56% of high school science students taking physical science do so from a teacher teaching out of field - is even approximately correct, it is not surprising that teachers do not feel qualified to teach science as inquiry.

Perhaps further evidence is lent to this mode of thinking by the attempt of the California Curriculum Commission to limit the amount of hands-on instruction in K-8 textbooks to a maximum of 20-25% (reported for example in Strauss, 2004). The reasoning given for the proposed change was that the commission was trying to balance the need for a comprehensive science curriculum with the limited science background of many K-8 teachers. This move was strongly opposed by a number of educators and scientists, and was eventually voted down by the California State Board of Education in March 2004.

3.2.4 There is a Dearth of Suitable and Readily Available Teaching Resources

The lack of textbooks and other curriculum materials which really encourage inquiry learning is commented on on a number of occasions in the literature. Hurd et al. (1980) found that whilst inquiry was a stated goal of biology programs, few laboratory activities (10%) stress independent inquiry. Tobin and Gallagher (1987), in noting an emphasis on content in science classrooms suggested that given the extensive use of the text, changing the text could be a means of bringing about change. This cannot be regarded as the sole reason for teachers not using inquiry methods though. As Eltinge and Roberts (1993) pointed out, a textbook may have a very high level of inquiry but be used in a manner which enhances rote learning - or alternatively as Romey (1968) noted, a highly inquiry oriented course can be run using the most traditional of textbooks. Jiménez Aleixandre (1994) agreed, reminding us that research has shown that classroom materials designed to involve pupils are not enough if the teacher’s strategy is not appropriate.

The situation does not appear to have improved significantly by the time Chinn and Malhorta (2002) conducted their research, as they noted that textbook curricular, which remained important in many schools, were dominated by oversimplified inquiry tasks that bore little resemblance to authentic scientific reasoning. They found that most of the research tasks developed by researchers had incorporated several additional features of authentic reasoning, but that most still omited several key features of authentic science.

Volkmann and Abell (2003) contended that although inquiry-based science was the buzz many curriculum materials are still based on traditional approaches that failed to engage students in inquiry.

Regardless of the use which teachers may make of materials they are supplied with, the scarcity of time which most teachers currently have for lesson preparation is also likely to be a factor deterring them from adopting strategies which require significant preparation time - which many inquiry techniques need, at least when teachers initially adopt them.

3.2.5 Assessment Methods Work against an Inquiry Approach

The question of assessment seems to be a never ending one in influencing how and what teachers teach. There are obviously great demands on teachers to adequately prepare students for assessment tasks, and if teachers do not perceive inquiry techniques as being the best means of doing this they will feel compelled not to use them - no matter how much they may believe in the greater value of such techniques. There are a number of references to this situation in the literature. For example, Tobin and Gallagher (1987) noted that academic work in high school classes was strongly influenced by the local assessment system, whilst Tobin et al. (1990) reported that teachers felt constrained by tests and exams.

Horizon Research (2003) commented that a factor working against inquiry, at least in the United States, might be the increasing influence of state and district tests. They stated that anecdotal evidence told them that teachers believed in the standards, but that on the other hand they were held accountable for state and district tests, which in many cases were not standards-based.

3.2.6 Other Considerations

Several other reasons have been suggested for inquiry methods not being adopted. One of these is that student behaviour may not lend itself to a number of the teaching strategies suggested for inquiry teaching. A BBC News item (School science labs inadequate, 2004) reported that earlier in 2004 a survey by Save British Science found that practical lessons had been cancelled in more than three-quarters of the 67 schools surveyed, and that in 57% of those cases the reason given was rowdy student behaviour. Dr Simon Campbell the president-elect of The Royal Society of Chemistry, was quoted as saying that fewer kids were having practical classes, largely because of poor discipline. In an inquiry approach appropriate laboratory work is important, so if less practical work is occurring in schools it is likely that inquiry methods are not being fully implemented.

A further factor working against the use of inquiry methods could be the idea of Medawar (1986) that the scientific paper is a fraud, with scientists rarely following the scientific method, but rather developing hypotheses that are imaginative and inspirational in nature. Woolnough (1989) agreed with this idea, commenting on an earlier work of Medawar's which said that science really proceeds by intuition, serendipity, and imagination, followed by rigorous attempts at disproof - and that science only appears to be inductive because of the convention in which it is presented.

Critics such as Ausubel (1964) take the stance that whilst learning by discovery has its proper place amongst the repertoire of accepted techniques available to teachers it has been elevated by some of its proponents into a panacea. Ausubel considered that if a student of science is to *discover* he must first *learn*, and that students cannot learn adequately by pretending to be junior scientists. However, one would have to question if this is not the way that some of the great scientists really learnt science. Ausubel also considered that despite their frequent espousal of discovery principles the various curriculum reform projects have failed thus far to yield any evidence in support of the discovery method - but that these projects were cited in the discovery literature under the heading 'research shows'. Hermann (1969) concurred with this view, stating that the results of discovery learning experiments were conflicting and often insignificant, and that whilst they tended to favour discovery learning compared to other methods many results were suspect due to limitations in experimental design and analysis. Hermann further noted that direct comparison of experimental findings is difficult due to differing ideas concerning the nature of discovery learning.

This consideration of issues which work against the teaching of science as inquiry may provide further points which can be looked at in developing an instrument to determine the extent to which inquiry methods are used in classrooms. Before attempting to design such an instrument, a brief consideration of the interrelationship of constructivism and inquiry teaching will be made. Constructivism is a major principle in current educational thinking, so unless its methods are seen as compatible with inquiry teaching there would really seem to be little point in proceeding with the development of an instrument to look at the extent of inquiry teaching.

3.3 INQUIRY METHODOLOGIES AND CONSTRUCTIVISM

A major educational thrust in science and mathematics education in recent times has been that of constructivism. Dana and Davis (1993) reported that scholars from a diversity of backgrounds were beginning to use constructivism to make sense of educational phenomena, although as Duit and Confrey (1996) acknowledged, providing evidence of the success of constructivist principles is somewhat difficult. Shymansky and Kyle (1992) noted that *Project 2061* agreed that scientific endeavour should be presented as a social enterprise, placing emphasis on human thought, action, depth of understanding, and the application of science to personal and societal issues; that learning strategies ought to be based upon a constructivist epistemology; and that reform should ensure the scientific literacy of virtually all students.

An extensive literature exists on constructivism, which will not be considered here. It should be sufficient for current purposes to use a view of constructivism such as that given by Maor and Taylor (1995), who in summarising the ideas of various authors decided that a personal constructivist perspective regards knowledge as being constructed by learners who give meaning to new experiences in terms of their prior knowledge and past experiences. This perspective emphasised a cognitively active approach to learning in which students construct knowledge which is viable for them, and incorporate it within their views of the world. This is in line with the definition of inquiry that is presented in the *National Science Education Standards*. Maor and Taylor went on to note that science educators have realised that personal constructivism fails to acknowledge the importance of the social aspects of learning, and so a social constructivist perspective has developed. This social constructivist perspective regards learning as a social activity in which learners are engaged in constructing meaning through discussions and negotiations among peers and teachers. Through social interactions students become aware of others' ideas, seek reconfirmation of their own ideas, and reinforce or reject their personal construction.

Germann, Haskins and Auls (1996) also commented on the importance of the constructivist epistemology, noting that within this epistemology teachers strive to help students make meaningful connections between what they already know from their experiences, both in and out of school, and new understandings that are scientifically acceptable. They added that where appropriate knowledge is not in the students' experience the teacher must provide it, and that where students have constructed misconceptions the teacher must provide learning activities that will help the students build more appropriate meanings.

There appear to be a number of similarities between the needs of constructivism and the strategies suggested for inquiry teaching, so that the two may be regarded as complementing each other. The following are some particular areas in which the intertwining of the two methodologies can be seen.

- Use of discussion - this is vital from the perspective of social constructivism, and is also critical to inquiry teaching in allowing students to clarify and refine their beliefs.

- Concept of knowledge being uncertain - inquiry methods note the importance of recognising the existence of alternative perspectives and interpretations, whilst constructivism sees the idea of conflict as being important in allowing cognitive change.

- Use of historical perspectives and stories - this is seen as important in inquiry as it allows students to see how science progresses, and to recognise it as a real enterprise. It can also be regarded as important in constructivism, as the use of such stories provides a starting point for students to relate their own experiences and beliefs to.

- Scientific method skills such as interpreting, generalising and problem-solving - are seen as basic to inquiry, as they allow people to use the processes of science, even in times of changing knowledge. With regard to constructivism, the development and use of these skills must provide individuals with the opportunity to further explore their own ideas and beliefs, and also provide them with the necessary tools to compare their own beliefs with those of others.

- Use of open - ended investigations - this is integral to the ideas of inquiry. It must also be extremely important in constructivism, as

> such investigations pave the way for conceptual growth, and also can bring about cognitive conflict, thus leading to conceptual change.

Gil-Pérez and Carrascosa-Alis (1994) said that the idea of linking science learning to the way of doing science - which many of the above points represent - was a characteristic of the discovery method, and that it was currently being reinforced by the constructivist paradigm.

Unfortunately for advocates of either inquiry or constructivist methodologies, Gallagher (1993) considered that in the dominant paradigm in science teaching - and for that matter most other subjects, at least at the secondary and tertiary levels - teaching had been associated with the transmission of knowledge; learning had been equated with memorising that information; and assessment of learning had been summative, to determine whether students had been successful in acquiring the information. He suggested that this paradigm was in fact deeply ingrained from teachers' own education, and that teachers' practices change more slowly than their vision - although they may accept new teaching ideas, they take some time to implement these effectively in their classrooms. This is the very situation which has existed with inquiry teaching methods - their use has been advocated, and even supported by teachers, but there has been very limited evidence of their successful implementation in classrooms. Given the time and resources which go into developing new methodologies, it is to be hoped that constructivism meets with more success than inquiry teaching has - and that 30 years on researchers will not be reading debates in the literature as to whether or not it is a desirable strategy (not that some divergence of opinion is not a healthy thing).

Llewellyn (2002) considered that to become an inquiry based teacher it was essential to develop the proper philosophical mind-set that accompanied inquiry, and noted that for many teachers the principles of constructivism lay the foundation for understanding inquiry.

In a consideration of teaching science through inquiry, Haury (2003) noted that inquiry-oriented teaching reflected the constructivist model of learning, so strongly held among science educators today. He said that in its essence inquiry-oriented teaching engages students in investigations to satisfy curiosities, with curiosities being satisfied when individuals have constructed mental frameworks that adequately explain their experiences.

The importance of the preceding discussion in this section is that it shows similarities between inquiry methods and constructivist thinking. Therefore, it is not necessary to abandon inquiry ideas, because of the general acceptance of constructivist ideas in science education, and the development of an instrument to assess the extent to which inquiry is used in science classrooms is in keeping with constructivist objectives.

In the guide to the *NSES*, *Inquiry and the National Science Education Standards* (National Research Council, 2000) a 1999 NRC report titled *How People Learn*, which synthesised research from a variety of fields, including cognition, child development and brain functioning was referred to. This document is reported to have demonstrated broad consensus about how learning occurs, listing the following broad findings:

- understanding science is more than knowing facts
- students build new knowledge and understanding on what they already know and believe
- students formulate new knowledge by modifying and refining their current concepts and by adding new concepts to what they already know
- learning is mediated by the social environment in which students interact with others
- effective learning requires that students take control of their own learning
- the ability to apply knowledge to novel situations, that is, transfer of learning, is affected by the degree to which students learn with understanding.

The guide considered that these findings connect in important ways with the definition of inquiry presented in the *NSES*, supporting the use of inquiry as a methodology.

3.4 SCALES FOR AN INQUIRY QUESTIONNAIRE

An objective of the current research, and the reason for the preceding literature review, is to develop an instrument that can be used to assess the extent to which teachers employ inquiry methodologies in their classrooms. On the basis of what the authors considered in the preceding sections have said constitutes and inhibits inquiry teaching six scales were devised for the questionnaire. These six scales, which will be considered in greater detail in the next chapter, are:

1. Open-endedness - the extent to which the laboratory activities emphasise an open-ended divergent approach to experimentation.
2. Discussion - the extent to which discussion of ideas occurs in the classroom.
3. Assessment - the extent to which assessment procedures emphasise process skills rather than memorisation of knowledge.
4. Scientific Method - the extent to which students are provided with the opportunity to develop critical thinking skills through the processes of the scientific method.
5. Historical perspectives/use of stories - the extent to which historical perspectives and stories are used in the class.
6. Uncertainty - the extent to which scientific knowledge is presented as being tentative and subject to change.

CHAPTER 4 - DEVELOPMENT OF THE *IS THIS AN INQUIRING CLASSROOM?* QUESTIONNAIRE (ITIC)

CHAPTER OVERVIEW

This chapter considers the use of questionnaires as measures of classroom environment, considering what has been reported and become conventional in the literature. It culminates in the development and analysis of the Preliminary Version of the Is This an Inquiring Classroom or ITIC questionnaire.

4.1 QUESTIONNAIRES AS MEASURES OF CLASSROOM ENVIRONMENT

The use of questionnaires as instruments to measure classroom environment - as opposed to techniques such as direct observation by an external observer - has been extensively covered in the literature by Fraser (Fraser, 1986, 1994). Fraser (1998) reported that in the 30 years since the pioneering use of classroom environment assessments (in an evaluation of Harvard Project Physics by Walberg and Anderson, 1968), learning environment assessments had been used in a rich variety of research applications spanning many countries. He noted that a striking feature of this field was the availability of a variety of economical, valid and widely-applicable questionnaires that had been developed and used for assessing students' perceptions of classroom environment. Fraser saw these questionnaires as having the dual advantage of, firstly, characterising the setting through the eyes of the participants themselves and, secondly, capturing data which an observer could miss or consider unimportant.

Rickards and Fisher (1999) considered that recent reviews (Fraser, 1986, 1994; Fraser & Walberg, 1991) showed that science education researchers had led the world in the field of classroom environment over the last two decades, and that this field had contributed much to understanding and improving science education, providing a means, for example, of monitoring, evaluating and improving science teaching and curriculum.

In light of the wide acceptance that questionnaires have gained as classroom research instruments it was considered that a questionnaire was an appropriate tool to develop and use in the current research study, firstly, to measure the extent to which inquiry teaching occurred in Tasmanian science classrooms and, secondly, to gauge both student and teacher preferences in this area.

The format of the questionnaire developed was based on that of previous learning environment questionnaires. In particular, the nine major such questionnaires described by Fraser (1998) were considered. These are the *Learning Environment Inventory* (*LEI*) (Fraser, Anderson, & Walberg, 1982), *Classroom Environment Scale* (*CES*) (Moos & Trickett, 1987), *Individualised Classroom Environment Questionnaire* (*ICEQ*) (Fraser, 1990), *My Class Inventory* (*MCI*) (Fraser, Anderson, & Walberg, 1982), *College and University Environment Inventory* (*CUCEI*) (Fraser, Treagust, & Dennis, 1986), *Questionnaire on Teacher Interaction* (*QTI*) (Wubbels, Brekelmans, & Hooymayers 1991), *Science Laboratory Environment Inventory* (*SLEI*) (McRobbie & Fraser, 1993), *Constuctivist Learning Environment Survey* (*CLES*) (Taylor, Fraser, & Fisher, 1997),and *What is Happening in This Class* (*WIHIC*) (Fraser, Fisher, & McRobbie, 1996) surveys.

Whilst a number of authors have reported using existing instruments to carry out their learning environment research (for example, Kim, Fisher, & Fraser, 1999, Rickards & Fisher, 1999, Henderson, Fisher, & Fraser, 2000), the world of classroom environment questionnaires is a dynamic one, with the ongoing production and modification of questionnaires by different authors in order to develop an instrument that meets their particular needs (for example, Fisher & Waldrip, 1997, Waldrip & Fisher, 2000, Fraser, Treagust, & Dennis, 1986). Additionally, a number of authors have reported on the modification and validation of new forms of existing questionnaires, or on applying them in new situations (for example, Taylor, Fraser, & Fisher, 1997, Nair &Fisher, 2000).

In developing the questionnaire to be used for the current research project, the experiences of other workers in the learning environments field were used to help make decisions relating to factors such as: the number of scales and items to be included; the number of response choices to be included; development of Actual and/or Preferred Forms; the use of class or personal items; and the inclusion of negative items.

Fraser (1986) identified three general steps in the development and validation of such a questionnaire - identification of salient dimensions, item writing, and field testing and item analysis. These are the steps which were followed in the development of the instrument to be used in this research, which has provisionally been titled the *Is This an Inquiring Classroom? (ITIC)* questionnaire.

4.2 SCALES FOR AN INSTRUMENT DESIGNED TO MEASURE INQUIRY

4.2.1 Introduction to the Scales

Information obtained in the literature review, which was reported in the preceding chapters, was used to identify suitable scales and to write suitable items for the questionnaire that was developed. For economy, it was desirable to develop an instrument with a relatively small number of reliable scales, each containing a fairly small number of items. On the basis of the literature review it was decided that the questionnaire developed should have six scales, and that twelve items would initially be developed for each of these six scales. More items than would be required for the final version of the questionnaire were developed, in order to allow for the deletion of items which did not perform well during the validation statistical analysis.

The objective in developing the Is This an Inquiring Classroom? (ITIC*)* questionnaire was to produce an instrument that would measure the extent to which teachers actually use inquiry in their classrooms. On the basis of what the literature reported about inquiry teaching the six scales shown in Table 4.1 were developed.

The order in which these six scales are presented is not intended to relate to their importance in any way. Titles for the scales have been deliberately kept brief, and the intent of each of the scales is outlined more fully in the following discussion.

Table 4.1
Descriptive Information for Each Scale of the ITIC Questionnaire.

Scale	**Scale Description**
Open-endedness	Extent to which the laboratory activities emphasise an open-ended divergent approach to experimentation.
Discussion	Extent to which discussion of ideas occurs in the classroom.
Assessment	Extent to which assessment procedures emphasise process skills rather than memorisation of knowledge.
Scientific Method	Extent to which students are provided with the opportunity to develop critical thinking skills through the processes of the scientific method.
Historical perspectives /use of stories	Extent to which historical perspectives and stories are used in the class.
Uncertainty	Extent to which scientific knowledge is presented as being tentative and subject to change.

4.2.2 Scale 1: Open-endedness

The Open-endedness scale assesses the degree of independence which students are given in practical / laboratory work. As such, it partially consists of items taken or modified from the SLEI (Science Laboratory Environment Inventory) Questionnaire’s Open-Endedness scale described by Fraser, McRobbie, and Giddings (1993). This SLEI scale attempts to measure the extent to which laboratory activities emphasise an open-ended, divergent approach to experimentation. Consideration was given to extending this scale to make it more like the Investigation scale of the ICEQ (Individualised Classroom Environment Questionnaire), which is described, for example, by Fraser (1994), and which takes investigations other than practical work into account. However, it was felt that some items in this ICEQ scale really fitted better into the Scientific Method scale of the current instrument. Items in this scale also broadly reflect the planning and design section of the Laboratory Analysis Inventory (LAI) developed by Tamir and Lunetta (1978), and presented in a modified form by Tamir (1989).

An extensive literature exists on the role of school science laboratories, much of which was reviewed by Hofstein and Lunetta (2003). Aspects of this literature are relevant to the development of the Open-endedness scale. Hofstein (2004) noted that whilst during the reforms of the 1960s the laboratory became the centre of science teaching and learning, the development of the *National Science Education Standards* and related literature emphasised the importance of rethinking the role and practice of laboratory work. To some extent, the Open-endedness scale attempts to pick up on what at least part of the role of laboratory work should be.

Articles by Hofstein, Shore and Kipnis (2004) and Hofstein, Navon, Kipnis and Mamlok-Naaman (2005) report on the results of a study in which a number of what are termed *inquiry-type* experiments were developed and implemented in Grade 11 and 12 Chemistry classes in Israel. The abilities and skills the experiments measured were:

- conducting an experiment
- observing and recording instructions
- asking questions and hypothesising
- planning an experiment
- conducting the planned experiment
- analysing the results, asking further questions, and presenting the results n scientific way

A number of these items are relevant to the Open-endedness scale, whilst the last one fits more with the Scientific Method scale. The above studies concluded that chemistry students who were involved in the inquiry activities were able to ask more and better questions regarding chemical phenomena and also that they developed the ability to also ask questions in non-experimental learning situations, such as reading scientific articles.

As practical work is an important component of inquiry teaching, it seemed justified to include a scale which looked only at this aspect. Throughout the literature discussed in Chapters 2 and 3 there is a theme of inquiry teaching requiring that students have to be given the opportunity to investigate their own ideas and problems, so a scale that gathered information about the degree to which this occurred seemed to be mandatory.

4.2.3 Scale 2: Discussion

A recurring theme in the literature is that of inquiry teaching aiming to give students a deeper understanding of scientific concepts, rather than just requiring that they memorise facts and concepts. If students are to develop such understanding most effectively they must have the opportunity to discuss their ideas with others. As Roth and Roychoudhury (1993) noted, in trying to convince others students had to verbalise and make explicit that which was most often left implicit. This required that students examined their own comprehension in detail, so making them more aware of any inadequacies in their own frameworks. McRobbie and English (1993) noted that concern was increasingly being expressed about students' levels of understanding of scientific concepts, and, from both their own work, and from the studies of others, concluded that effort needed to be made to develop the appropriate skills of argument in children.

Lowery and Leonard (1978) considered that questions are stimuli to inquiry, and noted that this opinion had also been expressed by other authors. It would seem that a discussion is a natural forum for appropriate questions to arise in. Germann et al. (1996) cite Bereiter (1994) as stating that the scientific community engages in a progressive discourse to advance scientific knowledge. This can still be regarded as the general model by which scientific knowledge advances - although it has been suggested that commercial interests have tended to lead to a situation where the old academic adage of *publish or perish* has to some extent moved to one of *publish at your peril* - and illustrates the importance of discussion in any scientific arena.

Additionally, from the social constuctivist viewpoint described by Maor and Taylor (1995) discussion is seen as being valuable as it can prompt the learner to ask questions such as:

- Are the solutions of others viable?
- Are they equally as viable as my solutions?
- What are the reasons for differences in my explanations and those of others?

Asking such questions must be regarded as true inquiry.

The thinking outlined above led to the inclusion of what has been termed the *Discussion* scale in the present questionnaire.

A number of questionnaires were found to have scales which contributed useful items or ideas to the construction of this scale. One of these was the Learning to Communicate scale of the 1994 version of the CLES (Constructivist Learning Environment Survey), which was subsequently referred to as the Student Negotiation scale by Taylor, Fraser, and Fisher (1997). Another was the Involvement scale of the WIHIC (What is Happening in this Class?) questionnaire described by Fraser, Fisher, and McRobbie (1996). The ICEQ Participation scale also related to discussion, as did the CUCEI (College and University Environment Inventory) Involvement scale (Fraser, 1994, provided some background information about the CUCEI). In practice, it may have been possible to use any one of these scales in its entirety as the discussion scale for the Is This an Inquiring Classroom? questionnaire. However, a mixture of these items was selected, with the choices made being based on the perceptions and preferences of the researcher as much as on any other factor.

The number of questionnaires which include discussion scales in one form or another points to the importance which is placed on this aspect of classroom environment, and the literature previously outlined points to it being of particular relevance in inquiry teaching.

4.2.4 Scale 3: Assessment

The Assessment scale measures the extent to which assessment tasks which students are set require merely that they recall facts which they have been able to memorise by rote. Such assessment is not in line with inquiry teaching, and is a factor which actually works against the use of inquiry methods, as was pointed out, for example, by Tobin et al. (1990). Bol and Strage (1996) cited Linn (1990) as commenting that lofty instructional goals which encouraged understanding and critical thinking were undermined by test items emphasising recognition of factual details, and continued on to cite a number of other studies which indicated that many test items emphasised memorisation rather than understanding.

The ongoing debate about assessment is one that has been referred to extensively in preceding sections, for example, in the comments of John Dewey.

Items within the assessment scale aim to measure factors such as the extent to which teachers set test questions which cannot be answered by rote memorisation, or, rather, set assessment tasks which involve critical thinking skills.

4.2.5 Scale 4: Scientific Method

The Scientific Method scale aims to measure the extent to which students develop critical thinking skills through processes which are commonly associated with the term scientific method, such as hypothesising, interpreting, generalising, predicting and problem-solving. Given the emphasis placed on these skills by numerous of the authors who have advocated an inquiry approach, it was considered essential to include a scale which attempted to measure the extent to which active development of these skills is actually encouraged in the classroom situation - for as Zohar, Weinberger, and Tamir (1994) noted, it seems that critical thinking skills do not develop unless explicit and deliberate efforts are invested in developing them.

Despite the call for science classrooms to incorporate activities which develop critical thinking skills, and which will thus allow students to function effectively in the future, it seems likely that, as Aubusson (1994) found, many teachers still tend to emphasise the teaching of knowledge despite espousing other ideas.

Aubusson's comments seem to indicate that little has changed since Hurd (1969) commented that the emphasis that teachers placed on knowledge was a problem in science classrooms. Hurd pointed out that facts, in and of themselves, do not make a science, with a science not simply being an abstraction from empirical data, but rather an intellectual creation often suggested by the data. He said that it was the discovery of order among the data that made the science, and that this process required a constructive imagination, intuition and an intellectual command of relevant concepts. The scientific method scale of the ITIC will attempt to assess the extent to which at least the first two of these parameters occur in science classrooms.

Existing instruments which provided useful items and ideas for this scale were the ICEQ Investigation scale, the What is Happening in this Class? Investigation scale and the Laboratory Analysis Inventory's Analysis and Interpretation items. The analysis and interpretation section of the Laboratory Analysis Inventory presented by Tamir (1989) also provided ideas.

4.2.6 Scale 5: Historical Perspectives/ Stories

The inclusion of the Historical perspectives/stories scale may seem strange to some readers, but this scale is important as one of the aims of an inquiry approach is to let students see the development of scientific thought. As it is more innovative than the other ITIC scales the Historical perspectives/Stories scale is considered in more detail at this juncture.

The use of stories and historical developments also represents a teaching strategy which may succeed in making science and scientists more real to students, and which may be of particular importance to girls and some other minority groups.

Ziman (1981) wrote of the impact a book on microbiologists which he read as a child had on him. He wrote that even though he went into the areas of mathematics and physics he had retained an affection for that book, saying that what it told him about the scientific life has not been falsified by his own experience - that science is intensely exciting, and that scientists are very much human beings. If one of the aims of inquiry teaching is to instil and maintain a sense of excitement, involvement and wonder, then it is desirable that more children are captured by stories such as these.

In his autobiographical book *Uncle Tungsten*, Oliver Sacks (2001) who went on to become a neurologist and author tells of how the history of science and scientists fascinated him as a child. He also quotes the chemist Cannizzarro who addressed a gathering of chemists at the first ever international chemical meeting in Karlsruhe in 1860. (Cannizzaro's greatest contribution to chemistry was reportedly his revival of the work of Avogadro. His paper *Sketch of a Course of Chemical Philosophy*, presented to the Karlsruhe conference, led to the recognition of the distinction between atomic and molecular weights. He suggested that since hydrogen is the lightest of all gases, the weight of half a hydrogen molecule should be used as the standard to which all other weights were compared. http://www.carlton.paschools.pa.sk.ca/chemical/molemass/cannizar.htm, retrieved August 18 2004.) Sacks stated that Cannizzaro felt very passionately that the history of chemistry needed to be in the minds of his students, and that in what Sacks considerd a beautiful essay (although Sacks omits to provide a reference for it) on the teaching of chemistry Cannizzaro concluded:

> It often happens that the mind of a person who is learning a new science, has to pass through all the phases which the science itself has exhibited in its historical revolution. (Sacks, 2001, p. 155)

Sacks considered that this was the situation for him as a child growing up in post-war England as he repeated the experiments he read about.

Such anecdotes demonstrate that learning about historical perspectives and the lives of scientists can have a great impact on students' thoughts about science and scientific thinking from an early age.

More anecdotally still, whilst working on the development of the Is This an Inquiring Classroom? questionnaire the researcher was involved in discussions with a group of teachers from varying disciplines about the *Wide Range Readers* green and blue books which were used by primary school children in Tasmania during the 1960s, and which all these teachers had been exposed to during their own primary school education. Individual teachers, including the researcher, recalled the stories these books had introduced them to about people such as Marie Curie (Schonell and Flowerdew, 1961) and events such as Halleys Comet (not to mention Alfred who burnt the cakes, and Robert who watched the spider), and which they have remembered for more years than they would care to admit to! As these books have been abandoned in favour of literature which is regarded as better meeting the needs of today's children, the teachers involved in the discussion wondered where, or if, children of today meet such stories - stories which captured the imaginations of a previous generation and possibly influenced their future career paths.

On a similar note to what Sacks reported about the ideas of Cannizzaro, Driver (1983) reminded us of the similarity between the ideas of children and the thinking of earlier scientific theories. This suggests that children should be given an historical perspective in order to help them see problems associated with their personal theories / conceptual model. Matthews (1990) commented on the need for more history and philosophy of science to be included in current science courses, noting that there is a bond of sympathy between the beginner and the pioneer.

Dawson (1994) considered that few upper level Australian high school students understood what science was trying to do, or how it proceeded, and that a number of students perceived science as not to do with people and not creative. Such attitudes are not in line with inquiry teaching, and including more stories about scientists could help to dispel this view. As Sutton (1994) suggested, science should be the study of what people have said and thought about nature, leading to an understanding of the system of meaning which people have built up. Milne (1998) considered that there were problems with the ways science stories were often told, but still suggested that if we wish to involve students more in thinking about the enterprise that we call science we would do well to tell stories that emphasise the human aspects of the development of scientific knowledge.

The above suggests that there seems to be general agreement that stories and a historical perspective are important in involving students in science - and such involvement is necessary for an inquiry approach to be successful. Kirkham (1989) perhaps summarises this best in reiterating the comment that the history of science reveals the tensions, misunderstandings, ambiguities, and inadequate conceptual models which have existed in the scientific community.

The Learning about Science (or Uncertainty of Science) scale of the CLES provided some thoughts for the development of suitable items for the Historical Perspectives/Stories scale of the Is This an Inquiring Classroom? questionnaire, although some of the CLES items related more to the following Uncertainty scale. Items from the content analysis presented by Tamir (1985) were also useful.

4.2.7 Scale 6: Uncertainty

The final scale to be considered for the Is This an Inquiring Classroom? questionnaire is Uncertainty. Although it may be suggested that this relates to the Discussion and Scientific Method scales, it in fact looks at something different. The aim of this scale is to measure the extent to which scientific knowledge is presented as being tentative and subject to change. These are factors which the literature has mentioned as being important if students are to develop critical thinking skills and thus be prepared to accept future changes in scientific thinking. It is therefore an important concept to introduce when using inquiry methods.

In discussing curriculum reform Hurd (1969) saw a problem with high school science courses as being that the subject was frequently taught as dogma, with the imperfections of knowledge seldom being pointed out. He considered that students left courses considering that they now had the answers - or worse still that it must have been fun in the good old days when there were still opportunities to make discoveries in nature. He said that students were not aware that there may be several acceptable explanations for an observation and that the choice was open to select the one most useful or satisfying at the moment - in science good answers are most likely those illuminated by a theory but there are no right answers. Hurd stated that the teaching of high school science courses kept the revisionary nature of science essentially a secret, with few lessons planned to illustrate science as a dynamically changing system of concepts and theories.

Some items from the CLES Learning about Science (Uncertainty of Science) scale were deemed suitable for use in developing the Uncertainty scale of the Is This an Inquiring Classroom? questionnaire. Some items from the content analysis provided by Tamir (1985) were also useful for formulating this scale.

4.3 ITEMS CONTAINED IN EACH SCALE

The items initially developed for each scale are shown in this section. Further development work, as described in the following sections, was needed before this questionnaire could be used in classrooms to make assessments of the extent to which teachers are utilising methods consistent with inquiry teaching.

At this stage each scale included more items than would be appropriate for the final questionnaire as it was expected that some would be found to be unreliable in the validation process.

As has been mentioned, some of the items included have been taken, or modified, from existing instruments, such as the SLEI, ICEQ, CLES, CUCEI and WIHIC questionnaires. The remainder were developed using the literature which has been previously discussed as a basis for determining suitable items. Some useful ideas were also gained from the transmission-interpretation scale of Gardner and Taylor (1980), which although not intended primarily for science classrooms, looked at differences between transmissionist teachers (who would represent a more traditional approach) and interpretative teachers (who would be more representative of an inquiry approach). The CES (Classroom Environment Scale) questionnaire, the development of which is summarised by Fraser (1994) also had a few items which were relevant.

With respect to inquiry in particular, the work of Tamir (1985, 1989) provided some useful insights.

4.3.1 Initial Items for Scale 1 - Open-endedness.

The 12 initial items that were developed for the Open-endedness scale are listed below. Each begins with the same leader, *In this class*.

In this class . . .

1. There is opportunity for us to pursue our own science interests.
2. We are required to design our own experiments for a given problem.
3. In laboratory work students collect different data from each other for the same problem.
4. We are allowed to go beyond the regular laboratory exercise and do some experimenting.
5. In our laboratory sessions some students do different experiments to others.
6. In our laboratory sessions, the teacher decides the best way for us to carry out the laboratory experiments.
7. We decide the best way to proceed during laboratory experiments.
8. We carry out laboratory investigations to test ideas which we come up with.
9. We carry out laboratory investigations to answer questions which arise in class discussions.
10. We carry out investigations to answer questions which puzzle us.
11. All students do exactly the same experiments.
12. We have to select which equipment to use for practical work.

4.3.2 Initial Items for Scale 2 - Discussion

The twelve initial items that were developed for the Discussion scale are listed below. Each begins with the same leader, *In this class*.

In this class . . .

1. We discuss the results we have obtained with each other.
2. We comment on other students’ opinions.
3. We talk to other students about our work.
4. We ask the teacher questions.
5. We discuss things which people have different opinions about.
6. We talk with other students about how to solve problems.
7. Our ideas and opinions are used during classroom discussions.

8. We explain our ideas to each other.
9. We pay attention to what other students are saying.
10. The teacher talks rather than listens.
11. Most students take part in discussions.
12. We sit and listen to the teacher without asking or answering questions.

4.3.3 Initial Items for Scale 3 - Assessment

The twelve initial items that were developed for the Assessment scale are listed below. Each begins with the same leader, *In this class*.

In this class . . .

1. We are allowed to use textbooks or notes when we are doing tests.
2. We have to memorise a lot of information.
3. We take a lot of theory notes.
4. Our tests have questions where we have to interpret data.
5. Our tests only have questions which we can memorise the answers to.
6. We have to really understand the work which we have done in order to answer the test questions.
7. Our teacher is more interested in checking that we have the right answer than in our thinking and reasoning.
8. If you want to do well, the most important thing is to memorise information for tests.
9. We do assignments where we have to think things out.
10. We can find the answers to most of the assignment questions we are set in library books.
11. The teacher will mark different answers to a question as being equally correct.
12. There is usually only one right answer which our teacher will accept to questions.

4.3.4 Initial Items for Scale 4 - Scientific Method

The twelve initial items that were developed for the Scientific Method scale are listed below. Each begins with the same leader, *In this class*.

In this class . . .

1. We have to try to explain the results of our investigations.
2. We are asked to suggest how we could improve the investigations which we have carried out.
3. We are asked to form our own hypotheses.
4. We are asked to apply ideas to new situations.
5. We have to analyse data.
6. We are asked to suggest further research which could be carried out.
7. We are asked to criticise the investigations which we have carried out.
8. We are asked to predict the results of experiments.
9. We are asked to make generalisations from data.
10. We draw conclusions from investigations.
11. We are asked to think about the evidence for statements.
12. We are asked to explain the meaning of statements, diagrams and graphs.

4.3.5 Initial Items for Scale 5 - Historical Perspectives/ Stories

The twelve initial items that were developed for the Historical Perspectives/Stories scale are listed below. Each begins with the same leader, *In this class*.

In this class . . .

1. As we study different topic we talk about the history of how these ideas have developed.
2. We learn about the history of science.
3. We learn about scientists.
4. The teacher tells us stories about science.
5. We talk about scientists and researchers who have worked in the area which we are studying.
6. We look at what people who are working as scientists do.

7. When we study a topic we are told about the trouble which scientists have had working things out.
8. The names of scientists are mentioned during lessons.
9. We learn about how people came to make scientific discoveries.
10. We are told personal information about what scientists were like.
11. We watch videos about the work and lives of scientists.
12. We learn that modern science is different from the science of long ago.

4.3.6 Initial Items for Scale 6 - Uncertainty

The twelve initial items that were developed for the Uncertainty scale are listed below. Each begins with the same leader, *In this class*.

In this class . . .

1. We learn about alternative theories for the same scientific idea.
2. We learn that scientists do not know how some things work.
3. Scientific knowledge is presented as being incomplete - there are things which are still not understood.
4. We learn that scientific information can change.
5. Our teacher expresses their own uncertainty about whether some scientific ideas are correct.
6. We learn that science has answers for everything.
7. We learn that once scientists have proven something their ideas will not change.
8. We learn that people can have different theories to explain the same thing.
9. We learn that science *cannot* provide perfect answers to problems.
10. We learn that science has changed over time.
11. We learn that science is influenced by people’s values and opinions.
12. We learn that science is about *inventing* theories.

4.3.7 Other Considerations in Item Writing

As mentioned earlier, Fraser (1986) identified the three general steps in the development and validation of instruments such as the Is This an Inquiring Classroom? questionnaire being developed here as: identification of salient dimensions, item writing, and field testing and item analysis. The development of the Is This an Inquiring Classroom? questionnaire, to this point in writing, reflects the first two of these steps. Extensive work was still needed to fulfil the requirements of the third step. The ITIC instrument may be regarded as containing what Fraser described as intuitive-rational scales. In the case of instruments using intuitive-rational scales the initial identification and definition of the dimensions are based primarily on the investigator's intuitive understanding of the dimensions to be assessed. This is in contrast to intuitive-theoretical scales, in which nomination to scales is based on some formal educational or psychological theory. Whilst inquiry teaching methods could be considered to constitute an educational theory, the basis of inquiry teaching was not considered to be formalised and generally agreed on to a sufficient extent to be regarded as a formal educational theory.

A further idea which needs to be considered in the development of items for a questionnaire such as this is whether the items should be written in a personal or class form. Aldridge and Fraser (1997) commented on the uses of these two forms, noting that other studies have remarked on the inability of existing questionnaires to identify subgroups within a class (if a class rather than a personal from is adopted for the questionnaire). Whilst consideration has been given to this idea in developing the present Is This an Inquiring Classroom? questionnaire, it was decided that it is what is happening in the class as a whole which is most important in determining whether inquiry teaching strategies are being used. For example, a particular student may take little part in discussions which occur in the classroom, but could still note and report that considerable discussion is occurring. With regard to determining the extent to which inquiry teaching is being implemented it was considered more important that the discussion was occurring than that some students do not participate - although, obviously, if too many students do not participate this could indicate that the strategy is not in fact an effective one. A possible strategy was to develop both class and personal forms, as has been the case with the WIHIC, so that teachers can choose the one most appropriate to their ends. However, it was decided that this may confuse rather than assist teachers and a single version using the class form was adopted.

4.4 LAYOUT OF THE *IS THIS AN INQUIRING CLASSROOM?* QUESTIONNAIRE

There are several important considerations to be made when designing the layout for an instrument such as the Is This an Inquiring Classroom? questionnaire. Firstly, its format must be readily accessible to teachers and, more importantly, students. If either of these groups have difficulty working out what the questionnaire requires them to do the researcher will end up with unreliable results. Secondly, the format of the questionnaire should make it relatively easy for the researcher or their assistants to access the information that they need in order to analyse their results and draw conclusions.

Fraser (1986) suggested several methods for facilitating the handscoring of questionnaires. In designing the physical layout of this questionnaire, the strategy of underlining items which need to be reverse scored has been adopted. The suggestion of Taylor, Fraser, and Fisher (1997), that all items belonging to a particular scale be placed together in order to contextualise items for participants, has also been employed. It seemed useful to adopt the strategy of grouping similar items together, firstly, so that people seeing the questionnaire for the first time could get a better idea of the nature of the different scales and, secondly, and perhaps more importantly, so that individuals answering the items had their thinking focussed on a particular aspect of their classroom environment, rather than being asked to consider one area, then something completely different, only to have to return to the previous one for a future item.

In line with what seem to be current trends, no particular attempt was made to include a certain number of negative items. The *CLES*, for example, contains no negative items. However, some such items were deemed appropriate where their wording was not confusing. Personal experience also informed this decision. Experienced teachers of above average academic ability and literacy skills sometimes report finding negative questionnaire items confusing, so including them in questionnaires which will be used with students of a range of abilities seems to be inviting trouble. After all, the aim of a learning environment questionnaire is to determine students’ perceptions of their classroom environment, not to test their mastery of the English language.

A feature of the Is This an Inquiring Classroom? questionnaire which differentiates it from many similar questionnaires is that preferred and actual answers have been included on the same recording sheet. Whilst it was thought that this may cause slight confusion in the way some items were worded, it was considered that this modification might provide more accurate results for comparisons to be made between what students and teachers perceived was happening in their classroom and what they would prefer. The reasoning behind this is that the choice of the number to mark on a questionnaire is sometimes arbitrary (for example in deciding if a particular event occurs often or very often). When the person comes to the second form of the questionnaire they may have forgotten what they chose initially, but if they fill both their preferred and actual choices in at the same time they can indicate accurately what they see as being the relative difference between the two, and so avoid inconsistencies. This state of affairs is something which the researcher has noted from personal experience of completing questionnaires for other researchers. Adopting the option of placing the Preferred and Actual Forms of the questionnaire on the same sheet has the additional advantage of reducing paperwork.

In completing the ITIC, students were asked to respond to each item on a five point scale which had the extreme alternatives of *strongly agree* and *strongly disagree*. The numerals 1 through 5 were listed next to each item under the *Actual* column and repeated under the *Preferred* column. Students were asked to circle their selection in each column, indicating the extent to which they agreed that each item described their science classroom. This occurred on the paper that listed the questionnaire items rather than on a separate answer sheet. It was thought that adopting this technique was likely to reduce transcription errors, as the person answering the item would be less likely to circle a response corresponding to an item other than the one that they intended.

The layout of the ITIC can be seen from the copies reproduced in the Appendices of this thesis.

4.5 CRITIQUE OF THE INITIAL VERSION OF THE QUESTIONNAIRE

4.5.1 The Critiquing Teachers

In order to get around the phenomenon of what might perhaps be termed *researcher blindness* - the fact that the person developing the instrument may have become so familiar with their instrument and what it is aiming to achieve that they become blind to what others may see as glaring faults with it - a group of experienced teachers were asked to critique the initial version of the ITIC questionnaire prior to its use and validation with students.

A group of five teachers kindly agreed to assist in the critiquing process. This group consisted of two males and three females, all of whom were currently employed in the Tasmanian government education sector. Their science teaching experience ranged from seven to over twenty years and all were committed exponents of the science subject area. All but one of the teachers had experience in both high school and college situations in Tasmania.

4.5.2 Instructions to Critiquing Teachers

This group of teachers were all sent a copy of the initial version of the Is This an Inquiring Classroom? questionnaire, included here as Appendix 1, together with a list of the items that had been written for each scale in the format shown in Section 4.3, as the latter format allowed them more space to make any changes and comments. The version of the questionnaire supplied to these teachers included the name of the questionnaire, but each of the scales was simply given a number rather than a name/title. Teachers were also supplied with a short statement outlining the objectives of the research project, as shown in Appendix 2.

The critiquing teachers were asked to:

- Suggest an appropriate name for each of the six scales that had been developed. This was so as to see if these experienced teachers saw each of the scales as measuring the factors that the researcher intended them to.
- Identify any items which they thought that students might find difficult to understand, and suggest how these items could be modified so as to be more easily understood by students. This process was designed to ensure that the items used on the questionnaire were accessible to students, so that the questionnaire would in fact provide an accurate picture of how students perceived their classroom environment.

4.5.3 What the Critiquing Teachers Said

The names that the group of teachers came up with for each of the six scales are shown in Table 4.2, which also shows the names that the researcher had designated for each of the scales.

Table 4.2
Scale Names Designated by Researcher Compared to Scale Names Suggested by Critiquing Teachers.

Scale	Researcher designated name	Teacher suggested name
1	Open-endedness	Experimental/Practical Work
2	Discussion	Classroom Communication/Discussion
3	Assessment	Assessment
4	Scientific Method	Interpretation of Data
5	Historical Perspectives / Stories	Science Stories
6	Uncertainty	Uncertainty in Science

The researcher felt that the scale names suggested by the teachers were in the spirit of the names that had previously been designated, and in some cases provided a better descriptor. Consequently, some scale names were modified following the teacher input. The final scale names are listed in Table 4.3 below.

Table 4.3

The Six Final Scale Names for the Is This an Inquiring Classroom? Questionnaire.

Scale number	Final scale name
1	Freedom in Practical Work
2	Communication
3	Assessment
4	Interpretation of Data
5	Science stories
6	Uncertainty in Science

With regard to the accessibility of the various questionnaire items to students, the critiquing teachers made the following particularly significant comments and suggestions:

- Replace, what they regarded as the Americanised term *laboratory work* with the term *practical work*, as the latter is the one commonly used in the Tasmanian context. This is an excellent example of the need to have other experienced individuals read questionnaire items. The researcher knew that what the teachers pointed out was indeed the case, but had themself become familiarised with the term laboratory work as a consequence of extensive reading of literature, much of which had originated in the USA.

- In a similar vein to the above, replace the term *investigations* with the term *experiments,* as the critiquing teachers believed this to be the one more commonly used in Tasmanian schools.

- Some items seemed to be saying basically the same thing, but in different words, so are both necessary? Once the researcher explained that some items would be removed in the validation process the critiquing teachers saw why this apparent duplication occurred.

- Change the term *memorise* to *remember* or *learn by heart,* as the latter are the terms that students use.

- Item 42 (item 4 of Scale 4) would be hard for students to understand.

- Item 65 (Item 7 of scale 6) provoked some discussion as it contained the term *proven*. It was considered that it would be best to remove this term in discussing the work of scientists.

Overall, the critiquing teachers said that they were satisfied that the items that appeared in the questionnaire were accessible to the majority of high school students, including those in Grade 7. Their main suggestions were as above, together with simplifying the language of the questionnaire as much as possible, so that items had less of a scientific voice about them.

There was a little discussion over terms such as data, interpret, hypothesis, generalisation, justify and theories, but the group's conclusion was that these were terms that students should have become familiar with in their science course. The group came up with, and was enthusiastic about, the idea of teachers discussing these terms with students immediately prior to giving the questionnaire, and thus combining some literacy work with the science lesson. Although the researcher could see the merit of this suggestion they did not feel that this was a practical suggestion given the large number of different classes that the questionnaire would finally be used with - there was no guarantee that all teachers who agreed to their classes participating would also be prepared to conduct the literacy exercise.

In line with the other suggestions made by the critiquing teachers, the initial version of the survey was modified and the *Is This an Inquiring Classroom? Preliminary* questionnaire was formulated. This preliminary questionnaire is included as Appendix 3. Again, for continuity in reading, the scale items are listed below.

4.6 THE REVISED QUESTIONNAIRE ITEMS FOR THE PRELIMINARY QUESTIONNAIRE

4.6.1 Preliminary Questionnaire Scale 1 - Freedom in Practical Work Items

In this class . . .

1. There is opportunity for us to find out about things that interest us in Science.
2. We are asked to design our own experiments.
3. In practical work students collect different data from each other for the same problem.
4. We are allowed to extend the practical work and do some experimenting.
5. In our practical sessions some students do different experiments to others.
6. In our practical sessions, the teacher decides the best way for us to carry out the experiments.
7. We decide the best way to proceed during experiments.
8. We carry out experiments to test ideas which we come up with.
9. We carry out experiments to answer questions which arise in class discussions.
10. We carry out experiments to answer questions which puzzle us.
11. All students do exactly the same experiments.
12. We have to select which equipment to use for practical work.

4.6.2 Preliminary Questionnaire Scale 2 - Communication Items

In this class . . .

1. We discuss the results we have obtained with each other.
2. We comment on other students’ opinions.
3. We talk to other students about our work.
4. We ask the teacher questions.
5. We discuss things which people have different opinions about.
6. We talk with other students about how to solve problems.
7. Our ideas and opinions are heard during classroom discussions.
8. We explain our ideas to each other.
9. We pay attention to what other students are saying.
10. The teacher listens to our ideas.
11. Most students take part in discussions.
12. We sit and listen to the teacher without asking or answering questions.

4.6.3 Preliminary Questionnaire Scale 3 - Assessment Items

In this class . . .

1. We are allowed to use textbooks or notes when we are doing tests.
2. We have to remember a lot of information.
3. We take a lot of notes.
4. Our tests have questions where we have to interpret data.
5. Our tests only have questions which we can memorise the answers to.
6. We have to really understand the work which we have done in order to answer questions on tests.

7. Our teacher is more interested in checking that we have the right answer than in our thinking and reasoning.
8. If you want to do well, the most important thing is to learn off by heart for tests.
9. We do assignments where we have to think things out.
10. We can find the answers to most of the assignment questions we are set in library books.
11. The teacher will mark different answers to a question as being correct.
12. There is usually only one right answer for each question.

4.6.4 Preliminary Questionnaire Scale 4 - Interpretation of Data Items

In this class . . .

1. We have to try to explain the results of our experiments.
2. We are asked how we could improve the experiments we have done.
3. We are asked to form our own hypotheses.
4. We are asked to apply ideas to new situations.
5. We have to interpret data.
6. We are asked to suggest further research which could be carried out.
7. We are asked to criticise the experiments which we have carried out.
8. We are asked to predict the results of experiments.
9. We are asked to make generalisations from data.
10. We draw conclusions from experiments.
11. We are asked to justify our conclusions.
12. We are asked to explain what statements, diagrams and graphs mean.

4.6.5 Preliminary Questionnaire Scale 5 - Science Stories Items

In this class . . .

1. As we study different topics we talk about the history of how science ideas have developed.
2. We learn about the history of science.
3. We learn about scientists.
4. The teacher tells us stories about science.
5. We talk about people who have worked in the area which we are studying.
6. We look at what people who are working as scientists do.
7. When we study a topic we are told about the trouble which scientists have had working in this area.
8. The names of scientists are mentioned during lessons.
9. We learn about how people made scientific discoveries.
10. We are told personal information about what scientists were like.
11. We watch videos about the work and lives of scientists.
12. We learn that modern science is different from the science of long ago.

4.6.6 Preliminary Questionnaire Scale 6 - Uncertainty in Science Items

In this class . . .

1. We learn about different theories for the same scientific idea.
2. We learn that scientists do not know how some things work.
3. Scientific knowledge is presented as being incomplete - there are things which are still not understood.
4. We learn that scientific information can change.
5. Our teacher questions some scientific theories.

6. We learn that science has answers for everything.
7. We learn that once scientists have come up with an idea, this idea will ***no***t change.
8. We learn that people can have different theories to explain the same thing.
9. We learn that science *cannot* provide perfect answers to problems.
10. We learn that science has changed over time.
11. We learn that science is influenced by people's values, opinion and beliefs.
12. We learn that science is about coming up with ideas.

Following these revisions, the Preliminary Questionnaire was ready for the validation process. Before it could be used in Tasmanian government schools it was necessary to seek permission from the Department of Education, Tasmania. Ethical considerations in the use of the Is This an Inquiring Classroom? questionnaire are outlined in the next section.

4.7 ETHICAL CONSIDERATIONS IN USING THE QUESTIONNAIRE

Ethical considerations which needed to be taken into account during the conduct of this research related largely to the information which would be obtained through the administration of the questionnaire.

Whilst the nature of the data was such that it was unlikely to be regarded as particularly sensitive, a number of precautions were taken to protect the interests of persons who were kind enough to be of assistance.

Firstly, normal Department of Education, Tasmania procedures were followed to gain permission to undertake this research in Tasmanian government schools. This involved submitting details of the proposed research along with details of the numbers of schools and students that would be asked to participate for consideration by the relevant departmental committee.

Once the Department of Education had granted permission for the research to be undertaken in Tasmanian government schools, as requested, it was also necessary to approach individual school principals to obtain permission for teachers and students from their particular school to participate. Teachers were asked to volunteer to involve themselves and their classes. All school principals approached were prepared to grant this permission provided that the teachers concerned did not have any issues with their classes being involved. All teachers or Science Department Coordinators approached agreed to their classes being involved in completing the Is This an Inquiring Classroom? questionnaire.

In seeking permissions from teachers they were told that the research would involve students completing questionnaires and giving their views on actual and preferred classroom environments. As the information to be collected related to classroom environment and the manner in which students preferred material to be presented, and questionnaires were anonymous, written permission from parents was not required for students to complete the questionnaires. Schools were offered the opportunity to be provided with a brief synopsis of the research that they could include in their school newsletter or similar publication if they wished, but none elected to take up this option.

The nature of the questionnaire is such that administering it involved minimal imposition on teachers and students in terms of the time involved.

Precautions were taken in terms of data manipulation and storage. In terms of computer usage, identifying data was only kept on the researcher’s personal computer files, and was protected by a password. No details of participating students’ names were collected in the final student questionnaires, whilst teachers were given the option of including their name if they wished to. When analysis was carried out on other computer systems, numbers were assigned to participants and their schools. The original data was stored in a secure location by the researcher.

In writing the study up, participating schools and teachers will not be mentioned by name, so as to protect confidentiality.

4.8 ADMINISTERING THE PRELIMINARY QUESTIONNAIRE

Once a questionnaire has been developed, and the items scrutinised by a group of expert practitioners it is necessary to administer the revised questionnaire to a sample of students in order to validate the questionnaire as an instrument.

For example, in developing the SLEI Fraser, McRobbie and Giddings (1993) administered the questionnaire to a sample of 3,727 students in 198 classes in 40 schools in 6 different countries. Whether or not there is a need to administer a questionnaire to an international sample is determined by the final intended audience for the questionnaire. As the Is This an Inquiring Classroom? questionnaire was intended for use in Tasmanian classrooms, at least in the first instance, administering the initial questionnaire to a sample taken from within Tasmania was deemed to be sufficient.

To this end, the preliminary version of the Is This an Inquiring Classroom? questionnaire was administered to 195 students from 8 classes at a Hobart high school. There were two classes of students from each of Grades 7 to 10 inclusive. The Grade 7-9 classes were heterogeneous with respect to ability level. The Grade 10 ones were broadly streamed, but at the researcher's request, selected by the school so as to cover a range of ability levels.

This school was selected for the validation of the questionnaire as it was readily accessible to the researcher and had a number of teachers who had indicated that they were prepared to assist in administering the questionnaire and observing their students' responses to it. The researcher offered to run the questionnaire with all classes involved, but several teachers preferred to do so themselves. An additional consideration in selecting this particular school was that it drew largely from a middle class area and students attending it tended to have fairly good literacy skills.

This meant that students' inability to read questionnaire items should not be too significant a factor with this group of students. This was deemed an important characteristic of the group of students to be used in the validation process, as the primary aim of this process was to determine if the questionnaire was a good instrument in terms of consistency within and between scales.

Students completing the questionnaire were asked to complete a cover sheet as shown in Appendix 3. This sheet provided the researcher with background information such as sex and student’s perception of their ability level. At this stage the class teachers believed that it was preferable to ask students to include their names on the questionnaire, so that students took it seriously, and also so that there was the possibility of teachers commenting on any particularly discrepant results. Students were, however, given the option of merely including their first name.

As the object of administering the questionnaire to this group of students was to determine if the items were appropriate to students of this age group, as well as validating the instrument, students were told that they could ask either the researcher or their class teacher if they were unclear what any items meant.

Observations by both the researcher and the other teachers administering the questionnaire revealed some useful points. These included:

- On average it took students around 20 minutes to complete the questionnaire. Interestingly, it often took more able students longer. The teachers involved suggested that this was possibly because these students gave greater thought to their answers.

- The term *seldom*, used as one of the terms on the scale that students were given to rate each item, proved unexpectedly problematic to students, a number asking what it meant.

- The term *generalisation* caused a few queries with several students in the lower grades asking about this.

- The terms *interpret* and *hypothesis* each led to a few queries.

- Overall, students seemed to have few problems completing the preliminary version of the questionnaire, and in most classes there were not more than two or three queries as to what items meant.

- Two students asked what the actual and preferred scales meant.

4.9 PRELIMINARY QUESTIONNAIRE DATA ENTRY

The data from the preliminary questionnaires was entered into an *Excel* worksheet by the researcher. One useful hint that the researcher was given was to use the number lock facility on the computer so that data could be entered using the number pad on the right hand side of the computer, rather than using the number keys at the top of the keyboard. Entering data became quite speedy using one hand, and this technique is recommended to others who need to enter large amounts of numerical data represented by the digits 1 though 5.

In entering the data, any items that had not been completed by students were left as blanks in the spreadsheet, except for the cases where there was deemed to be an excessive number of blanks, so that that particular student's questionnaire was discarded - as will be outlined more fully below.

A number of questionnaires - 29 out of the total of 195 - were discarded for a variety of reasons, where either the researcher or the class teacher judged that they did not give an accurate picture of what the student believed. Reasons for discards were categorised as follows:

1. Students circled either an actual or preferred response on each item, but not both. This was the situation that most concerned the researcher as it indicated that the basic layout of the questionnaire (with actual and preferred answers on the same version of the questionnaire) was problematic for students. Fortunately, only one questionnaire had to be discarded for this reason.

2. There were too many missing responses on a student’s questionnaire. Although the software used for statistical analysis was able to compensate for missing data values, it was felt that where a student had omitted too many responses their questionnaire was not giving an accurate picture of their classroom environment.

3. No preferred responses were indicated. This could also be an indication that the layout of the questionnaire, with actual and preferred responses on the same sheet, was confusing to students.

4. The patterning resulting from the student’s responses to the questionnaire made it seem unlikely that the student had taken the questionnaire seriously. For example, all responses were number 3, or all actual responses were number 1 and all preferred responses were number 5. In one case, it was also noted that the responses circle formed a perfect Christmas tree pattern on each page! Whilst all of these patterns were possible, they were judged unlikely and therefore discarded.

5. A combination of too many missing responses and patterning.

6. Scale 5 and/or Scale 6 - both of which were on the last sheet were missed completely. This is a similar situation to that outlined in point 2 above. However, it is listed separately as no questionnaires were found where all responses were missing for any of Scales 1 to 4. This seemed to indicate that maybe a fatigue factor was at play here - students were either sick of answering the questionnaire, or had lost concentration and missed the last page, by the time they reached these scales.

7. The actual and preferred responses were identical for all items. Whilst this is definitely a possible situation if students are satisfied with their science class, it seemed unlikely that there would be no items where students would have preferred a different situation to that which actually existed. It seemed more likely that these students had either misunderstood what the questionnaire required them to do, or not regarded answering the questionnaire as a serious activity.

8. The class teacher recommended that a particular student's questionnaire be discarded as the teacher did not believe that the responses were a serious attempt at answering the questionnaire. For example, when a student who the teacher knew to have low literacy levels finished in half the time that it took other students, the teacher felt that the student had not actually read all items.

The number of questionnaire from each grade group falling into each of these discard categories is shown in Table 4.4.

Table 4.4

Number of Preliminary Questionnaires Discarded by Reason for Discard and Grade Level.

Reason for discard	**Grade 7**	**Grade 8**	**Grade 9**	**Grade 10**	**Total**
Answered either actual or preferred	0	0	0	1	1
Too many missing responses	3	1	2	1	7
All preferred responses missing	0	0	0	1	1
Patterning	0	1	4	1	6
Combination of patterning & missing items	0	0	0	2	2
Missed Scale 5 &/or Scale 6	1	4	2	0	7
Teacher recommendation	0	1	1	0	2
Identical actual & preferred responses throughout	0	3	0	0	3
Total	4	10	9	6	29

Overall, 29 questionnaires were discarded, leaving a group of 166 on which the statistical analysis outlined in the next section was performed.

Where two responses were circled for one item the lowest number circled was entered into the spreadsheet.

An advantage of the researcher carrying out their own data entry was found to be that it enabled them to see any particular problems and trends which were occurring with respect to the way that students responded to items in the questionnaire.

4.10 STATISTICAL ANALYSIS OF PRELIMINARY QUESTIONNAIRE DATA

4.10.1 Background

Once a learning environment questionnaire such as the ITIC has been administered to the sample population it has been the custom in previous research studies to carry out a factor analysis and then analyse it for the three features listed below.

- Internal consistency (the extent to which items in the same scale measure the same dimensions). A suitable statistic for examining this is the Cronbach Alpha reliability coefficient.

- Discriminant validity (the extent to which a scale measures a unique dimension not covered by the other scales in the instrument). A suitable statistic for examining this is the mean correlation with other scales.

- The ability of the scales to differentiate between the perceptions of students in different classes. A suitable statistic for examining this is the ANOVA eta^2 results.

On the basis of a statistical analysis, items which are causing problems are removed. In the case of the SLEI, Fraser, McRobbie, and Giddings (1993) reported removing items with low item-remainder correlations (i.e. correlations between a certain item and the rest of the scale excluding that item) in order to improve internal consistency. They also reported improving discriminant validity by removing any item whose correlation with its assigned scale was lower than its correlation with any of the other scales. Following this procedure Fraser, McRobbie, and Giddings ran a series of factor analyses, and in developing a revised questionnaire removed several of their original scales completely. Similar procedures were adopted in the examination of the Actual and Preferred Forms of the ITIC Preliminary questionnaire presented here. At this stage analysis was carried out at the individual rather than the class level. This decision was taken due to the relatively low number of classes involved in completing the ITIC Preliminary questionnaire.

4.10.2 Principal Component Analysis - Actual Form of Questionnaire

The refinement and validation of the Actual Form of the ITIC Preliminary questionnaire involved principal component analyses, the purpose of which was to examine the internal structure of the set of 72 items. The extraction method used to generate the factors was principal components analysis with the rotation method being Varimax with Kaiser Normalisation. Since the ITIC instrument was designed with six scales, a six factor solution was considered.

Table 4.5 shows the factor loadings obtained from the analysis of the data for the Actual Form of the preliminary questionnaire for the 157 students from 8 classes. The percentage variance extracted and eigenvalue associated with each factor are also recorded at the bottom of each scale. In line with what has come to be conventionally accepted in the literature, factor loadings of 0.3 and above were included in this table. The principal component analyses depicted in Table 4.5 offered support for the 72 item Actual Form of the ITIC Preliminary questionnaire having six scales, although the Assessment, and to a lesser extent, Freedom, scales were still seen as being somewhat problematic at this stage.

By summing the percentage variance for each of the six scales it could be seen that 48% of the variance was explained by the six components. This was a satisfactory result at this stage, as all questionnaire items were still included. Some items were to be omitted from the final version of the questionnaire, as extra items were deliberately included in order that those which didn't perform well could be deleted.

The factor loadings indicated that Assessment was the most problematic scale, not loading well into just one component.

Table 4.5

Factor Loadings for Actual Form of the ITIC Preliminary Questionnaire.

Loadings smaller than 0.3 omitted.

		Component					
	Item no	component 1	component 2	component 3	component 4	component 5	component 6
Freedom	1						
	2						
	3		0.47				
	4						
	5						0.3
	6		0.50				0.33
	7		0.46				0.51
	8		0.48		0.36	0.52	
	9					0.33	
	10		0.47				0.33
	11		0.42				0.48
	12		0.47				0.49
Communication	13		0.48				
	14		0.79				
	15		0.78				
	16		0.73				
	17		0.62				
	18		0.71				
	19		0.56				
	20		0.66				
	21					0.40	
	22						
	23						
Assessment	24		0.78	0.40			
	25			0.57			
	26	0.41				0.61	
	27						0.68
	28						
	29					0.39	
	30					0.55	
	31						
	32		0.44		0.43		
	33			0.32			
	34					0.40	
	35					0.40	
Interpretation of Data	36	0.53					
	37				0.61		
	38				0.75		
	39				0.59		
	40				0.61		
	41				0.34	0.45	
	42				0.71		
	43				0.91		
	44			0.33	0.65		
	45	0.36	0.31		0.57		
	46				0.80		
	47			0.44	0.48		
	48				0.35		0.39
Science Stories	49	0.69			0.33		
	50	0.85					
	51	0.84					
	52	0.85					
	53	0.82		0.33			
	54	0.95					
	55	0.91		0.46			
	56	0.77					
	57	0.71					
	58	0.90					
	59	0.75		0.31			
	60	0.90		0.54			
Uncertainty in Science	61	0.74	0.41	0.4			
	62	0.47		0.73			
	63					0.37	
	64	0.44		0.96			
	65					0.60	
	66	0.45		0.54			
	67			0.82			
	68	0.43		0.68			
	69			0.82			
	70	0.36		0.87			
	71			0.95			
	72	0.32		0.71	0.49		
%variance		24.91	6.46	4.92	4.74	3.83	3.56
eigen-value		22.80	5.91	4.50	4.34	3.50	3.26

4.10.3 Principal Component Analysis - Preferred Form of Questionnaire

The general methods of refinement and validation that were described in the above section for the Actual Form of the ITIC Preliminary questionnaire were also used in the analysis of the Preferred Form of the ITIC Preliminary questionnaire.

Table 4.6 shows the factor loadings obtained from the analysis of the Preferred Form of the ITIC Preliminary questionnaire for the 157 students from 8 classes. The principal component analyses depicted in Table 4.6 offered support for the 72 item Preferred Form of the ITIC Preliminary questionnaire having six scales, although, as was the case with the Actual Form of the questionnaire, the Assessment, and to a lesser extent, Freedom, scales were still seen as being somewhat problematic at this stage.

4.10.4 Further Refinement of the ITIC Questionnaire

For both the Actual and Preferred Forms of the ITIC questionnaire the conceptual distinctions between the scales were regarded as being justified by the principal component analysis and supported by the mean scale correlations referred to below.

On the basis of this principal component analysis, a number of items were deleted from each scale for the Actual Form of the ITIC questionnaire, leaving those shown in Table 4.7. Shading has been used in this table to indicate to which component each item was being assumed to principally contribute.

As it was necessary that the Actual and Preferred Forms of the questionnaire contain identical items, the same items were deleted from the Preferred Form of the questionnaire. The effect of this is shown in Table 4.8.

Table 4.6

Factor Loadings for Items in the Preferred Form of the ITIC Preliminary Questionnaire.

		Component					
Scale	Item	component 1	component 2	component 3	component 4	component 5	component 6
Freedom	1					0.30	-0.41
	2			-0.33			-0.34
	3					0.58	
	4			-0.31			-0.32
	5			-0.39		0.43	
	6					0.45	
	7			0.31			
	8			0.48			
	9					0.39	
	10					0.59	
	11					0.67	
	12					0.52	
Communication	13					0.44	0.33
	14			0.68			
	15			0.75			
	16			0.73			
	17			0.64			
	18			0.66			
	19			0.46			0.44
	20			0.36			0.42
	21						0.43
	22						0.52
	23						0.60
	24			0.34	0.32		
Assessment	25	0.31	0.37				
	26		0.31			-0.33	
	27		-0.39			0.34	
	28		0.38		0.47		0.30
	29					-0.45	
	30						
	31		-0.45		-0.54		
	32		0.47		0.33		0.32
	33					0.34	0.48
	34				-0.33		
	35						0.42
	36				-0.35	0.35	
Interpretation of Data	37		0.65				0.34
	38		0.71				
	39		0.71				
	40		0.57				
	41		0.53				
	42		0.62				
	43	0.31	0.67				
	44		0.55				
	45	0.39	0.62				
	46		0.62				
	47		0.60		0.41		
	48	0.42	0.45				
Science stories	49	0.64	0.37				
	50	0.70					
	51	0.74					
	52	0.72					
	53	0.76					
	54	0.83					
	55	0.70					
	56	0.72					
	57	0.52					
	58	0.72	0.32				
	59	0.73					
	60	0.71					
Uncertainty in Science	61	0.55					
	62	0.39			0.46		
	63				-0.44		0.55
	64	0.37		0.42	0.42		
	65						0.49
	66	0.31	0.35	0.35	0.36		
	67	0.33			0.68		
	68	0.34			0.65		
	69	0.47					
	70	0.31			0.50		
	71	0.39			0.55		
	72				0.63		

Table 4.7

Factor Loadings for Those Items Kept in for Further Statistical Analysis of the Actual Form of the Is This an Inquiring Classroom? Preliminary Questionnaire. Shading indicates to which component each scale's items are being taken to primarily contribute.

	Item no	component 1	component 2	component 3	component 4	component 5	component 6
Freedom	5		0.33				0.30
	6		0.50				0.33
	7		0.46				0.51
	9					0.33	
	10		0.47				0.33
	11		0.42				0.48
	12		0.47				0.49
Communication	13		0.48				
	14		0.79				
	15		0.78				
	16		0.73				
	17		0.62				
	18		0.71				
	19		0.56				
	20		0.66				
	24		0.78	0.40			
Assessment	25			0.57			
	26	0.41				0.61	
	33			0.32			
	34					0.40	
	35					0.40	
	36	0.53					
Interpretation of Data	37				0.61		
	38				0.75		
	39				0.59		
	40				0.61		
	42				0.71		
	43				0.91		
	44			0.33	0.65		
	45	0.36	0.31		0.57		
	46				0.80		
Science Stories	49	0.69			0.33		
	50	0.85					
	51	0.84					
	52	0.85					
	53	0.82		0.33			
	54	0.95					
	56	0.77					
	57	0.71					
	58	0.90					
	59	0.75		0.31			
Uncertainty in Science	62	0.47		0.73			
	64	0.44		0.96			
	66	0.45		0.54			
	67			0.82			
	69			0.82			
	70	0.36		0.87			
	71			0.95			
	72	0.32		0.71	0.49		

Table 4.8

Factor Loadings for Those Items Kept in for Further Statistical Analysis of the Preferred Form of the Is This an Inquiring Classroom? Preliminary Questionnaire. Shading indicates which component each scale's items are being taken to primarily contribute.

	Item no	component 1	component 2	component 3	component 4	component 5	component 6
Freedom	5			`-0.39		0.43	
	6					0.45	
	7			0.31			
	9					0.39	
	10					0.59	
	11					0.67	
	12					0.52	
Communication	13					0.44	0.33
	14			0.68			
	15			0.75			
	16			0.73			
	17			0.64			
	18			0.66			
	19			0.46			0.44
	20			0.36			0.42
	24			0.34	0.32		
Assessment	25	0.31	0.37				
	26		0.31			-0.33	
	33					0.34	0.48
	34				-0.33		
	35						0.42
	36				-0.35	0.35	
Interpretation of Data	37		0.65				0.34
	38		0.71				
	39		0.71				
	40		0.57				
	42		0.62				
	43	0.31	0.67				
	44		0.55				
	45	0.39	0.62				
	46		0.62				
Science Stories	49	0.64	0.37				
	50	0.70					
	51	0.74					
	52	0.72					
	53	0.76					
	54	0.83					
	56	0.72					
	57	0.52					
	58	0.72	0.32				
	59	0.73					
Uncertainty in Science	62	0.39			0.46		
	64	0.37		0.42	0.42		
	66	0.31	0.35	0.35	0.36		
	67	0.33			0.68		
	69	0.47					
	70	0.31			0.50		
	71	0.39			0.55		
	72				0.63		

4.10.5 Reliability and Validity of the ITIC

In keeping with general practice in learning area research, the reliability and validity of the ITIC Preliminary quesionnaire was investigated through examining, firstly, the internal consistency/reliability as indicated by the Cronbach alpha reliability coefficient and, secondly, the discriminant validity as indicated by the mean correlation with other scales of each of the ITIC Preliminary scales. These values are shown in Table 4.9, for both the Actual and Preferred Forms of the questionnaire.

Table 4.9
Scale Item Mean, Cronbach Alpha Reliability and Discriminant Validity (mean correlation with other scales) and *eta*^{2} for each scale.

Scale	**Version**	**No. of items**	**Alpha reliability**	**Mean correlation with other scales**	**Scale mean**	**Scale SD**	**ANOVA results *Eta*^{2}**
Freedom	Actual	7	0.71	0.39	2.40	0.67	0.13 **
	Preferred	7	0.64	0.28	3.60	0.56	
Communication	Actual	9	0.83	0.35	3.41	0.73	0.1*
	Preferred	9	0.85	0.33	3.94	0.66	
Assessment	Actual	6	0.50	0.20	2.97	0.61	0.20***
	Preferred	6	0.31	0.10	3.10	0.57	
Interpretation of Data	Actual	9	0.87	0.41	3.15	0.81	0.23***
	Preferred	9	0.88	0.36	3.14	0.82	
Science Stories	Actual	10	0.92	0.45	2.29	0.88	0.50***
	Preferred	10	0.92	0.32	2.98	0.92	
Uncertainty in Science	Actual	8	0.90	0.45	3.20	0.96	0.25***
	Preferred	8	0.85	0.41	3.52	0.75	

n=157 * $p<0.05$ ** $p<0.01$ *** $p<0.001$

Table 4.9 indicates that for the sample of students that completed the ITIC Preliminary questionnaire the alpha coefficients for the Actual Form ranged from 0.50 to 0.90, using the individual as the unit of analysis, and those for the Preferred Form from 0.31 to 0.92. This suggests that each of the ITIC Preliminary questionnaire scales has acceptable reliability/internal consistency. This can be interpreted as meaning that items which have been grouped together to form a scale are measuring the same dimension of the classroom environment. As would be expected from the results of the principal components analysis, the coefficients for the Assessment scale are the least satisfactory.

The mean correlation of a particular scale with the other scales in the questionnaire was used as a measure of the discriminant validity of the ITIC Preliminary questionnaire. The mean correlations for the Actual Form ranged from 0.20 to 0.45, and for the Preferred Form from 0.10 to 0.41 indicating that the ITIC Preliminary questionnaire measured distinct, although somewhat overlapping, aspects of the learning environment. In other words, the different scales are measuring different dimensions or aspects of the classroom environment.

The third feature that was listed as being desirable for a learning environment questionnaire was the ability to distinguish between the perceptions of students in different classrooms, that is, that students within the same class should perceive their learning environment similarly, while mean within-class perceptions should vary significantly from class to class. This effect was examined through analysis using one-way ANOVA, with class membership as the main effect and using the individual as the unit of analysis. The results in Table 4.9 indicate that each scale differentiated significantly between classrooms. The eta^2 values represent the amount of variance in environment scores accounted for by class membership. For the ITIC Preliminary questionnaire these ranged from 0.10 to 0.50. The levels of significance indicated by these eta^2 scores show that the Actual Form of the ITIC Preliminary questionnaire is effective in distinguishing between classes. Such distinction between classes would not be expected when considering students' preferences, so eta^2 values are not generally shown for the Preferred Form of questionnaires.

On the basis of the above analysis of both the Actual and Preferred Forms of the ITIC Preliminary questionnaire it was considered that the instrument that had been developed was a useful one and that with some modification it would be suitable for its intended purpose of measuring the extent to which inquiry methods were incorporated into science teaching in various classrooms. The modifications that are necessary are considered in the next chapter.

CHAPTER 5 - THE FINAL STUDENT QUESTIONNAIRE

CHAPTER OVERVIEW

This chapter documents the development, use and analysis of the final student version of the Is This an Inquiring Classroom? or ITIC questionnaire, Actual and Preferred Forms. Discussion progresses from the development of the final version of the ITIC questionnaire through the collection of data from schools to the interpretation of the student responses.

5.1 FINAL QUESTIONNAIRE ITEMS

5.1.1 Formulating the Final Version of the Student Questionnaire

On the basis of the statistical analysis of the ITIC Preliminary questionnaire data, as described in Chapter 4, eight items were selected to be included for each scale of the final ITIC questionnaire. A major consideration in making the selection was the factor loading that each item returned from the principal components analysis shown in Table 4.5. Items that loaded more heavily into a scale other than their assigned one were discarded. Where a scale contained more than eight satisfactory items, and these items were close together in terms of how they loaded in the factor analysis, items that were as diverse as the nature of the scale allowed were chosen. This took into consideration the comments of the critiquing teachers that items that were effectively duplicates of others should not be included.

The results of the statistical analysis revealed that eight items could be chosen without modification from those used in the preliminary version of the questionnaire for the following four scales:

- Scale 2 - Communication.
- Scale 4 - Interpretation of Data.
- Scale 5 - Science Stories.
- Scale 6 - Uncertainty in Science.

In the case of Scale 1, Freedom in Practical Work, one item was rewritten and the others were taken directly from the ITIC Preliminary questionnaire.

In the case of Scale 3, Assessment, all items were completely rewritten because of the low values that this scale returned in the principal components analysis.

Thus the final version of the ITIC questionnaire was developed. The final version of the ITIC questionnaire is included as Appendix 4. In considering the layout of this final version of the ITIC the following points are worth noting:

- Items within each scale were named using the first letter of the scale name and then a number. This meant that when carrying out any analysis it was immediately obvious which scale an item belonged to - as opposed to the preliminary version of the questionnaire, where continuous numbering was used across all scales.

- Although the preliminary version of the questionnaire showed that having Actual and Preferred responses on the same sheet seemed to have confused some students, the number of questionnaire responses that had to be discarded for this reason was not particularly high in relation to the overall number of discards (discard numbers are shown in Table 4.4). It was judged that the advantage gained by using this strategy (greater comparability of actual and preferred responses), as previously discussed, outweighed the potential confusion to some students.

- As many reverse score items as possible were removed as they can be a source of confusion.

- At the suggestion of a researcher experienced with questionnaires, the rating scale was reversed so that it started with *almost never* (score of 1) and ended with *almost always* (score of 5). On the preliminary version of the questionnaire, the *almost always* choice was listed first (still with a score of 5).

- Alternate items were shaded, making it less likely that students would get their answers out of line.

- A reasonable font size and spacing was maintained to make the questionnaire easily legible for students.

- The questionnaire was formatted so that no scale ran over two pages. It was hoped that this would emphasise which items belonged together.

- As with the Preliminary Version of the questionnaire, it was considered better if students wrote their responses directly onto the questionnaire sheet rather than transcribing them to a separate answer sheet. It was hoped that this strategy would cut out potential transcription errors.

- No student names were asked for on the questionnaire cover sheet, as these were not required for analysis purposes.

The student questionnaires were professionally printed on an A3 sheet. This sheet could be folded, making it easy for students to work with.

Consideration was given to rotating the six scales of the questionnaire, in the same manner that candidate names are rotated on Australian electoral papers. This would have avoided problems caused by students becoming fatigued by the time that they reached the last scales. However, it was deemed impractical in this case due to the minimum number requirements/costs of having the questionnaire printed.

Both the items from the ITIC Preliminary questionnaire that were omitted from the final version and those that were incorporated into it are indicated in the following sub-sections.

5.1.2 - Final Version of Scale 1 - Freedom in Practical Work

Items 1, 2, 3, 4 and 8 from the preliminary version of the questionnaire (as shown in Appendix 3) were omitted, leaving the following seven items:

- We are asked to design our own experiments.

- We are allowed to extend the practical work and do some experimenting.

- We carry out experiments to answer questions that come up in class discussions.

- All students do exactly the same experiments.

- We carry out experiments to answer questions that interest us.

- We carry out experiments to test ideas which ***we*** come up with.

- We decide the best way to do things during practical work.

The following item was rewritten

- We carry out practical investigations that take more than one lesson.

5.1.3 - Final Version of Scale 2 - Communication

Items 19, 21, 22 and 23 from the preliminary version of the questionnaire (as shown in Appendix 3) were omitted, leaving the following eight items:

- Most students take part in discussions.

- We talk to other students about our work.

- We explain our ideas to each other.

- We comment on other students' opinions.

- We talk with other students about how to solve problems.

- We discuss the results we have obtained with others.

- Our ideas and opinions are listened to during classroom discussions.

- The teacher listens to our ideas.

5.1.4 - Final Version of Scale 3 - Assessment

Due to the low and scattered factor loadings that items from the Assessment scale returned in the principal components analysis of the ITIC Preliminary Version, the eight items for this scale were rewritten. The rewrite endeavoured to retain the ideas that the items on the ITIC Preliminary questionnaire had attempted to capture. The eight new items were vetted by several experienced researchers, but no trialling of the new scale was carried out. In taking this approach it was recognised that care would have to be taken in any subsequent interpretation of results obtained from the assessment scale, but it was still deemed worth proceeding with the scale at this stage.

The eight new items were:

- Our tests mainly have questions that you can memorise the answers to.
- We are allowed to use our notes or textbooks in tests.
- There can be more than one correct answer to test or assignment questions.
- In tests (or assignments) we are given the results of an experiment or investigation and asked what these show.
- It is important to explain your answers carefully.
- We have to really understand the work to do well on tests.
- We can copy the answers to assignment questions straight from books or the internet.
- Test or assignment questions ask us what our opinion is and why we think this.

5.1.5 - Final Version of Scale 4 - Interpretation of Data

Items 41, 45, 47 and 48 from the preliminary version of the questionnaire (as shown in Appendix 3) were omitted, leaving the following eight items:

- We have to try to explain the results of our experiments.
- We are asked to make generalisations from data.
- We are asked what diagrams and graphs mean.
- We are asked to predict the results of experiments.
- We use information from our experiments to predict what will happen in a different situation.
- We are asked to justify our conclusions (to say why we think what we do).
- We are asked how we could improve the experiments we have done.
- We are asked to form our own hypotheses.

5.1.6 - Final Version of Scale 5 - Science Stories

Items 55, 57, 59 and 60 from the preliminary version of the questionnaire (as shown in Appendix 3) were omitted, leaving the following eight items:

- We learn about scientists.
- The names of scientists are mentioned during lessons.
- We learn about the history of science.
- The teacher tells us stories about science.
- As we study different topics we talk about the history of how science ideas have developed.

- When we study a topic we are told about the trouble which scientists have had working in this area.
- We are told personal information about what scientists were like.
- We look at what people who are working as scientists do.

5.1.7 - Final Version of Scale 6 - Uncertainty in Science

Items 61, 63, 65 and 66 from the preliminary version of the questionnaire (as shown in Appendix 3) were omitted, leaving the following eight items:

- We learn that science *cannot* provide perfect answers to problems.
- We learn that science has changed over time.
- We learn that people can have different theories to explain the same thing.
- We learn that science is influenced by people’s values, opinion and beliefs.
- We learn that science is about coming up with ideas.
- Scientific knowledge is presented as being incomplete - there are things that are still not understood.
- We learn that scientific information can change.
- Our teacher questions some scientific theories.

5.2 QUESTIONNAIRE COVER SHEET AND ATTITUDE SCALE

The ITIC questionnaire cover sheet was designed to collect non-identifying information about students. This consisted of grade level, gender, predicted Grade 9/10 science result, and attitude to science items.

5.2.1 College Science Classes

In the case of college students, the researcher coded the questionnaires with a subject code before students completed them. Grade 11 and Grade 12 students were not differentiated, as many Tasmanian college classes are comprised of a mixture of Grade 11 and 12 students. Questionnaires were coded to indicate if the students completing it were in a college Biology, college Physical Science, college Chemistry or college Physics class. The nature of college science enrolments means that in general:

- Biology classes consist of a mixture of Grade 11 and Grade 12 students.
- Physical Science classes are predominantly Grade 11 students, as Physical Science is a lead in subject to Physics and Chemistry. However, some Grade 12 students choose it for the first time and some who did not gain a satisfactory result in Grade 11 repeat it.
- Chemistry and Physics classes are virtually all Grade 12 students. There may also be some repeating (Grade 13 students), and in exceptional circumstance Grade 11 students may be permitted to enrol in these subjects.

5.2.2 Predicted Grade 9/10 Result

As the researcher believed that students' academic ability may affect whether they favoured an inquiry approach or not, an attempt was made to ascertain the approximate academic level of students. As asking teachers to code individual student questionnaires was not felt to be ethical - and would place an unreasonable burden on participating teachers - an attempt was made to include an item that would let students indicate their ability level on their anonymous questionnaire. On the ITIC Preliminary questionnaire, this was the item *How would you rate your performance in your science class?*, with students being given the option of circling from 1 for the bottom group through to 5 for the top group. The problem that became evident with this item was that if students were in the bottom part of a top level science class they were likely to circle 1 or 2. Equally if student were in the top part of a bottom level class they might circle 4 or 5. Therefore, in reality, the results of this item were meaningless.

On the cover sheet for the final questionnaire students were asked, instead, to predict whether they would get a result at the top, middle or bottom level course in Grades 9 and 10. Students were familiar with this terminology as TCE (Tasmanian Certificate of Education) awards were given at what were commonly referred to as top, middle and bottom levels. It was recognised that Grade 7 and 8 students would not be as familiar with this terminology, but the researcher, and teachers consulted, considered that most would have heard of it, particularly from older siblings and students. In the case of college students this item was not relevant, as all participating college classes were pretertiary ones, and students could therefore be categorised as top level Grade 10 with respect to academic ability.

5.2.3 Attitude to Science Scale

The concept of an *Attitude to Science* scale was developed whilst scoring the ITIC Preliminary questionnaires. In particular, it was thought that it would be useful in those cases where actual and preferred answers were identical. If the attitude to science scale indicated that students were dissatisfied with their science class then it could reasonably be assumed that students either had not taken the questionnaire seriously, or that they had misunderstood the requirements for filling it in. Additionally it was believed that the scale may provide some interesting background information. The Attitude to Science scale was taken from Henderson, Fisher and Fraser (2000), who validated it with college Biology classes. They indicated that some of the items are from the *TOSRA Test of Science-Related Attitudes* (Fraser, 1981). This scale was used intact as it had already been validated.

The ten items included in the Attitude to Science scale were:

- I look forward to science lessons.
- Science lessons are fun.
- I enjoy the activities we do in science.

- The things we do in science are among the most interesting things we do at school.
- I want to find out more about the world in which we live.
- Finding out about new things is important.
- I enjoy science lessons in this class.
- I like talking to my friends about what we do in science.
- We should have more science lessons each week.
- I feel satisfied after a science lesson.

5.3 ADMINISTRATION OF THE STUDENT QUESTIONNAIRE

5.3.1 Choice of Schools

In order to get a representative sample of students, nine high schools and eight colleges were approached. All agreed to assist in this research by having classes of students complete the ITIC questionnaire.

As there are only eight government colleges for Grade 11/12 students in Tasmania they were all approached, giving a statewide sample.

In selecting high schools (Grade 7-10 students) it was decided to use ones in the south of the state as they were more readily accessible to the researcher.

Following consultation with a number of science teachers it was decided not to use those schools where it was known that literacy levels were lower than average as many students at these schools would not have had the literacy levels required to decode and answer questionnaire items. Although this could have been overcome by having teachers or the researcher read items to these students, teachers felt that this would be a big ask on both them and the students. As the classroom teachers are in the best position to know their students capabilities, their advice was taken in this regard.

The Tasmanian government education system has, for historical reasons, two single sex high schools in the Hobart area. It was felt that if one of these was used it would also be necessary to use the other in order to avoid biasing gender numbers too heavily. Fortunately, both schools agreed to be involved when approached. The remainder of the high schools chosen were coeducational. Overall the high schools selected drew from a wide cross section of the greater Hobart area and beyond, and the participating schools included large numbers of students from both housing commission (representing a lower socioeconomic demographic) and rural areas in their intakes. In particular, two of the participating schools are classified as district high schools (in the Tasmanian context this means that they have a K-12 school population) and are situated in more rural areas, despite being only around 30 minutes drive from central Hobart.

Overall, it was judged that the seven high schools selected would give a representative sample of Tasmanian Grade 7 to Grade 10 students. As all colleges were used the same can be said for Grade 11/12 students. As previously noted, Tasmanian students generally have the opportunity of electing to study subjects in either Grade 11 or Grade 12, so these two grade groups cannot realistically be separated.

5.3.2 Administration of Questionnaires

The researcher worked with one contact person at each school/college who coordinated the in-school organisation. As was the case with the Preliminary Version of the questionnaire, coordinators felt that it would be preferable if teachers gave their own classes the questionnaire rather than the researcher visiting the school to do so. This was also much more time efficient for the researcher, who is most grateful for the assistance received from teachers and school coordinators. The only problematic aspect of this was that the researcher cannot be sure exactly what information and instructions teachers gave to students completing the questionnaire. To provide some conformity in the administration of the questionnaires, teachers and school coordinators were provided with instruction/information sheets. Copies of these sheets are included in the Appendices, as listed below:

- Appendix 5 - Letter to high school coordinators.
- Appendix 6 - Letter to college coordinators.
- Appendix 7 - Instructions to administering high school teachers.
- Appendix 8 - Instructions to administering college teachers.

As these documents indicate, each high school was asked to have three classes in each of Grades 7 through 10 complete the questionnaire. In the case of smaller schools this was not always feasible. The colleges vary in size, as do the number of classes they run in each of the science subjects being investigated in this study (Biology, Chemistry, Physical Science and Physics). The researcher therefore negotiated with the school coordinators as to how many classes of each subject grouping they would have complete the questionnaire. The letter to these schools included a reminder as to how many classes had been agreed on. In the case of both high schools and colleges schools were requested not to have only classes taught by one teacher complete the questionnaire, so as to give a variety of student classroom experiences. Obviously the size of schools and, in the case of colleges, subject expertise of teachers, affected how many different teachers schools had timetabled on classes.

The questionnaire was sent to schools late in Term 2 of 2002 (August/September). It was considered that giving the questionnaire at this stage of the year had allowed students adequate time to form an accurate impression of their science classroom environment. Most schools completed it during the last few weeks of term, although some chose to keep the questionnaires and have students complete them at the beginning of Term 3 (mid September).

5.4 QUESTIONNAIRE DATA ENTRY

Questionnaires were returned from 2208 students in 122 classes in 16 different Tasmanian high schools and senior secondary colleges. Each student in the sample responded to the ITIC, which contained 48 items as previously outlined. These items had been construct and content validated by teachers and fellow researchers and through statistical analysis. Questionnaires were discarded for the same reasons outlined in section 4.9, with the exception that when actual and preferred items were identical, the questionnaire was not discarded if the student's attitude to science scale showed that they were satisfied with their science class. This was virtually never the case.

A breakdown of the student population that completed the ITIC questionnaire is shown in Tables 5.1 and 5.2.

Table 5.1
Breakdown of the Student Population Completing the 1519 High School Questionnaires

Number of:	Grade 7	Grade 8	Grade 9	Grade 10	Total
Classes	23	21	25	15	84
Female students	207	194	216	97	714
Male students	241	207	206	138	792
Sex not indicated	3	4	1	3	11
Total students	451	405	425	238	1519

The number of questionnaires returned from Grade 10 students is substantially lower than from other grades. A likely explanation for this is that proffered by one large high school that did not return any Grade 10 questionnaires. This was that teachers felt that the latter part of the Grade 10 year was too important to interrupt normal lessons to allow students to complete a questionnaire.

Table 5.2
Breakdown of the Student Population Completing the 691 College Questionnaires from 38 Classes

Number of:	Physical science	Chemistry	Physics	Biology	Total
Classes	13	8	9	8	38
Female students	109	67	39	97	312
Male students	131	68	87	65	351
Sex not indicated	9	10	4	5	28
Total students	249	145	130	167	691

The questionnaires returned from college students were in the approximate numbers that were expected. Working on the premise that most Physical Science students and half of Biology students are Grade 11, and that virtually all Chemistry and Physics students are Grade 12, these results are likely to represent approximately half Grade 11 and half Grade 12 students.

5.5 OBSERVATIONS DURING DATA ENTRY

Some class sets of questionnaires that were returned were smaller than expected. Speaking with school coordinators revealed that in some cases teachers gave questionnaires to their classes when some students were absent for sporting or other events. This was, unfortunately, a situation over which the researcher had no control. In the case of college classes, completing the questionnaire may have been an optional activity, with some students choosing not to complete a questionnaire.

Comments that some students wrote on their questionnaires indicated that their science teacher had changed during the year, and that their response to certain items depended on which teacher they had. This was an unfortunate but again unavoidable situation from a research viewpoint.

The item in which students predicted whether they would achieve a bottom, middle or top level award in Grade 9/10 has probably resulted in an overrepresentation of the middle group. This would be due to some lower end of top level students placing themselves in the middle level group, along with some upper end of bottom level students.

More discards occurred from students who ranked themselves at bottom level. This is not surprising as these students frequently have lower literacy skills, and so would have experienced more difficulty in completing the questionnaire appropriately.

5.6 STATISTICAL VALIDATION OF STUDENT ITIC ACTUAL AND PREFERRED FORMS

As with the preliminary version of the ITIC, the data from students completing the final version of the ITIC was analysed to check the:

- *a priori* factor structure of the ITIC
- internal consistency of each of the scales
- discriminant validity
- ability of the ITIC to differentiate between classrooms.

5.6.1 Factor Analysis of the ITIC Student Version

The first step in the validation of the ITIC was to carry out a series of factor analyses in order to examine the internal structure of the set of 48 items. As the final version of the ITIC contained the same number of scales as the preliminary version, the principal component analysis performed was as outlined in Chapter 4. The results of this factor analysis, for 2208 students in 122 classes in 16 schools, are shown in Tables 5.3 (Actual Form) and 5.4 (Preferred Form). In line with what has been customary in the literature, the only results depicted in Table 5.3 and 5.4 are those that are greater than or equal to the conventionally accepted value of 0.30.

Examination of the factor analyses indicates that there are no problems with the Interpretation of Data, Science Stories or Uncertainty in Science scales in either the Actual or Preferred Forms.

Three items in the Actual Form of the Freedom in Practical Work scale (items F6, F7, and F8) show some tendency to load into components other than the one to which they have been assigned. However, as these loadings into alternative components are less than 0.35 these items can be regarded as satisfactory. A similar situation exists with item F4 in the Preferred Form. In the Preferred Form item F5 is problematic, not showing a loading greater than 0.30 into any component. As the loadings for this item were satisfactory in the Actual Form it has not been excluded, but needs careful monitoring in future research studies.

In the case of the Communication scale in the Preferred Form, item C8 shows some tendency to load into another component, but again this tendency is less than 0.35, so the item can be regarded as satisfactory.

The factor loadings for the Assessment scale indicate that, as was the situation with the ITIC Preliminary questionnaire, it is not performing in a satisfactory manner in either the Actual or Preferred Forms, and is in need of further modification.

In summary, the factor analyses in Tables 5.3 and 5.4 support a five scale, 40 item instrument, which does not endeavour to measure the extent to which science classes are assessed using methods that are in line with inquiry methodologies.

Table 5.3

Factor Loadings for the Student Version of the ITIC Questionnaire, Actual Form. Loadings smaller than 0.3 omitted

	Item no	component 1	component 2	component 3	component 4	component 5	component 6
Freedom in Practical Work	F1					0.44	
	F2					0.59	
	F3					0.61	
	F4					0.32	
	F5					0.46	
	F6		0.34			0.51	
	F7					0.61	0.32
	F8		0.31			0.41	
Communication	C1		0.53				
	C2		0.73				
	C3		0.75				
	C4		0.61				
	C5		0.75				
	C6		0.68				
	C7		0.56				
	C8		0.41	0.31			
Assessment	A1						0.68
	A2						-
	A3						0.47
	A4			0.36			
	A5		0.36	0.51			
	A6		0.30	0.41			
	A7						-
	A8						0.52
Interpretation of Data	I1			0.57			
	I2			0.59			
	I3			0.61			
	I4			0.60			
	I5			0.56			
	I6			0.66			
	I7			0.59			
	I8			0.53			
Science Stories	S1	0.70					
	S2	0.74					
	S3	0.77					
	S4	0.68					
	S5	0.71					
	S6	0.70					
	S7	0.72					
	S8	0.62					
Uncertainty in Science	U1				0.59		
	U2				0.69		
	U3				0.72		
	U4				0.68		
	U5				0.69		
	U6				0.68		
	U7				0.71		
	U8				0.47		
	%variance	22.56	6.79	5.57	4.20	3.89	3.01
	eigen-value	10.83	3.26	2.67	2.02	1.87	1.44

Table 5.4

Factor Loadings for the Student Version of the ITIC Questionnaire, Preferred Form. Loadings smaller than 0.3 omitted

	Item no	component 1	component 2	component 3	component 4	component 5	component 6
Freedom in Practical Work	F1					0.56	
	F2					0.63	
	F3					0.68	
	F4			0.31		0.47	
	F5					-	
	F6					0.60	
	F7					0.70	
	F8					0.58	
Communication	C1			0.56			
	C2			0.70			
	C3			0.72			
	C4			0.62			
	C5			0.72			
	C6			0.69			
	C7			0.61			
	C8			0.50			
Assessment	A1						-0.59
	A2						0.65
	A3						0.56
	A4		0.46				
	A5		0.47				
	A6		0.43				
	A7						-0.70
	A8					0.32	
Interpretation of Data	I1		0.63				
	I2		0.62				
	I3		0.65				
	I4		0.65				
	I5		0.62				
	I6		0.67				
	I7		0.62				
	I8		0.62				
Science Stories	S1	0.74					
	S2	0.74					
	S3	0.78					
	S4	0.70					
	S5	0.73					
	S6	0.71					
	S7	0.73					
	S8	0.64					
Uncertainty in Science	U1				0.61		
	U2				0.67		
	U3				0.68		
	U4				0.63		
	U5				0.68		
	U6				0.67		
	U7				0.69		
	U8				0.50		

5.6.2 Validation Information for Actual and Preferred Forms of the Student ITIC

The reliability and validation statistics for both the Actual and Preferred Forms of the ITIC student version are shown in Table 5.5. As was reported for the ITIC Preliminary version in Chapter 4, the alpha reliability coefficient was used as the index of scale internal consistency and the mean correlation of a scale with the remaining scales was used as a convenient index of scale discriminant validity.

Whilst the assessment scale did not perform in a satisfactory manner in the factor analyses and will not be reported in subsequent discussion, the results it generated are included in Table 5.5 as they may be of interest in future research studies attempting to develop a satisfactory Assessment scale.

In line with previous research, statistics are reported for two units of analysis, firstly, the individual student's score and, secondly, the class mean score. Reliabilities for class means are higher than those where the individual student is used as the unit of analysis for all scales.

With regard to scale internal consistency, it can be seen from Table 5.5 that for the Actual Form of the ITIC the alpha reliability ranged from 0.71 to 0.88 with the individual student as the unit of analysis, and from 0.82 to 0.96 when the class mean was used as the unit of analysis. For the Preferred Form of the ITIC the alpha reliability ranged from 0.73 to 0.91 with the individual student as the unit of analysis, and from 0.76 to 0.95 when the class mean was used as the unit of analysis. This indicates that all five remaining scales (disregarding the Assessment scale) of both the Actual and Preferred Forms of the student ITIC have satisfactory internal consistency. This premise is based on the literature where values greater than 0.5 (DeVellis (1991), Norusis (1993)) or 0.6 (Nunnally, 1978) have been regarded as indicating satisfactory internal consistency. In general terms, this means that items within the same scale can be regarded as measuring the same dimension of classroom environment. In the case of the ITIC specifically, items within a particular scale can be regarded as measuring the same dimension of inquiry methodologies in science classes.

Table 5.5

Internal consistency (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation With Other Scales) and Ability to Differentiate Between Classrooms (Eta^2) for the ITIC Student Actual and Preferred Forms. Results in the shaded portion relate to the Assessment scale, which performed poorly in tbe factor analysis.

Scale	Version	Alpha reliability		Mean correlation with other scales				ANOVA results (eta^2) Actual
				with Assessment scale		without Assessment scale		
		Individual	Class means	Individual	Class means	Individual	Class means	
Freedom in practical work	Actual	0.71	0.82	0.41	0.47	0.41	0.51	0.23***
	Preferred	0.73	0.76	0.41	0.14	0.40	0.14	_
Communication	Actual	0.84	0.93	0.45	0.62	0.44	0.62	0.27***
	Preferred	0.86	0.94	0.44	0.55	0.45	0.52	_
Assessment	Actual	0.36	0.53	0.40	0.53	0.40	_	0.30***
	Preferred	0.71	0.42	0.35	0.47	0.35	_	_
Interpretation of Data	Actual	0.81	0.90	0.45	0.67	0.44	0.64	0.22***
	Preferred	0.86	0.92	0.47	0.57	0.50	0.55	_
Science Stories	Actual	0.88	0.96	0.38	0.52	0.39	0.55	0.34***
	Preferred	0.91	0.95	0.40	0.43	0.43	0.44	_
Uncertainty in Science	Actual	0.86	0.93	0.42	0.62	0.43	0.63	0.16***
	Preferred	0.87	0.93	0.45	0.55	0.49	0.55	_

The mean correlation of a scale with the other four scales was used as a convenient index of scale discriminant validity. For the Actual Form of the ITIC, the mean correlation of one scale of the ITIC with the other four scales ranged from 0.39 to 0.44 when the individual student was used as the unit of analysis, and from 0.51 to 0.64 when the class mean was used as the unit of analysis. For the Preferred Form of the ITIC, the mean correlations ranged from 0.40 to 0.50 when the individual student was used as the unit of analysis, and from 0.14 to 0.55 when the class mean was used as the unit of analysis.

These values indicate that each scale of the ITIC can be regarded as measuring distinct, although somewhat overlapping, aspects of the classroom environment. In the case of the ITIC specifically, it means that the five scales of the instrument are measuring different dimensions of inquiry teaching methodologies within science classes, but that there is some overlap between these dimensions. This overlap is perhaps not surprising given that all scales have been developed to attempt to measure the extent to which inquiry teaching methodologies are being used.

The ability of the Actual Form of an instrument such as the ITIC to differentiate between students in different classrooms has traditionally been regarded as a further important characteristic in science classroom research (eg Fraser, 1986) and will be examined next. Students within the same class should perceive their classroom environment relatively similarly, while mean within-class perceptions would be expected to vary from class to class. This differentiating ability is not expected in the Preferred Form of a questionnaire, as it can be assumed that students within the same cohort may have similar preferences despite actually being taught in different ways.

The ability of the ITIC Actual Form to discriminate between the perceptions of students in different classes was examined using a one-way analysis of variance (ANOVA) with class membership as the main effect. The results of this are included in Table 5.5. It was found that each scale of the Actual Form of the ITIC differentiated significantly ($p<0.001$) between classes and that the eta^2 statistic representing the proportion of variance explained by class membership ranged from 0.16 to 0.34.

5.6.3 Validity of the Attitude Scale

For the student sample in this study, the ten item Attitude to Science scale was found to have an alpha reliability coefficient of 0.90 with the individual student as the unit of analysis and 0.96 when class means were used. This indicates that items within the attitude scale can be seen as measuring similar things.

5.7 SUMMARY OF THE VALIDATION DATA

Analysis of the data from the Student version of the ITIC has shown that the ITIC is a five scale instrument with acceptable validity and reliability. It is therefore appropriate to further analyse the data that has been collected via it. As was mentioned previously, the Assessment scale results are not reported in the following consideration of the student ITIC data, as the results of the principal components analysis showed that the Assessment scale items did not load well into just one component, indicating that Assessment could not be regarded as a distinct scale.

As the ITIC questionnaire has been found to have acceptable validity and reliability, the information obtained from it can be analysed further, in order to address the research questions that were posed in Chapter 1. The results of this analysis will be considered in the next chapter.

CHAPTER 6 - APPLICATION OF THE STUDENT ITIC

6.1 ACTUAL/PREFERRED COMPARISONS FROM THE ITIC STUDENT DATA

This chapter reports and considers the results of the various statistical analyses that were carried out on the student ITIC data. This includes speculating on some of the reasons behind the results obtained and the implications of the findings.

6.1.1 Actual and Preferred ITIC Scale Means

As one of the objectives of the current research study was to compare the extent to which inquiry methodologies were being used in Tasmanian high school and college science classes with the extent to which both students and teachers would prefer that such methodologies were used an appropriate strategy in the analysis of results was to compare the actual and preferred scale means, initially across all students and then for particular sub-groups. The results of employing this strategy are outlined in the following sections.

The initial step was to calculate scale means and standard deviations for each of the ITIC scales. These results, for the 2,207 students in 122 classes, are shown in Table 6.1. As students responded on a five-point scale, ranging from 1 to 5, the values fall within these bounds. The results indicate that for all scales the preferred mean is higher than the actual one, although this difference is very marginal in the case of the Interpretation of Data scale. These differences are more easily seen in Figure 6.1, which displays the profile of the data from Table 6.1 graphically.

From these data, it is evident that relative to the actual science class learning environments that they are experiencing students would prefer greater levels of the behaviours indicated by the Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science scales. In other words, students are expressing a preference for a more inquiry oriented science class - although students are themselves unlikely to be aware of the term inquiry as used in relation to a teaching pedagogy. In the case of the Interpretation of Data scale, there is close alignment between the actual and preferred means.

Table 6.1
Means and Standard Deviations for the Preferred and Actual Forms of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.65	3.37	0.72***	0.60	0.66
Communication	3.20	3.73	0.53***	0.81	0.75
Interpretation of Data	3.37	3.40	0.03	0.72	0.77
Science Stories	2.41	2.96	0.55***	0.84	0.93
Uncertainty in Science	3.25	3.49	0.24***	0.82	0.81

*$p<0.05$, **$p<0.01$, ***$p<0.001$ n=2,207

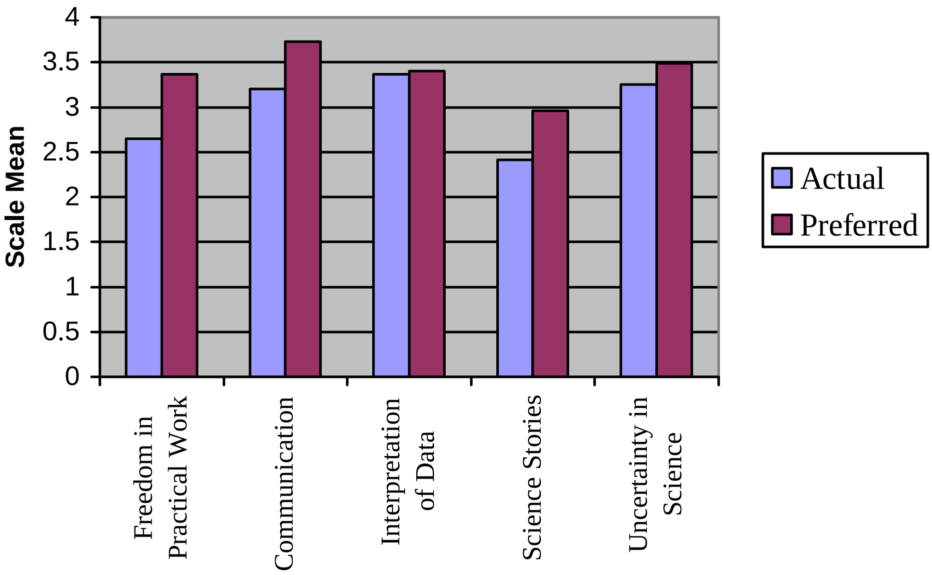

Figure 6.1. ITIC scale means.

In order to determine whether the differences observed in Figure 6.1 and Table 6.1 were statistically significant, a paired samples *t*-test was used to examine differences in the means of the student responses to the Actual and Preferred Forms of the five ITIC scales. The results of this analysis are included in Table 6.1. These results indicate that there was a statistically significant difference between students' actual and preferred science class learning environments on four of the five scales - Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science. In all cases student responses indicated that they would prefer to experience higher levels of inquiry than they currently were.

Interpretation of Data was the only ITIC scale for which there was not a significant difference between students' actual and preferred science class learning environments. This may have been partially brought about by the fact that it is also the scale with the highest mean score in the Actual Form, so students may not have seen as much reason to indicate that they would prefer higher levels for the Interpretation of Data items.

A second possible reason for there being no significant difference in the case of the Interpretation of Data scale is that students may perceive the behaviours represented by the Interpretation of Data items as being more challenging and so do not wish to experience more of them in their science classes. Students are frequently more concerned about their capacity to achieve good results than whether the method of instruction that is being employed gives optimal learning experiences - at least unless the potential benefits of a different instructional approach are explained to them. This is particularly the situation with college classes, where students' final assessments determine their tertiary entrance score and hence the tertiary courses that they will be admitted to. Hence, even able students may be hesitant to indicate that they would like to experience more of items that they find challenging if they believe that having more of these activities in their science classes would lead to them gaining lower marks.

A third possibility is that students are simply less enthusiastic about completing the types of activities indicated by items in the Interpretation of Data. Anecdotal classroom evidence suggests that this latter possibility is the most likely explanation, with teachers generally noting that students much prefer to actually do practical work than to analyse their findings.

6.1.2 Implications of Actual/Preferred Comparison

Overall, if teachers seek to modify their science classroom environments to make them more in line with what the student mean preferred scores for each of the ITIC scales indicate, they should endeavour to incorporate more inquiry methodologies, as indicated by the ITIC Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science scale items, into their science classes.

The data does not indicate the need for any change in the extent to which teachers include items relating to the Interpretation of Data scale. However, teachers need to make a professional judgement as to whether they think that students would benefit from participating in more of the types of activities indicated by the items in this scale, even though the students have not indicated a preference to do so.

6.2 THE IMPACT OF GENDER

6.2.1 Comparison of Male and Female ITIC Responses

Parker, Rennie and Fraser (1996) noted that of all school subjects, probably the greatest inequity between the sexes in enrolments, achievements and attitudes occurs for science. With this in mind, it is important that a study such as the present one examine whether any differences exist in the responses of male and female students. Such an interrogation of the data may, firstly, enhance understanding of why the differences that Parker, Rennie and Fraser refer to exist, and, secondly, suggest ways to minimise these differences. To this end, the student ITIC data were examined for differences by gender.

In order to examine if there was a difference in male and female students' perceptions of their actual and preferred classroom environments, with respect to the ITIC scales, the *t*-test described above was repeated, with the data for males and females being considered separately. The results of this analysis are shown in Tables 6.2 (female students) and 6.3 (male students).

Tables 6.2 and 6.3 show similar trends in the data for male and female students, with the data for both genders indicating a significant difference between students' actual and preferred science class learning environments on all scales except Interpretation of Data - the same trend that was seen when the data for males and females were considered collectively in Table 6.1.

Table 6.2
Means and Standard Deviations for the Preferred and Actual Forms of the ITIC for Female Students.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.40	3.18	0.79***	0.61	0.64
Communication	3.24	3.78	0.54***	0.81	0.75
Interpretation of Data	3.39	3.39	0.00	0.75	0.77
Science Stories	2.32	2.95	0.63***	0.84	0.92
Uncertainty in Science	3.27	3.52	0.25***	0.83	0.80

**p*<0.05, ***p*<0.01, ****p*<0.001 *n*=1,026

Table 6.3
Means and Standard Deviations for the Preferred and Actual Forms of the ITIC for Male Students.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.42	3.40	0.98***	0.64	0.66
Communication	3.15	3.70	0.53***	0.81	0.75
Interpretation of Data	3.36	3.40	0.04	0.69	0.78
Science Stories	2.48	2.97	0.49***	0.84	0.95
Uncertainty in Science	3.24	3.46	0.23***	0.80	0.83

**p*<0.05, ***p*<0.01, ****p*<0.001 *n*=1,142

Table 6.4 further examines differences in perception of classroom environment according to student gender, by comparing the difference between the mean scores for the responses of males and females on each scale of the Actual and Preferred Forms of the ITIC.

Table 6.4
Comparison of Means and Differences for the Preferred and Actual Forms of the ITIC for Male and Female Students.

Scales	Actual		Difference	Preferred		Difference
	Male (M)	Female (F)	(M-F)	Male (M)	Female (F)	(M-F)
Freedom in Practical Work	2.42	2.40	0.02	3.40	3.18	0.22***
Communication	3.15	3.25	-0.10**	3.69	3.78	-0.10**
Interpretation of Data	3.36	3.39	-0.02	3.40	3.39	0.01
Science Stories	2.48	2.32	0.16***	2.97	2.95	0.02
Uncertainty in Science	3.24	3.27	-0.03	3.47	3.52	-0.05

**p*<0.05, ***p*<0.01, ****p*<0.001   *n*=2,169

The results contained in Table 6.4 indicate that male and female students perceived their actual science class learning environments similarly with respect to Freedom in Practical Work, Interpretation of Data and Uncertainty in Science, but that there were statistically significant differences in Communication and Science Stories.

With regard to their preferred science class learning environment, males and females were in agreement as to what their preferred learning environment would look like with respect to Interpretation of Data, Science Stories and Uncertainty in Science, but there were significant differences between males and females in the areas of Freedom in Practical Work and Communication.

6.2.2 Possible Reasons for Observed Male/Female Response Differences

Nair & Fisher (2000) noted that generally studies in the classroom have shown that girls and boys differ in their perceptions of their classroom environment, with girls generally seeing their classroom environment in a more positive light. The perceptions of males and females differ significantly for two ITIC scales, with girls recording a higher mean score for one of these and a lower mean score for the other. Examination of the three scales where there is not a statistically significant difference between the mean response of males and females indicates that the differences that exist are too low to be worthy of any comment. A likely reason for girls' mean scores not indicating a more positive perception of their classroom environment in the case of the ITIC questionnaire items is that it is not really possible to say whether the aspects of classroom environment being measured by the ITIC represent a more positive classroom environment, only that they indicate higher or lower levels of inquiry.

The statistically significant difference between the perceptions of girls and boys with respect to the Science Stories scale is somewhat surprising, as it would seem to indicate that teachers somehow provide boys with more learning opportunities in regard to Science Stories items. It would have seemed likely that learning about scientists, the history of science and how science ideas developed, and inviting scientists into classrooms, would have been more whole class activities, and so would have occurred equally with males and females. However, it is possible that these behaviours occur in small group situations, which provide the opportunity for teachers to work with single sex groups. Teachers could then conceivably give more Science Stories type information to the all boy groups.

A different possibility is that girls may report this aspect of their science class learning environment inaccurately, perhaps due to disinterest in the way the material is presented and subsequent 'turning off' during these Science Story episodes in the classroom, or forgetting about them sooner than boys do. It is possible that either the largely male dominated history of science or the manner in which this material is presented in science classes holds less interest for girls. The alternative that boys perceive this aspect of their science class environment inaccurately seems less likely, as it is more difficult to envisage a scenario where boys imagine that they are learning about things when they really are not. It is interesting to see that there is not a significant difference between males and females for the Preferred Form of the Science Stories scale, with both boys and girls indicating that they would like significantly more Science Stories. This would seem to suggest that the above hypothesis regarding girls switching off is unlikely to be the situation that exists, unless males and females interpret the meaning of the items in the Science Stories scale differently. It is possible that when the girls read the items they assumed that learning about scientists meant learning about their personal lives, whilst boys assumed that learning about scientists meant learning about their work, and that the latter kind of stories were told in science classes, but not the former.

A further hypothesis is that the data may have been affected by classes where there are many more boys than girls (or all boys). Perhaps teachers of these classes made a point of including Science Stories type materials, whilst teachers of mainly or all girl classes did not. This hypothesis will be investigated further in a later section of this chapter.

The statistically significant difference between the scores of males and females for the Communication scale, with females perceiving an environment where there is more of the behaviours indicated by the Communication scale is not as surprising, as in general female students show a more positive approach to both oral and written communication. The perceived difference in the actual classroom environment may simply indicate a greater propensity on the part of female students to participate in the activities described by the items in this scale. For example, female students may engage in behaviours such as talking to other students about their work (item C2), explaining their ideas to others (item C3), talking to other students about how to solve problems (item C5) and discussing the results that they have obtained with others (item C6) even thought the teacher has not specifically instructed them to do so. If this is the case, then it is student rather than teacher behaviours that are influencing the amount of inquiry type communication that is occurring in science classrooms. The responses to the Preferred Form of the questionnaire show that females would still prefer a higher level of Communication than males prefer - in fact, by exactly the same amount that was the case with the Actual responses - but that both males and females would prefer higher levels of the types of Communication behaviours that this scale indicates currently exist. Perhaps males are less likely than females to make their own opportunities for these behaviours and need them to be explicitly provided by the teacher.

The statistically significant difference in the responses of males and females on the Preferred Form of the Freedom in Practical Work scale is not altogether surprising, as it can be regarded as being in line with previous research which has indicated that males prefer competitive and individualised learning, whilst females favour learning which involves cooperative models and mutual assistance. Nair & Fisher (2000) cite a number of studies where this situation has been found to exist

In a science classroom situation the tendency for girls to want more instruction and not be as great a risk takers as boys can be seen in the greater propensity of boys to try things out and see what happens, whilst girls are keen to go about things the 'right' way and not make a mistake or damage equipment. For example, boys are more likely to randomly mix chemicals and try moving pieces of electrical equipment to different settings - in other words they experiment more. Whether this is because boys have more of an innate tendency to experiment or because girls are keener not to do the wrong thing by the teacher are points open to debate and further research.

6.2.3 Possible Influence of Single Sex Schools

As was noted previously, two of the high schools that data were collected from were single sex schools. It is possible that teachers modify their methodologies when they are working with single sex classes, and that this may have skewed the results shown in Table 6.4, as was suggested in the hypothesis regarding the differences in male and female mean responses to the Science Stories scale that was put forward in the previous section. In order to check this possibility, the *t*-tests used to generate the results in Table 6.4 were rerun, omitting the two single sex schools. The results of this new analysis are shown in Table 6.5

Table 6.5

Comparison of Means and Differences for the Preferred and Actual Forms of the ITIC for Male and Female Students, Single Sex Schools Omitted.

Scales	Actual		Difference	Preferred		Difference
	Male (M)	Female (F)	(M-F)	Male (M)	Female (F)	(M-F)
Freedom in Practical Work	2.45	2.42	0.03	3.37	3.16	0.21***
Communication	3.17	3.18	-0.01	3.69	3.71	-0.02
Interpretation of Data	3.39	3.40	-0.01	3.42	3.39	0.03
Science Stories	2.54	2.39	0.15***	2.98	2.94	0.04
Uncertainty in Science	3.28	3.28	0.00	3.50	3.49	0.01

*$p<0.05$, **$p<0.01$, ***$p<0.001$ n=1,746

Comparing Tables 6.4 and 6.5 it can be seen that there is still a significant difference in how male and female students perceive their classroom environment with respect to behaviours relating to the Science Stories scale, with males still reporting significantly higher levels of these behaviours than did females. In fact, removing the single sex classes resulted in the Science Stories mean score for both males and females increasing, by nearly the same amounts. Therefore, it does not appear that teachers changed the extent to which they provided learning opportunities represented by items from the Science Stories scale in response to having a single sex class, so this hypothesis should be discarded.

Table 6.5 also shows that the difference that was observed between males and females perceptions of their preferred classroom environments with respect to the Communication scale was not significant once the data for the single sex schools was omitted. Comparing the changes in the actual mean values seems to indicate that teachers of all girl classes provide more opportunities for the kinds of behaviours indicated by the Communication scale - or that students in all girl classes themselves make more of these kinds of behaviours occur. Removal of the data for the single sex schools also resulted in there not being a significant difference in the preferred mean scores on the Communication scale for male and female students. As the mean preferred score for males did not change when the data for the single sex schools was omitted, it seems that girls in a single sex school show a greater preference for the types of behaviours indicated by the Communication scale than do girls in a coeducational school. It is possible that students in an all girls school are less inhibited about sharing their ideas than those in mixed classes.

6.2.4 Summary of Male/Female Responses

Overall, the following points about differences with respect to gender can be made from the ITIC results:

- There are no differences in the way that male and female students perceive their classroom environment with respect to Freedom in Practical Work, but students want there to be. Males want higher levels of freedom than females.
- A difference exists in how males and females perceive their classroom environment with respect to Communication, and students want this difference maintained. However, if the influence of single sex schools is removed, there is no significant difference in either actual or preferred scores on the Communication scale.
- There are no differences in the way that male and female students perceive their classroom environment with respect to Interpretation of Data and Uncertainty in Science, and students want this situation maintained.
- A difference exists in how males and females perceive their classroom environment with respect to Science Stories, and students do not want this difference to exist.

6.2.5 Implications of Male/Female Responses

The implications of the analysis of the similarities and differences in male and female student ITIC responses for teachers of science classes seeking to modify their classes to be more in line with what the ITIC results are that:

- They need to provide more inquiry opportunities, as defined by the ITIC Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science items, to students overall.

- Whilst they need to provide more opportunities for Freedom in Practical Work overall, they need to try to extend these opportunities for males whilst not making such extension work mandatory and so disenfranchising girls.
- They need to ensure that they provide females with as many opportunities for participating in Science Stories behaviours as they do males.
- While they need to provide more opportunities for inquiry Communication behaviours overall, they need to provide some extra opportunities in this area for females. However, teachers need to bear in mind that girls in coeducational classes may not want additional opportunities in this area.

Whilst catering for differences in the preferences of males and female students is easiest in single sex schools or classes, it is still possible in mixed classes through the use of small group work, where it may be possible for the tasks given to all female groups to be varied from those given to all male groups.

6.3 Variations across Grades/College Subjects

The effect of grade level, and in the case of college students the particular science subject that they were studying, on how students perceived their actual and preferred science class learning environments was examined by a series of *t*-tests, the results of which are shown in Tables 6.6 through 6.13 and then through an ANOVA (analysis of variance), the results of which are shown in Tables 6.14 and 6.15.

6.3.1 Analysis by High School Grade Level

Tables 6.6 to 6.9 examine the difference in the Actual and Preferred responses of high school students, with each grade level from 7 to 10 being considered individually. This examination was carried out in order to determine if the response of any particular grade group differed from the response for the sample student population as a whole.

Table 6.6

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Grade 7 Students Preferred and Actual Scores on the Five Scales of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.35	3.35	1.00***	0.62	0.70
Communication	3.18	3.71	0.53***	0.80	0.79
Interpretation of Data	3.25	3.34	0.09**	0.69	0.83
Science Stories	2.19	2.87	0.67***	0.78	0.97
Uncertainty in Science	3.14	3.41	0.27***	0.83	0.87

*p<0.05, **p<0.01, ***p<0.001 n=450

Table 6.7

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Grade 8 Students Preferred and Actual Scores on the Five Scales of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.28	3.40	1.11***	0.60	0.67
Communication	3.08	3.69	0.60***	0.78	0.75
Interpretation of Data	3.18	3.27	0.10*	0.72	0.74
Science Stories	2.26	2.82	0.56***	0.75	0.92
Uncertainty in Science	3.18	3.40	0.22***	0.83	0.90

*p<0.05, **p<0.01, ***p<0.001 n=405

Table 6.8

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Grade 9 Students Preferred and Actual Scores on the Five Scales of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.38	3.36	0.98***	0.68	0.64
Communication	2.96	3.57	0.61***	0.81	0.82
Interpretation of Data	3.27	3.26	-0.01	0.76	0.81
Science Stories	2.16	2.84	0.68***	0.75	0.92
Uncertainty in Science	3.11	3.41	0.29***	0.87	0.82

*$p<0.05$, **$p<0.01$, ***$p<0.001$ $n=423$

Table 6.9

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Grade 10 Students Preferred and Actual Scores on the Five Scales of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.55	3.38	0.83***	0.73	0.68
Communication	2.97	3.59	0.62***	0.88	0.79
Interpretation of Data	3.29	3.34	0.05	0.77	0.76
Science Stories	2.40	3.01	0.61***	0.88	0.89
Uncertainty in Science	3.18	3.42	0.24***	0.85	0.78

*$p<0.05$, **$p<0.01$, ***$p<0.001$ $n=238$

Examination of the above *t*-test results for Grades 7, 8, 9 and 10 students (the high school grades in Tasmania) shows that there are statistically significant differences in students' actual and preferred environments across all high school grades on the Freedom in Practical Work, Communication, Science Stories and Uncertainty in

Science scales. This is the same situation that existed when the data for all students was considered in one *t*-test. However, an interesting difference that the data in Tables 6.6-6.9 shows is that Grade 7 and 8 students indicate that they would like there to be significantly more Interpretation of Data work in their science classes. The results for the overall sample, and also for Grades 9 and 10 students, do not show any significant difference on this scale.

6.3.2 Possible Reasons for Grade Level Differences

Grade 7 represents the first year of high school in Tasmania, and a possible explanation for the above result can be made in terms of the suggestion that teachers sometimes make that students in fact regress during their initial time at high school, with high school teachers expecting less of the students than their primary school teachers did. This situation may exist because teachers are initially unaware of the capabilities of Grade 7 students and have classes of students from diverse primary school experiences. Teachers are often concerned not to push Grade 7 students too much and so disenchant them with high school life.

6.3.3 Implications of Grade Level Differences

The implication for teachers of the above analysis of the results for the different high school grades is that teachers should make more learning opportunities relating to the Interpretation of Data scale items available to Grades 7 and 8 students. Although students in these grades are still being familiarised with science laboratory equipment and techniques, they could still be provided with opportunities to engage in the kinds of activities suggested by the items in this ITIC scale.

6.3.4 Analysis by College Subject

Tables 6.10 through 6.13 contain similar *t*-test results to those contained in Tables 6.6 - 6.9, but this time for college classes. As has been noted previously, Physical

Science students would largely be in Grade 11, Biology students would be a mix of Grade 11 and Grade 12 students and Physics and Chemistry students would largely be in Grade 12.

Table 6.10
Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Physical Sciences Students Preferred and Actual Scores on the Five Scales of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.47	3.16	0.70***	0.56	0.58
Communication	3.49	3.93	0.44***	0.71	0.64
Interpretation of Data	3.61	3.56	-0.05	0.63	0.68
Science Stories	2.76	3.14	0.38***	0.77	0.86
Uncertainty in Science	3.46	3.63	0.17***	0.67	0.66

**p*<0.05, ***p*<0.01, ****p*<0.001   *n*=249

Table 6.11
Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Biology Students Preferred and Actual Scores on the Five Scales of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.32	3.07	0.74***	0.55	0.65
Communication	3.37	3.84	0.48***	0.68	0.59
Interpretation of Data	3.65	3.58	-0.07	0.67	0.71
Science Stories	2.25	2.84	0.59***	0.78	0.95
Uncertainty in Science	3.39	3.68	0.29***	0.79	0.73

**p*<0.05, ***p*<0.01, ****p*<0.001   *n*=167

Table 6.12

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Chemistry Students Preferred and Actual Scores on the Five Scales of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.51	3.05	0.54***	0.52	0.55
Communication	3.65	3.96	0.30***	0.64	0.60
Interpretation of Data	3.65	3.68	0.03	0.54	0.68
Science Stories	2.94	3.28	0.34***	0.80	0.80
Uncertainty in Science	3.53	3.73	0.20***	0.69	0.68

**p*<0.05, ***p*<0.01, ****p*<0.001 *n*=145

Table 6.13

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Physics Students Preferred and Actual Scores on the Five Scales of the ITIC.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.75	3.23	0.47***	0.47	0.61
Communication	3.55	3.93	0.38***	0.72	0.65
Interpretation of Data	3.79	3.69	-0.10	0.55	0.71
Science Stories	3.32	3.43	0.10	0.76	0.88
Uncertainty in Science	3.51	3.69	0.18***	0.65	0.68

**p*<0.05, ***p*<0.01, ****p*<0.001 *n*=130

Examination of the results for college classes shows that students in Physical Sciences, Biology and Chemistry classes show the same trend as did the overall data combined, with there being significant differences between students' actual and preferred classroom environments on the Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science scales.

An interesting variation occurs with the Physics students, where there is no significant difference between the actual and preferred classroom environments on the Science Stories scale.

6.3.5 Possible Reasons for College Subject Differences

The cohort of students enrolled in Physics classes is sometimes suggested to be the most able group of science students, and they are generally extremely mathematically able. It is possible that this group of students has a preference for more theoretical science work and is not as interested in experiencing behaviours indicated by the Science Stories scale. Examination of the make up of the Physics cohort that completed the ITIC, as shown in Table 5.2, indicates that the cohort is predominantly male (87 male students compared with 39 female ones). Whilst it is interesting to muse that this may have an impact, the previous examination of gender differences does not offer any support to this idea. It may simply be that as Physics already has the highest actual mean score on the Science Stories scale students do not perceive any need for more of these behaviours to be evident in their science classes.

6.3.6 Differences in Perception between Grade Levels

Tables 6.14 and 6.15 examine whether there are statistically significant differences between students' perceptions of their classroom environment according to their grade level. These results were generated by conducting an ANOVA analysis on each of the ITIC scales, with grade membership as the main effect. Table 6.14 contains the data for the Actual responses and Table 6.15 for the Preferred responses. In these two tables the responses for students in the college science classes (Physical Sciences, Biology, Chemistry and Physics) have been combined to one group, which has been termed college. As outlined previously, this group consists of a mix of

Grade 11 and Grade 12 students. The college classes were combined as they are a mix of two year groups rather than a single year group, and as high school students in all the participating schools moved to a college for Grades 11 and 12. Therefore, this method of analysis emphasises any differences that exist between the high school and college situations. The high school grades were kept separate in order to determine at what point, if any, in the continuum differences emerged.

Table 6.14
Scale Means and Statistical Significance of Differences in Mean Scores for Each Actual ITIC Scale by Grade Level.

Scale	Mean Scores					F
	G 7 n=451	G 8 n=405	G 9 n=423	G10 n=238	College n=691	
Freedom in Practical Work	2.35	2.28	2.38	2.55	2.50	11.86***
Communication	3.18	3.08	2.96	2.97	3.50	44.54***
Interpretation of Data	3.25	3.18	3.27	3.29	3.66	44.24***
Science Stories	2.19	2.26	2.16	2.40	2.78	58.85***
Uncertainty in Science	3.14	3.18	3.11	3.18	3.47	19.22***

**p*<0.05, ***p*<0.01, ****p*<0.001

Table 6.15
Scale Means and Statistical Significance of Differences in Mean Scores for Each Preferred ITIC Scale by Grade Level.

Scale	Mean Scores					F
	G 7 n=451	G 8 n=405	G 9 n=423	G10 n=238	College n=691	
Freedom in Practical Work	3.35	3.40	3.36	3.38	3.12	16.72***
Communication	3.71	3.69	3.57	3.59	3.92	18.27***
Interpretation of Data	3.34	3.27	3.26	3.34	3.62	21.45***
Science Stories	2.87	2.82	2.84	3.00	3.15	12.75***
Uncertainty in Science	3.40	3.40	3.41	3.42	3.67	13.18***

**p*<0.05, ***p*<0.01, ****p*<0.001

The results presented in Tables 6.14 and 6.15 indicate that there were statistically significant differences in students' mean responses between grades on all ITIC scales. Post hoc tests were employed to investigate between which particular grades these differences occurred.

In the case of the Freedom in Practical Work scale on the Actual Form of the ITIC, the post hoc tests indicated that:

- The mean responses from college students were significantly higher than those for Grades 7, 8 and 9 ($p<0.05$ for Grade 9 and $p<0.001$ for Grades 7 and 8).
- The mean responses from Grade 10 students were significantly higher than those for Grades 7, 8 and 9 ($p<0.01$ for Grade 9 and $p<0.001$ for Grades 7 and 8).

In the case of the Communication scale on the Actual Form of the ITIC, the post hoc tests indicated that:

- The mean responses from college students were significantly higher than those for the four high school grades ($p<0.001$ in all cases).
- The mean responses from Grade 7 students were significantly higher than those for Grades 9 and 10 ($p<0.001$ for Grade 9 and $p<0.01$ for Grade 10).

In the case of the Interpretation of Data and Uncertainty in Science scales on the Actual Form of the ITIC, the post hoc tests indicated that:

- The mean responses from college students were significantly higher than those for the four high school grades ($p<0.001$ in all cases).

In the case of the Science Stories scale on the Actual Form of the ITIC, the post hoc tests indicated that:

- The mean responses from college students were significantly higher than those for the four high school grades ($p<0.001$ in all cases).
- The mean responses from Grade 10 students were significantly higher than those for Grades 7 and 9 ($p<0.01$ for Grade 9 and $p<0.05$ for Grade 7).

Overall, these results indicate that college students tended to experience greater levels of inquiry, as defined by the ITC scales, than did students in any high school grades. These results are likely to result from a combination of factors, predominantly:

- Teachers perceiving college students as being more experienced than high school students, and consequently being prepared to allow them more opportunity to participate in inquiry behaviours.
- The college students were all from pretertiary classes who had elected to study science subjects, so there were likely to be higher levels of student engagement and fewer behaviour issues in the college classes.
- The college science syllabuses possibly requiring that college students participate in more inquiry science than do the high school documents.

The post hoc test results also indicated that the only instance where the amount of inquiry experienced by high school students was similar to that experienced by college students was on the Freedom in Practical Work scale, where Grade 10 students experienced similar levels of inquiry to college students, which was significantly more than that experienced by students in lower grades. The reasons for this are likely to be similar to those suggested in the first dotpoint above.

Interestingly, the post hoc tests indicated that there were few significant differences between the different high school grade levels. Given that college students consistently reported higher levels of inquiry than did high school students, it would have seemed reasonable to hypothesise that the amount of inquiry behaviours that students experienced would increase as they moved through the high school years. A significant difference existed in the case of the Science Stories scale, where Grade 10 students reported higher levels of inquiry than did Grade 7 or 9 students. It is possible that this difference resulted from teachers being aware that Grade 10 students are on the verge of making career choices, and so making a point of providing them with more information about scientists. The reason for there not being a significant difference between Grade 10 and Grade 8 students is not clear. It may relate to sampling error.

An interesting result occurred in the case of the Communication scale, where Grade 7 students reported experiencing higher levels of inquiry behaviours than did either Grade 10 or Grade 9 students. A possible explanation for this difference could be that Grade 7 students are generally enthusiastic about science, as it is a subject area that they have often had little experience of, and therefore they are keen to participate in discussions. This enthusiasm may wane as students move to higher grade levels.

The post hoc test results for the Preferred Form of the ITIC showed a similar overall trend to those for the Actual Form, with college means tending to be higher than those for high school classes. An exception to this occurred in the case of the Freedom in Practical Work scale, where the mean response from college students was significantly lower ($p<0.001$) than those for Grades 7, 8, 9 and 10. A likely reason for this is that college students are concerned about their exam performance and want their practical tasks to be more directed. Interestingly, a finding from Hofstein, Ben-Zvi, Samuel & Kempa (1975) was that in certain features chemistry students in 12th grade had a less positive attitude toward laboratory work than those in 10th or 11th grades.

In the case of the Communication, Interpretation of Data and Uncertainty in Science scales on the Preferred Form of the ITIC, the post hoc tests indicated that:

- The mean responses from college students were significantly higher than those for Grades 7, 8, 9 and 10 ($p<0.001$ in all cases).

In the case of the Science Stories scale on the Preferred Form of the ITIC, the post hoc tests indicated that:

- The mean responses from college students were significantly higher than those for Grades 7, 8, 9 ($p<0.001$ in all cases).

There were no significant differences between the preferences of students from different high school grades.

These results indicated that, in general, as well as actually experiencing higher levels of inquiry behaviours, college students preferred there to be higher levels of inquiry. Exceptions to this were the Freedom in Practical Work scale, where college students indicated a preference for lower levels of inquiry, and the Science Stories scale for Grade 10 students, who did not show significantly different preferences to those of college students. These results seem to indicate that college students may recognise the importance or usefulness of the skills that inquiry methodologies build. This is perhaps not surprising, given that the college students have chosen to pursue study in a scientific field. However, the result for Freedom in Practical Work indicates that other pressures, possibly exams, seem to be influencing the preference of the college cohort.

6.3.7 Differences in Perception between College Subjects

Tables 6.16 and 6.17 examine whether there are statistically significant differences between students' perceptions of their classroom environment according to college subject. These results were generated by conducting an ANOVA analysis on each of the ITIC scales, with subject membership being the main effect. Table 6.16 contains the data for the Actual responses and Table 6.17 for the Preferred responses

Table 6.16
Scale Means and Statistical Significance of Differences in Mean Scores for Each Actual ITIC Scale by College Subject.

Scale	Mean Scores				F
	Physical Sciences n=249	Biology n=167	Chemistry n=145	Physics n=130	
Freedom in Practical Work	2.47	2.32	2.51	2.75	16.43***
Communication	3.49	3.37	3.65	3.55	4.60**
Interpretation of Data	3.61	3.65	3.65	3.79	2.54
Science Stories	2.76	2.25	2.94	3.32	49.15***
Uncertainty in Science	3.46	3.39	3.53	3.51	1.21

*$p<0.05$, **$p<0.01$, ***$p<0.001$

The data presented in Table 6.16 show that statistically significant differences were apparent in students' actual responses across different subjects for three of the five ITIC scales, namely Freedom in Practical Work, Communication and Science Stories. Post hoc tests were conducted for these three scales.

In the case of the Freedom in Practical Work scale on the Actual Form of the ITIC, the post hoc tests indicated that:

- The mean responses from Biology students were significantly lower than those for any of the other three subjects ($p<0.05$ for Physical Sciences, $p<0.01$ for Chemistry and $p<0.001$ for Physics).

- The means responses from Physics students were significantly higher than those for both Chemistry ($p<0.001$) and Physical Sciences ($p<0.001$).

Therefore, Physics students reported experiencing more inquiry behaviours, as defined by to the Freedom in Practical Work scale, than did students in any other subject, and Biology students reported experiencing fewer such behaviours.

In the case of the Communication scale on the Actual Form of the ITIC, the post hoc tests indicated that:

- The mean responses for Chemistry students were significantly higher than those for Biology students ($p<0.01$).

In the case of the Science Stories scale on the Actual Form of the ITIC, the post hoc tests indicate that;

- The mean responses from Biology students were significantly lower than those for any of the other three subjects ($p<0.001$).
- The means responses from Physics students were significantly higher than those for both Chemistry ($p<0.001$) and Physical Sciences ($p<0.001$).

Again, Physics students reported experiencing more inquiry behaviours, this time as defined by the Science Stories scale, than did students from the other college subjects and Biology students reported experiencing fewer.

Overall, the results of the post hoc tests can be regarded as indicating that Physics is the subject where students experience the most inquiry methodologies, as defined by the ITIC scales, and Biology is the subject where students experience the least inquiry methodologies. These are interesting results, given that many Tasmanian science teachers have generally regarded Physics as a more traditional subject and Biology as a more discovery based one. This perception has largely been brought about as Biology has been seen as the subject that has always had an open-book exam and where discussion of social issues relating to science has had a more obvious place in the curriculum. The results reported here indicate that these teacher perceptions are inconsistent with the reality of current classroom practice, at least from the perspective of students.

Table 6.17
Scale Means and Statistical Significance of Differences in Mean Scores for Each Preferred ITIC Scale by College Subject.

Scale	Mean Scores				F
	Physical Sciences n=249	Biology n=167	Chemistry n=145	Physics n=130	
Freedom in Practical Work	3.16	3.07	3.05	3.23	2.86*
Communication	3.93	3.85	3.96	3.92	0.90
Interpretation of Data	3.56	3.58	3.68	3.62	1.67
Science Stories	3.14	2.84	3.28	3.43	12.59***
Uncertainty in Science	3.63	3.68	3.73	3.69	0.61

*$p<0.05$, **$p<0.01$, ***$p<0.001$

The data presented in Table 6.17 shows that statistically significant differences were apparent in students' preferred responses across different subjects for two of the five ITIC scales, namely Freedom in Practical Work and Science Stories. Post hoc tests were conducted for these two scales.

Although there was a significant difference, at the 0.05 level, between subjects on the Freedom in Practical Work scale, the only difference shown by the post hoc tests was that the mean response for Physics was greater than the mean response for Chemistry, with $p=0.075$. This probability is greater than the conventionally accepted 0.05 value and so will not be considered as significant here.

In the case of the Science Stories scale on the Preferred Form of the ITIC, the post hoc tests indicate that:

- The mean responses from Biology students were significantly lower than those from Physical Sciences ($p<0.01$), Chemistry ($p<0.001$) or Physics ($p<0.001$) students.
- The mean responses from Physics students were significantly higher than those from Physical Sciences students ($p<0.05$).

Therefore, the greatest difference in the perception of the different science subject students with regard to the amount of inquiry behaviours that they would prefer to experience relates to the Science Stories scale.

6.3.8 Implications of Perception Differences between College Subjects

The implications of the examination of the results for the different college subjects are that:

- Biology teachers should be aware that their classrooms are not as inquiry oriented as those in other college science subjects, and teachers may want to make changes which will increase the use of inquiry methodologies in Biology classes.

- Teachers from different subject areas should consider sharing the inquiry strategies that they employ, as different subjects have been shown to have different strengths with regard to some ITIC scales. This situation may in fact come about by default, as from 2004 all the college pretertiary science syllabuses have had six common criteria. The existence of common criteria makes it more likely that teachers from different subject areas will have a conversation about the teaching methodologies that they employ.

6.4 VARIATION BY PREDICTED GRADE 10 ACHIEVEMENT LEVEL

In order to examine the effect of students' ability level on their perception of their actual and preferred classroom environments, *t*-tests as described previously, were carried out, with the data for top, middle and bottom level predicted Grade 10 achievement level groups considered separately. These results are shown in Tables 6.18 through 6.20. Table 6.21 shows a similar analysis for the college students. All college students were studying pretertiary subjects, and as such would have been extremely unlikely to have gained a Grade 10 result that was anything but top level.

Table 6.18

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Predicted Top Level Grade 10 Students Preferred and Actual Scores on the ITIC Scales.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.47	3.54	1.07***	0.69	0.61
Communication	3.26	3.90	0.64***	0.78	0.70
Interpretation of Data	3.49	3.52	0.03	0.69	0.78
Science Stories	2.27	3.03	0.76***	0.77	0.90
Uncertainty in Science	3.37	3.71	0.34***	0.87	0.79

$^*p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$ n=422

Table 6.19

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Predicted Middle Level Grade 10 Students Preferred and Actual Scores on the ITIC Scales.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.36	3.32	0.96***	0.63	0.67
Communication	3.04	3.59	0.55***	0.79	0.77
Interpretation of Data	3.19	3.24	0.05	0.69	0.76
Science Stories	2.23	2.84	0.61***	0.78	0.91
Uncertainty in Science	3.12	3.33	0.22***	0.80	0.81

$^*p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$ n=922

Table 6.20

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for Predicted Bottom Level Grade 10 Students Preferred and Actual Scores on the ITIC Scales.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.20	3.21	1.01***	0.68	0.79
Communication	2.61	3.22	0.61***	0.89	0.88
Interpretation of Data	2.85	2.99	0.13	0.85	0.89
Science Stories	2.17	2.56	0.40***	0.85	1.04
Uncertainty in Science	2.81	3.01	0.20*	0.87	1.00

*p<0.05, **p<0.01, ***p<0.001 n=125

Table 6.21

Scale Means, Standard Deviations and Statistical Significance of Differences in Mean Scores for College Students Preferred and Actual Scores on the ITIC Scales.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.50	3.13	0.63***	0.55	0.60
Communication	3.51	3.92	0.41***	0.70	0.62
Interpretation of Data	3.66	3.62	-0.05	0.61	0.69
Science Stories	2.78	3.15	0.37***	0.86	0.89
Uncertainty in Science	3.47	3.67	0.21***	0.70	0.68

*p<0.05, **p<0.01, ***p<0.001 n=691

These results indicate that in the case of students who predicted that they would get a top or middle level result at the end of Grade 10 the significant differences between their actual and preferred responses were as for the overall group, with all ITIC scales except Interpretation of Data showing significant differences at the 0.001 level. The data presented in Table 6.21 indicate that this is also the case for the group of college students. In the case of the group of students who predicted that they would get a bottom level Grade 10 result, the pattern is similar, with the exception that for the Uncertainty in Science scale the significant difference for this group is at the 0.05 level. This seems to indicate that lower ability students do not want to experience as much uncertainty in their classroom environment as do more able students.

The possible relationship between student ability and the extent to which students perceived that inquiry teaching methodologies were occurring in their science classes was investigated by examining the correlation between ability level (as reflected by the predicted Grade 10 achievement level) and each of the ITIC scales. This analysis was only carried out for Grade 7-10 students because, as previously mentioned, all college students surveyed can reasonably be assumed to have achieved a top level result in Grade 10.

The association between students' perception of their actual science class learning environment and their predicted Grade 10 achievement level was analysed using both simple and multiple correlation analyses. The results of these analyses are reported in Table 6.22. The simple correlation, *r*, describes the bivariate association between predicted Grade 10 achievement and an ITIC scale, whilst the standardised regression weight, *ß*, characterises the association between predicted Grade 10 achievement level and an ITIC scale when all other ITIC dimensions are controlled, thus representing a more conservative test of association.

Table 6.22

Statistical Associations between ITIC scales, Actual Form and Achievement Level in Terms of Simple Correlations (r) and Standardised Regression Coefficients (ß).

	Actual	
Scale	*r*	*ß*
Freedom in Practical Work	0.13***	-0.06**
Communication	0.29***	0.16***
Interpretation of Data	0.32***	0.21***
Science Stories	0.21***	0.08***
Uncertainty in Science	0.24***	0.04
Multiple correlation, *R*	0.37***	
R^2	0.13	

**p*<0.05, ***p*<0.01, ****p*<0.001, *n*=2,162

Examination of the simple correlation coefficients in Table 6.22 indicates that for the Actual form of the ITIC there were statistically significant relationships (*p*<0.001) between students' perceptions of their learning environment and their predicted Grade 10 achievement level for all scales. These relationships were all positive, indicating that when greater levels of inquiry behaviours, as defined by the ITIC scales are reported, predicted Grade 10 achievement levels are higher. An examination of the beta weights indicates that these statistically significant associations (*p*<0.01) were preserved with the more conservative analysis in the case of the Communication, Interpretation of Data and Science Stories scales. There was also a statistically significant association with the Freedom in Practical Work scale, but this became a negative relationship, indicating that greater levels of the activities indicated by the Freedom in Practical Work scale correlated to lower predicted Grade 10 achievement levels.

The multiple correlation, *R*, data indicate a statistically significant positive correlation between students' perceptions of the amount of inquiry that occurred in their science classes and predicted Grade 10 achievement levels. The R^2 value indicates that 13% of the variance in predicted Grade 10 achievement level can be attributed to the amount of inquiry that occurred in science classes.

Overall, these data seem to indicate that students who report higher levels of inquiry behaviours occurring in their science classes predict that they will achieve a higher level result at the end of Grade 10. Whilst this may indicate that higher levels of inquiry behaviours have a positive influence on student achievement, a possibility that should be acknowledged at this point is that teachers who perceive that they have an able class may provide these students with an increased exposure to inquiry methodologies. Hence, the relationship described may not be a causal one - the higher levels of inquiry behaviours may not cause the higher predicted achievement levels.

6.5 CORRELATIONS BETWEEN STUDENT ATTITUDE AND INQUIRY

Table 6.23 reports associations between students' perceptions of their science class learning environment, as measured by the five ITIC Actual Form scales, and students' attitude towards their science class. As was the case in the examination of student achievement levels in the previous section, multiple regression analysis involving the set of five ITIC scales was conducted, in addition to a simple correlation analysis. The multiple regression analysis provided a more conservative set of associations between each ITIC scale and attitude when all other ITIC scales were mutually controlled.

An examination of the simple correlation (r) figures in Table 6.23 indicate that there were statistically significant ($p<0.001$) positive associations between students' perceptions of their science class learning environment and their attitude toward their science class for all ITIC scales. In the case of the Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science scale these relationships were preserved when the beta weights were calculated. In the case of the Interpretation of Data scale the beta weight was still statistically significant, but at the 0.01 level.

Table 6.23

Statistical Associations Between ITIC Scales (Actual Form) and Student Attitude in Terms of Simple Correlations (r) and Standardised Regression Coefficients (ß).

Scale	*r*	*ß*
Freedom in Practical Work	0.34***	0.19***
Communication	0.52***	0.32***
Interpretation of Data	0.38***	0.08**
Science Stories	0.37***	0.11***
Uncertainty in Science	0.36***	0.08***
Multiple correlation, *R*	0.58***	
R^2	0.33	

$*p<0.05$, $**p<0.01$, $***p<0.001$ $n=2{,}207$

The multiple correlation, *R*, data indicate a statistically significant positive correlation between students' perceptions of the amount of inquiry that occurred in their science classes and their attitude towards their science class. The R^2 value indicates that 33% of the variance in student attitude can be attributed to the amount of inquiry that occurred in their science classes.

Therefore, students have more positive attitudes toward their science classes when there are higher levels of inquiry, as defined by the ITIC scales, occurring. An examination of the beta weights shows that Communication was by far the strongest independent predictor of students' attitudes towards their science class. This finding is similar to one from Hofstein, Shore & Kipnis (2004), that students who were involved in inquiry type investigations developed a much more positive attitude towards learning chemistry in general, and towards learning chemistry in a laboratory setting in particular, as compared to students in a control group who did not carry out inquiry type investigations.

The association between the amount of inquiry that students perceived to be occurring and their attitude towards their science class was examined further by repeating the above analyses for each grade level and college subject separately. The results of these analyses are shown in Tables 6.24 and 6.25.

Table 6.24
Statistical Associations Between ITIC scales (Actual Form) and Student Attitude in Terms of Simple Correlations (r) and Standardised Regression Coefficients (ß) for the Grade 7-10 Data.

	Grade 7 *n*=451		Grade 8 *n*=405		Grade 9 *n*=423		Grade 10 *n*=238	
Scale	*r*	*ß*	*r*	*ß*	*r*	*ß*	*r*	*ß*
Freedom in Practical Work	0.43***	0.14**	0.29***	-0.02	0.22***	0.01	0.39***	0.19**
Communication	0.52***	0.27***	0.51***	0.28***	0.47***	0.31***	0.33***	0.00
Interpretation of Data	0.52***	0.26***	0.50***	0.15*	0.43***	0.17**	0.47***	0.31***
Science Stories	0.38***	0.06	0.46***	0.14*	0.35***	0.12*	0.38***	0.17*
Uncertainty in Science	0.43***	0.01	0.41***	0.21***	0.35***	0.01	0.33***	0.00
Multiple correlation, R	0.60***		0.62***		0.53***		0.53***	
R^2	0.36		0.38		0.28		0.28	

**p*<0.05, ***p*<0.01, ****p*<0.001 *n*=1,516

Table 6.25

Statistical associations between ITIC scales (Actual Form) and student attitude in terms of simple correlations (r) and standardised regression coefficients (ß) for the college subject data

	Biology		Chemistry		Physical Sciences		Physics	
Scale	*r*	*ß*	*r*	*ß*	*r*	*ß*	*r*	*ß*
Freedom in Practical Work	0.37***	0.22*	0.18*	0.03	0.19**	0.07	0.12	-0.01
Communication	0.25***	0.09	0.37***	0.20*	0.25***	0.16*	0.30***	0.19*
Interpretation of Data	0.33***	0.14	0.39***	0.21*	0.26***	0.15*	0.32***	0.10
Science Stories	0.26***	0.17*	0.35***	0.18*	0.18***	0.09	0.50***	0.42***
Uncertainty in Science	0.22***	0.00	0.33***	0.04	0.15*	0.01	0.39***	0.04
Multiple correlation, *R*	0.44***		0.49***		0.33***		0.56***	
R^2	0.20		0.24		0.11		0.31	

*$p<0.05$, **$p<0.01$, ***$p<0.001$ $n=691$

Perhaps the most obvious trend that emerges from these data is the greater occurrence of significant correlations in the high school grade data (shown in Table 6.24) compared with the college subject data (shown in Table 6.25). The high school data shows 33 statistically significant correlations (26 with $p<0.001$, 3 with $p<0.01$ and 4 with $p<0.05$) out of a possible 40, whilst the college data shows 28 statistically significant correlations (17 with $p<0.001$, 1 with $p<0.01$ and 10 with $p<0.05$) . Considering the correlations with a statistical significance of $p<0.001$, the high school data shows 26 cases, whilst the college data shows 17. This seems to indicate that the amount of inquiry that is occurring is a more significant predictor of student attitude in the high school context than it is in the college one. This difference may relate to the fact that college students have all chosen to study science subjects. In the high school classes, on the other hand, there are a number of students who only study science because it is compulsory within their school. It may be that students who are not predisposed toward the study of science are more engaged when inquiry methodologies are employed in their science classrooms.

Examination of the beta weights shows that for Grades 7, 8 and 9 Communication is the strongest independent predictor of students' attitudes towards their science class, whilst for Grade 10 Interpretation of Data is the strongest predictor. It is interesting to note that the Interpretation of Data scale is the strongest predictor in the case of Grade 10 students responses indicated that they did not wish to experience more of the types of behaviours indicated by this scale, there being no significant difference between the actual and preferred response for Grade 10 students. In the case of the college students, the beta weights indicated that Communication and Interpretation of Data were the strongest independent predictors of students attitude towards their science classes for Chemistry and Physical Sciences students, whilst Freedom in Practical Work was the strongest predictor for Biology students and Science Stories for Physics students. Again, it is interesting that Science Stories is the strongest predictor for Physics students, as this group of students indicated that they did not wish to experience greater amounts of Science Stories behaviours. Therefore, although Physics students do not wish to experience more of these types of behaviours it appears to be important that these behaviours are present in their classes.

The multiple correlation, R, data indicate statistically significant positive correlations between students' perceptions of the amount of inquiry that occurred in their science classes and their attitude towards their science class across all high school grade levels and across all college science subjects. The R^2 value indicates the percentage of the variance in predicted student attitude that can be attributed to the amount of inquiry that occurred in science classes. In the case of high school grades, this percentage varies form 28% to 38%, whilst in the case of the college subjects it varies from 11% to 24%.

The data in Table 6.24 indicate that the amount of inquiry occurring is a stronger indicator of student attitude for Grade 7 and 8 students than it is for Grade 9 and 10 students. The data in Table 6.25 indicate that the perceived amount of inquiry occurring in their science class is a stronger indicator of student attitude toward that subject in the case of Physics students than it is for other college subjects. The amount of inquiry that is occurring does not explain as much of the variance in student attitude in the case of Physical Sciences students.

6.6 CHAPTER SUMMARY

In summary, the data presented in this chapter suggest that, at least from a student perspective, there should be more inquiry methodologies included in both high school and college science teaching. This conclusion is drawn as there were statistically significant differences in student Actual and Preferred means on four ITIC scales, Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science, and these differences held when males and females were considered as separate groups, when high school grades were considered as separate groups and when students from the different predicted Grade 10 achievement levels were considered as separate groups. The differences also held for college Biology, Chemistry and Physical Sciences classes, and in the case of three of the scales for college Physics classes.

The correlation analyses reported in this chapter also support the inclusion of higher levels of inquiry methodologies, as defined by the ITIC, in both high school and college science classes as all scales showed statistically significant relationships between the perceived level of inquiry and predicted Grade 10 achievement levels. Similarly, all scales showed statistically significant correlations between the perceived inquiry levels and student attitude toward science.

Hence, increasing the extent to which inquiry methodologies are used in science classes at both high school and college levels could be expected to lead to an increase in students' attitude toward science and possibly in students' achievement levels at the end of Grade 10. Given the shortage of students currently choosing science based course both in Australia and internationally, such changes are extremely desirable.

A further important finding to emerge from the data presented in the current chapter is that in the case of the college science subjects the subjects where students perceive that there are highest levels of the inquiry behaviours defined by the ITIC are not necessarily those that many teachers might first assume. Biology teachers, in particular, might want to re-evaluate their practice as a consequence of these findings. The next chapter will further investigate the use of inquiry methodologies in science classes, this time from the perspective of teachers.

CHAPTER 7 - THE TEACHER VERSION OF THE *IS THIS AN INQUIRING CLASSROOM?* QUESTIONNAIRE

CHAPTER OVERVIEW

As one of the objectives of this research study was to investigate whether teachers and students had similar perceptions of the extent to which inquiry methodologies were employed in their science classes, it was necessary to collect teacher data similar to the student data which has been reported in the previous chapters. This chapter reports the methods used for collecting teacher data, along with the results obtained.

7.1 DEVELOPMENT OF THE TEACHER VERSION OF THE QUESTIONNAIRE

The teacher version of the *Is This an Inquiring Classroom?* (ITIC) questionnaire was developed from the student version described in Chapter 5. The basic changes that were made to questionnaire items for use in the teacher version were:

- replacing personal pronouns such as *We* and *Our*, which were directed at students to the more impersonal *Students*
- changing references from *the teacher* to *I*.

For example, item C8 on the Communication scale, which on the ITIC student version is *The teacher listens to our ideas* became *I listen to students' ideas* on the teacher version.

The teacher version of the questionnaire is included as Appendix 9. The changes that were made to the questionnaire items in each of the scales can be seen by comparing the teacher version with the student version included as Appendix 4.

A preliminary version of the teacher questionnaire was not given to a sample group of teachers. It was thought that if questionnaire items worked with the student population then they were likely to work with the teacher population, as items were likely to be less confusing to teachers than to students. The decision not to have a preliminary teacher questionnaire also overcame the potential problem that it would have been difficult to find sufficient willing science teachers to have one group complete the preliminary version of the teacher questionnaire and then another group complete the final version. The same teachers could have been asked to complete both the preliminary and final versions, but they are unlikely to have been enthusiastic about completing the questionnaire twice and, additionally, asking teachers to complete a questionnaire similar to one that they had completed previously may have had an influence on the answers that they gave.

Once the items for the six scales of the ITIC had been rewritten for the teacher version of the questionnaire they were critiqued by a teacher and an experienced researcher, who deemed them appropriate.

7.2 TEACHER QUESTIONNAIRE COVER SHEET AND ATTITUDE SCALE

A number of pieces of background teacher information were considered potentially relevant, and therefore collected as part of the questionnaire. Although it was thought that not all of this information may prove relevant in the final analysis of the teacher questionnaire it was collected as the anonymous nature of the questionnaire meant that it would have been impossible to collect this information at a later date. The information used in the final analysis of the data was:

- gender
- school type (high school or college)
- grades taught.

For each of these items, categories were specified in order to make scoring of the teacher questionnaires practical. These categories can be seen on the questionnaire cover sheet which is included in Appendix 9.

It was thought that the attitude of teachers to science and their science classes may influence their beliefs about science teaching pedagogies, so the Attitude to Science

Scale used on the student version of the questionnaire was modified for use on the teacher version of the questionnaire. Six items were included. These were:

1. I enjoy teaching my science classes.
2. I feel satisfied after a science lesson.
3. The things we do in science are among the most interesting things done at school.
4. I like talking to others about what we do in my science classes.
5. I like talking to others about science related topics.
6. I am interested to hear about new science ideas and discoveries.

Teachers were also asked if they would be willing to be interviewed for this research project, and were asked to include their name and contact details if they were. This section was included in case discrepancies in the data collected made further investigation, including discussions with teachers, desirable.

As only a relatively small number of the teacher version of the ITIC questionnaire was required, the teacher questionnaires were photocopied rather than professionally printed. Whilst the student questionnaires were printed on white paper, the teacher version was printed on green paper in order to avoid confusion between the two versions when they were being used in schools.

Aside from these modifications, the same strategies were adopted in the layout of the teacher version of the questionnaire as were outlined for the student version in Sections 4.4 and 5.1.1.

7.3 ADMINISTRATION OF THE TEACHER QUESTIONNAIRE

The teacher version of the questionnaire was completed by teachers from the same schools as the students who completed the questionnaire. It was completed on a purely voluntary basis, and it was obvious from the number of returns, together with comments from school coordinators, that a number of teachers chose not to complete a questionnaire although students from their classes did so. This was not surprising, given the general aversion that many teachers seem to have to completing questionnaires.

7.4 TEACHER QUESTIONNAIRE DATA ENTRY

Teacher questionnaires were returned from 65 teachers in 15 different schools. None of the teacher questionnaires had to be discarded due to being completed inappropriately.

Strategies used in entering the data for the teacher questionnaires were the same as those previously outlined for the entry of student data.

A breakdown of the teacher population that returned questionnaires is shown in Table 7.1. Male and female teachers were considered as separate groups, in case gender differences similar to those identified for students in Chapter 6 were also evident in the teacher population.

Table 7.1
Breakdown of the Population of 65 Teachers From 15 Schools That Completed the ITIC Questionnaire.

	High Schools (Grade 7-10)	Colleges (Grade 11/12)	Total
Male teachers	19	23	42
Female teachers	10	13	23
Total	29	36	65

7.5 ANALYSIS OF ITIC TEACHER DATA

The analysis procedures and considerations for the analysis of both the Actual and Preferred Forms of the ITIC teacher version were the same as those outlined for the analysis of the ITIC Preliminary questionnaire in section 4.10 and the ITIC student version in section 5.6. Consequently, the reasons behind each of the statistical analyses used are not repeated in this chapter.

7.5.1 Principal Components Analysis - Actual and Preferred Forms of ITIC Teacher Version

The factor loadings obtained for the 65 teachers from 15 schools are shown in Tables 7.2 (Actual Form) and 7.3 (Preferred Form). In line with the custom that has been adopted by other researchers, factor loadings less than 0.3 are not shown.

The principal components analysis for the Actual Form of the ITIC teacher questionnaire shows that 42 of the 48 items have a factor loading of 0.3 or greater with their assigned scale. Of the six items that have a factor loading of less than 0.3, one is from the Freedom in Practical Work scale, one from the Communication scale, three from the Assessment scale and one from the Uncertainty in Science scale. Of the 42 items with a loading greater than 0.3, seven have a lower correlation with their assigned scale than with one of the other scales. One of these is from the Freedom in Practical Work scale, one from the Communication scale, one from the Assessment scale, two from the Interpretation of Data scale and two from the Uncertainty in Science scale. These results are good given the size of the sample, so the factor analysis seems to confirm the six scale structure of the Actual Form of the ITIC Teacher Version.

The above indicates that the Actual Form of the ITIC Teacher Version requires further examination if it is to be used in future research, so in this thesis the results obtained from the teacher version of the questionnaire will be interpreted with caution. However, given the relatively low number of teacher questionnaires completed in comparison to the number of student questionnaires, it would be strategic to have a larger sample of teachers complete the ITIC before either completely rewriting or excluding items other than those in the Assessment scale. It was not feasible to undertake such research in Tasmania at the time of this study, as many members of the science teacher population who were willing to assist in the research had already completed the ITIC questionnaire.

A similar situation to that found for the Actual Form of the ITIC Teacher Version exists with the Preferred Form of the ITIC. The principal components analysis for the Preferred Form of the ITIC Teacher Version showed that 40 of the 48 items have a factor loading of 0.30 or greater with their assigned scale. Of the eight items that have a factor loading of 0.30 or less with their assigned scale, two are from the Freedom in Practical Work scale, two from the Communication scale and four from the Assessment scale. Of the remaining 40 items, three items have a lower correlation with their assigned scale than with one of the other scales. One of these is from the Assessment scale, one from Interpretation of Data and one from Science Stories. The remaining items confirm the six scale structure of the Preferred Form of the ITIC Teacher Version, although, as with the Actual Form, care must be taken in interpreting the data obtained, given the relatively small sample size.

Closer examination of both the Actual and Preferred Forms of the ITIC Teacher Version suggests that the Assessment scale, in particular, is somewhat problematic and not performing as desired, and that it should be deleted or rewritten. This is the same situation that was found to exist with the student version of the ITIC, and, as was the case for the student data, results from the assessment scale will not be reported in later sections of this thesis. Therefore the ITIC Teacher Version will be regarded as a five scale instrument.

Table 7.2

Factor Loadings for the Teacher Version of the ITIC Questionnaire, Actual Form. Loadings smaller than 0.3 omitted

	Item no	component 1	component 2	component 3	component 4	component 5	component 6
Freedom	F1					0.45	
	F2					0.62	
	F3					0.67	
	F4					0.53	
	F5			0.48		0.37	
	F6					0.72	
	F7					0.80	
	F8		0.34			-	0.53
Communication	C1		0.66				
	C2		0.83				
	C3		0.70				0.52
	C4		0.58				
	C5		0.77				
	C6		0.81				
	C7		0.52		0.53		
	C8		-		0.42		
Assessment	A1						0.58
	A2		0.30				0.59
	A3					0.35	-
	A4				0.31		0.50
	A5						0.64
	A6		0.34			-0.46	-
	A7			0.55	0.32		0.35
	A8			0.33	0.38		-
Interpretation of Data	I1				0.66		-
	I2				0.58		0.35
	I3				0.63		0.31
	I4				0.47	0.35	-
	I5			0.35	0.48		-
	I6				0.38		0.40
	I7				0.42		0.48
	I8	0.32			0.40		-
Science Stories	S1	0.75					
	S2	0.64					0.44
	S3	0.81					
	S4	0.70					
	S5	0.84					
	S6	0.79		0.36			
	S7	0.81					
	S8	0.71					
Uncertainty in Science	U1			0.65			
	U2		0.36	0.72			
	U3	0.44		0.68			
	U4	0.31		0.71			
	U5		0.35	0.56	0.31		
	U6		0.58	0.41			
	U7		0.57	0.53			
	U8	0.60		-			

Table 7.3

Factor Loadings for the Teacher Version of the ITIC Questionnaire, Preferred Form. Loadings smaller than 0.3 omitted

	Item no	component 1	component 2	component 3	component 4	component 5	component 6
Freedom	F1	0.58				-	
	F2	0.49				0.33	
	F3	0.47				0.55	
	F4		0.42			0.65	
	F5					-	-0.53
	F6	0.35				0.70	
	F7	0.35				0.63	
	F8				0.39	0.55	0.36
Communication	C1		0.45		0.45	0.41	
	C2		0.35		0.73		
	C3				0.75		
	C4				0.63		
	C5				0.65		
	C6	0.31	0.43		0.57		
	C7		0.39	0.50	-		
	C8		0.38	0.34	-		
Assessment	A1				0.45		0.36
	A2						0.72
	A3	0.38		0.31		0.43	-
	A4					0.63	-
	A5						0.64
	A6						0.45
	A7			0.36			-
	A8				0.36	0.52	-0.54
Interpretation of data	I1			0.46	0.41		
	I2			0.79			
	I3			0.66			0.37
	I4			0.69			
	I5		0.50	0.39		0.39	
	I6			0.80			
	I7			0.78			
	I8		0.41	0.50		0.44	
Science Stories	S1	0.79					
	S2	0.69					
	S3	0.84					
	S4	0.71	0.40				
	S5	0.74	0.43				
	S6	0.72					
	S7	0.74			0.36		
	S8	0.48			0.57		
Uncertainty in Science	U1		0.63				
	U2		0.80				
	U3		0.77				
	U4	0.35	0.74				
	U5		0.65		0.46		
	U6	0.38	0.73				
	U7	0.45	0.73				
	U8		0.50				

7.5.2 Reliability and validity of the ITIC Teacher Version - Actual and Preferred Forms

Table 7.4 reports validation information for both the Actual and Preferred Forms of the ITIC Teacher Version. The alpha reliability coefficient was used as the index of scale internal consistency.

Table 7.4
Alpha Reliability Coefficient and Correlation With Other Scales for the Actual and Preferred Forms of the ITIC Teacher Questionnaire.

Scale	Version	Alpha reliability	Mean correlation with other scales with Assessment scale	Mean correlation with other scales without Assessment scale
Freedom	Actual	0.78	0.27	0.27
	Preferred	0.83	0.45	0.46
Communication	Actual	0.87	0.36	0.36
	Preferred	0.86	0.54	0.56
Assessment	Actual	0.57	0.36	_
	Preferred	0.42	0.37	_
Interpretation of Data	Actual	0.79	0.38	0.35
	Preferred	0.86	0.48	0.50
Science Stories	Actual	0.92	0.39	0.40
	Preferred	0.91	0.43	0.52
Uncertainty	Actual	0.90	0.43	0.44
	Preferred	0.93	0.49	0.55

For the Actual Form of the ITIC teacher version the alpha reliability ranged from 0.57 to 0.92 and for the Preferred Form from 0.42 to 0.93. If the Assessment scale is excluded, the alpha reliability values for the Actual Form range from 0.78 to 0.92 and for the Preferred Form from 0.83 to 0.93. These alpha reliability values indicate that the scales of the ITIC teacher questionnaire are showing acceptable internal consistency.

The mean correlation of one scale with the other five scales was taken as an index of scale discriminant validity - the extent to which the scale measures a dimension different to that measured by any other scale. For the Actual Form of the ITIC teacher questionnaire, excluding the Assessment scale, the mean correlations of one scale with the other five ranges from 0.27 to 0.44, and for the Preferred Form from 0.46 to 0.56. These values can be regarded as small enough to confirm the discriminant validity of both the Actual and Preferred Forms of the ITIC Teacher Version, but are large enough to indicate that there is some degree of overlap between the scales.

As mentioned in the discussion of the student ITIC data, the somewhat overlapping nature of the scales of the ITIC questionnaire is perhaps not entirely surprising given that the ITIC instrument was designed to investigate the extent to which inquiry teaching occurs in science classrooms, and the different dimensions that have been identified as representing inquiry could be regarded as being interrelated.

The alpha reliability coefficient for the attitude scale of the ITIC teacher version was 0.78, indicating that this scale has satisfactory internal consistency.

7.6 INTERPRETATION OF THE ITIC TEACHER DATA

The results from the Assessment scale will not be reported in the following discussion, as the factor analysis indicated that Assessment was not a distinct scale. In order to allow comparisons to be made between student and teacher data none of the items which did not perform in the factor analysis were excluded from further analysis of the teacher data.

7.6.1 Actual and Preferred ITIC Scale Means

Table 7.5 displays the descriptive statistics for the data obtained from the 65 teachers completing the ITIC teacher version. Trends can be seen more easily by studying the graphical presentation in Figure 7.1. Examining the differences between the actual and preferred responses it can be seen that teachers indicated a preference for the inclusion of more inquiry methodologies in their science classes across all scales. The greatest difference between teachers' actual and preferred classroom environments exists for the Freedom in Practical Work and Science Stories scales, and the least difference for the Interpretation of Data scale.

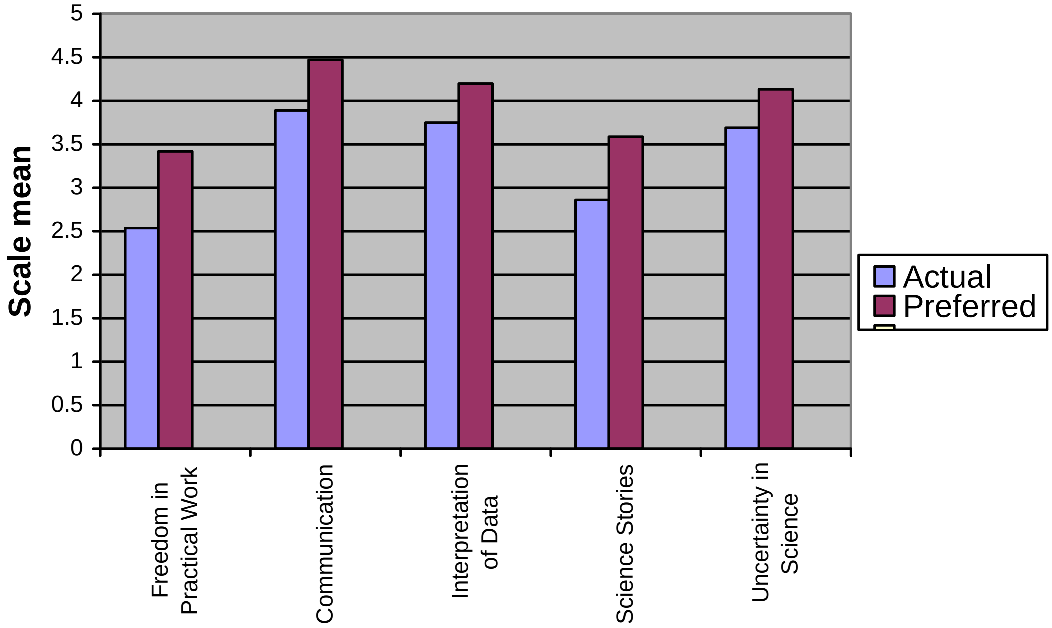

Figure 7.1. Scale Means for Teacher Data.

The significance of the differences between the actual and preferred teacher responses was examined using a paired samples *t*-test. The results of this analysis are shown in Table 7.5. They indicate that there were significant differences between teachers' Actual and Preferred classroom environments for all five ITIC scales. Therefore, teachers would prefer more inquiry methodologies, as defined by the five ITIC scales, to be used in their science classes.

Table 7.5

Means and Standard Deviations for the Preferred and Actual Forms of the ITIC Across All Teachers.

Scales	Mean		Difference	Standard deviation	
	Actual (A)	Preferred (P)	(P-A)	Actual (A)	Preferred (P)
Freedom in Practical Work	2.54	3.42	0.88***	0.55	0.58
Communication	3.89	4.47	0.59***	0.60	0.45
Interpretation of Data	3.75	4.20	0.45***	0.47	0.47
Science Stories	2.86	3.59	0.73***	0.72	0.63
Uncertainty in Science	3.69	4.13	0.45***	0.81	0.64

*$p<0.05$, **$p<0.01$, ***$p<0.001$ $n=65$

7.6.2 Gender Differences for ITIC Teacher Data

An independent samples *t*-test was used to examine differences in the responses of male and female teachers. The results of this analysis are shown in Table 7.6. These results indicate that the perceptions that male and female teachers had of their science class environment were significantly different for the Science Stories scale.

Table 7.6

Comparison of Means and Differences for the Preferred and Actual Forms of the ITIC for Male and Female Teachers.

Scales	Actual		Difference	Preferred		Difference
	Male (M)	Female (F)	(M-F)	Male (M)	Female (F)	(M-F)
Freedom in Practical Work	2.59	2.44	0.15	3.36	3.54	-0.18
Communication	3.89	3.89	0.00	4.45	4.50	-0.05
Interpretation of Data	3.76	3.73	0.03	4.14	4.32	-0.19
Science Stories	3.07	2.47	0.61***	3.63	3.53	0.10
Uncertainty in Science	3.70	3.66	0.04	4.06	4.26	-0.20

*$p<0.05$, **$p<0.01$, ***$p<0.001$ $n=65$

Males reported significantly higher levels of activities relating to the Science Stories scale occurring in their science classes. There was no significant difference between the responses of males and females on the Preferred version.

7.6.3 Differences Between College and High School Teachers

In order to investigate whether differences existed in the amount of inquiry that teachers perceived as actually existing, or being preferable, between high school and college environments a *t*-test was again used. The results are shown in Table 7.7. The different college subjects were not considered individually as there were not enough teachers from each subject area to make this feasible.

Table 7.7
Comparison of Means and Differences for the Preferred and Actual Forms of the ITIC for College and High School Teachers.

Scales	Actual		Difference	Preferred		Difference
	College C	High school (H)	(C-H)	College C	High school (H)	(C-H)
Freedom in Practical Work	2.52	2.57	-0.05	3.36	3.49	-0.13
Communication	4.14	3.59	0.56***	4.52	4.39	0.13
Interpretation of Data	3.93	3.54	0.39***	4.29	4.09	0.19
Science Stories	3.07	2.60	0.46**	3.62	3.56	0.07
Uncertainty in Science	3.94	3.38	0.56**	4.25	3.98	0.27

*$p<0.05$, **$p<0.01$, ***$p<0.001$ $n=65$

The results in Table 7.7 indicate that there are significant differences in the amount of inquiry that teachers perceive to be occurring on four of the ITIC scales, Communication, Interpretation of Data, Science Stories and Uncertainty in Science. In all cases, there are significantly more of these behaviours occurring in the college environment. It is possible that the greater maturity of students, together with the fact that college courses only contain top academic level students makes it more feasible for college teachers to include more inquiry type activities in their courses.

However, it is more difficult to see why this would be the case with the Science Stories scale. Perhaps the fact that college teachers tend to specialise in a particular subject area rather than teach a general science course which covers many fields of science makes it easier for college teachers to become familiar with stories of science and scientists that relate to their area. It is also likely that visits by scientists, or, by students to scientific facilities may be more common at this level. This is likely to occur as this group of students are in the process of making decisions about their future careers and tertiary courses, and a number of groups of individuals, which may include teachers, scientists, career counsellors and university personnel, are keen to give college science students as much insight as possible into potential career pathways.

In the case of the preferred data, there are no significant differences in the amount of inquiry that teachers would prefer to be occurring between the college and high school environments. This indicates that high school and college teachers have similar beliefs regarding the extent to which inquiry methodologies should be used in science classrooms.

7.6.4 Teacher Attitude and Inquiry

Table 7.8 reports the associations between the five actual ITIC scales and teacher attitudes towards their science classes. The simple correlation, *r*, describes the bivariate association between teacher attitude and an ITIC scale, whilst the standardised regression weight, *ß*, characterises the association between teacher attitude and an ITIC scale when all other ITIC dimensions are controlled.

Table 7.8

Statistical Associations Between ITIC Scales (Actual Form) and Teacher Attitude in Terms of Simple Correlations (r) and Standardised Regression Coefficients (ß).

Scale	*r*	*ß*
Freedom in Practical Work	0.35**	0.22
Communication	0.43***	0.21
Interpretation of Data	0.36**	0.13
Science Stories	0.35**	0.08
Uncertainty in Science	0.41***	0.16
Multiple correlation, *R*	0.55***	
R^2	0.31	

**p*<0.05, ***p*<0.01, ****p*<0.001 *n*=65

Examination of the simple correlation coefficients in Table 7.8 indicates that for the Actual Form of the Teacher ITIC there are statistically significant relationships between the amount of inquiry that teachers perceive is occurring in their science classes and teachers' attitudes toward their science classes on all ITIC scales. The positive nature of the data indicate that teachers have a more positive attitude toward their class classes where there is more inquiry occurring in those science classes. A possible interpretation of this is that inquiry methodologies involve more teacher time to prepare and deliver, and that it is teachers with a more positive attitude who are more likely to commit the time needed to prepare and deliver an inquiry approach. However, the statistical significance noted in the simple correlation coefficients is not conserved when the beta weights are calculated, so caution must be taken in drawing any conclusions.

The multiple correlation, *R*, data indicate a statistically significant positive correlation between teachers' perceptions of the amount of inquiry that occurred in their science classes and teacher attitude toward science. The R^2 value indicates that 31% of the variance in teacher attitude can be attributed to the amount of inquiry that occurred in their science classes.

7.7 Summary of Teacher Data

The main points that the analysis of the teacher data reveals are:

- Teachers would prefer their classrooms to include significantly more inquiry methodologies, as defined by the ITIC scales.
- There is significantly more inquiry relating to the Science Stories scale occurring in the classrooms of male teachers.
- There are no significant differences in the amount of inquiry that male and female teachers would prefer to occur in their science classes.
- There is significantly more inquiry occurring in college science classes than in high school ones.
- There is no significant difference in the amount of inquiry that college and high school teachers would prefer to occur in their classrooms.
- On the basis of simple correlation coefficients, teachers have a significantly more positive attitude toward their science classes when there is more inquiry occurring in those classes.

7.8 Comparison of Teacher and Student ITIC Data

Once both the student and teacher data had been analysed, the two sets of data were examined in order to determine the similarities and differences in the way these two groups rated both their actual and preferred classroom environments. This information was considered important, as it is desirable that any decision to bring about changes to classroom environments take into consideration the opinions of both groups - although there may be sound reasons for giving the opinions of one group more weight than those of the other. Table 7.9 displays the mean score and standard deviation for each group for each of the ITIC scales.

In order to establish whether the differences that existed were significant, tests were run to compare the teacher and student data. However, the quite disparate sizes of the two sample groups mean that the results of this analysis should be interpreted with some caution.

The analysis that was run gave an estimate of the *t*-value. Where this estimate is either greater than +2.0 or less than -2.0, the differences in the mean values of the teacher and student responses is considered to be significant. The results of this analysis are shown in Table 7.9.

Table 7.9
Comparison of Mean Scores and Standard Deviations for Teacher and Student ITIC Data.

	Mean		Standard deviation		t
	Student	Teacher	Student	Teacher	
Actual data					
Freedom in Practical Work	2.65	2.54	0.60	0.55	0.41 ns
Communication	3.20	3.89	0.81	0.60	-2.19 *
Interpretation of Data	3.37	3.75	0.72	0.47	-1.27 ns
Science Stories	2.41	2.86	0.84	0.73	-1.39 ns
Uncertainty in Science	3.25	3.69	0.82	0.72	-1.36 ns
Preferred data					
Freedom in Practical Work	3.37	3.42	0.66	0.58	-0.19 ns
Communication	3.73	4.47	0.75	0.45	-2.39 *
Interpretation of Data	3.40	4.20	0.77	0.47	-2.59 *
Science Stories	2.96	3.59	0.93	0.63	-1.86 ns
Uncertainty in Science	3.49	4.13	0.81	0.64	-2.01 *

ns- not significant * significant difference teacher *n*=65, student *n*=2,207

The results in Table 7.9 indicate that with respect to actual classroom environment, teacher and student perceptions were similar on all ITIC scales except Communication. Therefore, teachers and students concurred as to the nature of their science class learning environment with respect to the amount of inquiry methodologies, as defined by the ITIC scales, that was occurring. In the case of the Communication scale teachers perceived that there were significantly higher levels of inquiry methodologies occurring than did students. A possible explanation for this is that teachers perceive that more of the classroom discussion that is occurring relates to work than is really the case - with students being better placed to assess this.

With regard to the Preferred Form of the ITIC, teachers and students had similar preferred classroom environments with respect to behaviours indicated by the Freedom in Practical Work and Science Stories scales. However, the response of the two groups indicated that they had significantly different preferences on the remaining three scales, Communication, Interpretation of Data and Uncertainty in Science. In all three cases the mean preferred score for the teacher sample group was higher than the mean preferred score for the student sample group. An interesting trend that can be perceived in the data sets for the Communication, Interpretation of Data and Uncertainty in Science scales is that in all cases the student actual mean score is the lowest value, the student preferred mean score is the next highest value, with teacher actual mean score being next and teacher preferred mean score being the highest value.

These results indicate that on the three scales where there are significantly different preferences between teacher and student preferred classroom environments, teachers want there to be more inquiry behaviours than do students, although both groups want there to be more inquiry than is currently the case.

7.9 Chapter Overview

This chapter has examined the results of the teacher data analysis and gone on to compare the teacher data with the student data which had been reported in previous chapters.

The main conclusions from the teacher data have already been summarised in Section 7.7, so these will not be reiterated here. Overall, teachers would prefer that their science classes had higher levels of inquiry behaviours, as defined by the ITIC, than is currently the case.

The comparison of the data for the teacher and student groups showed that these two groups are largely in agreement as to the extent to which inquiry methodologies, as defined by the ITIC, occur in their science classes. Therefore, the ITIC appears to be successful in measuring the amount of inquiry that is actually occurring in science classrooms.

Following on from this investigation of the perceptions and preferences of teachers and students, with regard to the degree to which ITIC inquiry methodologies occur in their science classes, the next chapter will examine the curriculum documents that were in use in these classrooms, in order to determine the extent to which these documents suggest the use of the same inquiry methodologies

CHAPTER 8 - INQUIRY METHODOLOGIES INDICATED IN THE CURRICULUM DOCUMENTS IN USE WHEN THE ITIC WAS ADMINISTERED.

CHAPTER OVERVIEW

This chapter examines the extent to which the curriculum documents which were current at the time that students and teachers completed the ITIC either prescribed or advocated the use of inquiry teaching methodologies, as defined in the ITIC. This analysis was carried out with a view to comparing the perceptions that students and teachers had of both their actual and preferred science classroom environments with the intent of the relevant curriculum documents.

In the discussion of the science syllabus documents the following method will be used to highlight where links to ITIC inquiry methodologies exist:

1. The parts of the syllabus documents that imply the use of ITIC inquiry methodologies will be reproduced in the text. Italics will be used to highlight particular connections implied by part of this text.

2. The ITIC scale/s that the reproduced statements can be taken as referring to will be shown in bold in brackets at the end of the italicised section. The key that will be used to represent the different ITIC scales is:

   (F) - Freedom in Practical Work

   (C) - Communication

   (I) - Interpretation of Data

   (S) - Science Stories

   (U) - Uncertainty in Science.

The inclusion of a reference to an ITIC scale means that the italicised text implies a relation to one or more items in that scale. References to an ITIC scale are included where it seems that an experienced science teacher would see and make direct connections. Naturally, the preferred pedagogies of individual teachers may mean that they also incorporate inquiry methodologies in relation to text that is not italicised. The attempt here is to note references which imply that all teachers should be employing inquiry methodologies.

Where it seems that a comment in the syllabus documents strongly indicates the use of inquiry methodologies, but where it is possible that the stated condition could be met without using inquiry a **?** is used to denote this.

For example, **F?** is used where there is a strong reference to practical work, but where it would be possible to carry this out using purely *cookbook* type practicals and not allowing students the opportunity for any open-ended investigations.

A further example is **C?,** which may indicate that the syllabus documents require students to develop and explain opinions, but do not specify that this presentation should be oral - so the presentation could be written and there may be no oral sharing as indicated by the ITIC Communication scale.

As has been noted previously, up to 2005 Tasmania did not have any statewide syllabus documents for any Grades 7 and 8 subjects, including Science. Consequently these grades are not include in the following discussion, which looks firstly at the Grade 9/10 syllabus documents and then at the college (Grade 11/12) syllabus documents.

8.1 INQUIRY METHODOLOGIES IN THE GRADES 9/10 SCIENCE SYLLABUS DOCUMENTS

8.1.1 The Grade 9/10 Syllabus Documents

The syllabuses termed 9SC125/124/123/106B Science and 10SC425/424/423/406B (Tasmanian Secondary Assessment Board, undatedi, undatedj) Science were the ones in use for Grades 9 and 10 Science respectively up to the beginning of 2005, when a new curriculum, known as the *Essential Learnings* was introduced into Tasmanian schools for all grades up to and including Grade 10. As such, the aforementioned syllabuses are the ones that the Grade 9 and 10 students completing the ITIC questionnaire would have experienced. The 425 and 125 syllabuses were generally termed top level syllabuses, with 424 and 124 being termed middle level and 423 and 123 being termed bottom level. The 406 and 106 syllabuses were specifically intended for special needs students (ones with very low academic ability, generally as a consequence of an intellectual disability). Very few students received awards at these special needs syllabuses, and it is unlikely that any special needs students completed the ITIC (as their teachers are unlikely to have deemed doing so to be an appropriate activity for them), so discussion will be limited to the other syllabuses.

Particular reference will be made to the *Version 3, Accredited until December 2004*, syllabus documents for 10 SC425B Science. These consist of the syllabus document itself (Tasmanian Secondary Assessment Board, undatedj) and the Science Standards document (Tasmanian Secondary Assessment Board, undatedk). 10SC425B is the most demanding of the four Grade 10 syllabuses listed above, but both the lower level Grade 10 syllabuses and all the Grade 9 ones really represent only a modification of the degree of sophistication which this syllabus requires of students, with large portions of the syllabus documents being identical. Hence, comments which are made about 10 SC425 with respect to the use of inquiry methodologies are applicable to the lower level syllabuses mentioned above.

The Science Standards document provides teachers with additional information to use when determining whether students should be awarded a rating of A, B or C against each of the criteria listed in the syllabus document. It includes possible sources of evidence against each of the criteria.

In examining the standards document, the requirements that it lists for a student to receive a C rating at the top level syllabus will be considered, as this is the minimum rating required for students to go on to receive an award of ‘Satisfactory Achievement’ at the top level. Teachers of both Grades 9 and 10 needed to ensure that they were providing students with learning experiences which would allow them the opportunity to receive at least C ratings at top level.

The *Version 3, Accredited until December 2004* syllabus document is virtually identical to an earlier document which is labelled *Version 2, Accredited until*

December 2003. The main difference between these two documents and an earlier one labelled *Published for 2001, Accredited until 2003* is that the algorithm for determining students' awards and the names of awards was changed. Similar differences exist between the versions of the 9 SC125/124/123/106B syllabuses.

8.1.2 Inquiry Methodologies in the Grade 9/10 Documents

The Subject description for the Grade 9 and 10 Science subjects states, in part:

> There is *an emphasis on open-ended investigations* **(F)** through working scientifically, applied through the four conceptual strands of the National Statement and Profile. It further develops science skills and concepts applicable to science in daily life. Techniques and processes are *developed through investigations* **(F)** and problem solving in the immediate environment.

This description makes the point that it is the processes of science rather than any particular content knowledge which is important. The content section of the syllabus statements state that the goals for science education are for students to:

- develop personal understanding of the physical, biological and technological worlds and *to devise solutions to problems arising from their own needs* **(I)**
- *take a confident part in discussions and decision-making* about science and science policy **(C)**
- prepare for post-school options.

It goes on to say that these goals are to be achieved through students working scientifically, as described in the national statement for Science (Curriculum Corporation, 1994a), and that principles and activities for effective learning in science are suggested in the statement (pp. 5-8 and pp. 30-35). Examination of the referenced pages in the national statement highlights that there are strong links to the Freedom in Practical Work, (**F**), Interpretation of Data (**I**), Science Stories (**S**) and

Uncertainty in Science (**U**) scales of the ITIC. Links to the Communication scale are not shown as strongly, although they seem to be implied (**C?**).

The syllabus document states that the content of the syllabuses is based on the Working Scientifically strand of the national statement and the curriculum profile (Curriculum Corporation, 1994a, 1994b), and that it includes:

- *planning investigations **(F)***
- *conducting investigations* **(F?)**
- *processing data* **(I)**
- *evaluating findings* **(I)**
- using science
- acting responsibly.

Actual knowledge content is not specified beyond saying that there should be a balanced coverage from the various conceptual strands and organisers in the National Science Statement, and that the selection of areas of study should give a balanced coverage of issues relating to the environment, work and daily life.

The eight assessment criteria contained in the syllabus document, together with some additional relevant information provided by the Science Standards document, are listed in Table 8.1, which also shows links to ITIC inquiry methodologies.

Table 8.1

ITIC Links in the Grade 9/10 Syllabus and Standards Documents.

Criterion	Requirements for a 10SC425 rating of C	Sources of Evidence from the Standards document	ITIC links
1. use equipment, make observations and collect data	Safely and effectively manipulate a range of equipment and materials without supervision. Make qualitative observations and collect quantitative data, *selecting instruments appropriate to the task.*	• *take enough measurements* to gauge reliability; • make measurements to a degree of accuracy appropriate to the equipment and any other measurements involved; • take care in observations and in using equipment to avoid errors (reading a scale from the side instead of in front); • consult and compare information from a number of sources when different views are likely or important. *Student work samples can be found on pages 78 - 81 in Science- A Curriculum Profile for Australian Schools.*	**F?**
2. acquire and *convey information*	*Communicate information in a variety of ways,* selecting an appropriate format.		**C?**
3. *process data*	*Rearrange data independently into an appropriate format.* Additional Comments: *Interpreting observations, identifying patterns, forming generalisations,* considering accuracy and reliability.	Is able to distinguish between dependent and independent variables. Is able to use equations and formula to determine unknown quantities where data concerning the values of other variables involved are given. Selects ways to present information that clarifies patterns and assists in *making generalisations.* Evident when students, for example: • organise data into tables and graphs *to reveal trends and relationships*; • use devices such as diagrams, flow charts and concept maps to identify patterns and *make generalisations*; • write descriptions of patterns in data and ways *they justify conclusions*; • summarise and relate information from different sources to develop and argument and *construct generalisations*; • plan the form and logic of a report or presentation to communicate the results effectively.	**I**
4. *make predictions, evaluate*	*Determine whether predictions and findings are*	Evident when students, for example: • examine and report on how their findings	**I**

findings and draw conclusions	*reasonable answers to the questions asked*	satisfy the investigations original aims; • *suggest further investigations* that would further clarify questions asked; • *justify their conclusions* on the basis of their data.	
5. *plan and organise investigations*	*Plan and organise a fair investigation to solve a problem*.	Suggest ways of doing investigations, giving consideration to fairness. Evident when students, for example: • with teacher support, *develop alternative strategies for doing their investigations*; • *compare the fairness and effectiveness of their own plans and those suggested by other students;* • *propose and discuss the steps of their investigations*; • *suggest focus questions* (in groups and individually) to assist their planning; • list possible sources of information, such as people, books and encyclopaedias for their investigations.	**F, C**
6. understand scientific ideas			
7. understand the impact of science on society	Can demonstrate *an awareness of the complexity of the issues generated by the impact of scientific ideas.* Can propose and compare options when making decisions.	Proposes and compares options when making decisions or taking action. Evident when students for example: • *list alternative means of achieving a particular outcome*, such as lifting a load; • *produce alternative solutions to a problem* (stopping a cat killing birds or iron rusting); • *speculate on the consequences of different choices* when conducting an investigation, working through a problem, or trying to achieve an outcome; • *compare the different science based technologies used to perform the same task* in different countries.	**S, U**
8. work as a member of a group.	Fill a number of roles in a group *and accept the ideas of others* as well as responsibility for group decisions.		**C**

8.1.3 Overview of Inquiry Methodologies in the Grade 9/10 Science Syllabuses

The Freedom in Practical Work scale of the ITIC is strongly reflected in the subject description and there are links in two of the assessment criteria. Examination of the parts of the national statement on science that the syllabus document refers to show strong links to this scale, with the work samples referred to in criterion 1 illustrating that the ITIC link should be designated as **F** rather than **F?**. There are definite links to items F2, F5 and F8, whilst links to F3, F4, F6 and F7 seem to be implied.

The Communication scale of the ITIC is reflected in the content section of the syllabus document and also in three of the assessment criteria. The requirements for students to work in groups, compare the effectiveness of their plans seem to cover all items in the Communication scale.

The Interpretation of Data scale of the ITIC is reflected in the goals for science education list in the 10SC425 syllabus document, and in the summary of the Working Scientifically strand from the national statement and curriculum that the 10Sc425 document provides. In addition, two of the assessment criteria (Criteria 3 and 4) strongly reflect this scale, containing numerous links to it. There are links to items I1, I2, I3, I6 and I7. Links to items I4, I5 and I8 seem to be strongly implied in the activities that students are required to do. I8 is specifically stated in the national statement.

The Science Stories scale of the ITIC is reflected in one of the assessment criteria. The relevant pages of the national statement, as referenced in the syllabus document, also make connections to it. Connections to items in this scale tend to be implied rather than explicit. For example, in order to discuss issues such as genetic engineering, use of pesticides or in vitro fertilisation (as listed in the national statement) students would really need to have heard about the work of scientists (items S3, S4, S5, S6). The national statement also states that students should find out about the work of scientists in the community (links to items S1, S2, S8).

The Uncertainty in Science scale of the ITIC is particularly reflected in one of the assessment criteria (criterion 7). There are links to items U1, U2, U3, U6 and U7. Links to U4 and U5 are implied.

Overall, there can be seen to be considerable overlap between the ITIC scales, and the Grade 9/10 science syllabus documents.

8.2 PRESCRIPTION OF INQUIRY METHODOLOGIES IN COLLEGE SCIENCE

Students from four college science subjects were surveyed to collect data for the ITIC questionnaire. Only students from classes studying at the top level or pretertiary (accepted for university entry) level courses were considered. The four science subjects were:

- 12 BY826 C Biology (Tasmanian Secondary Assessment Board, undated a, b)
- 12 CH856 C Chemistry (Tasmanian Secondary Assessment Board, undated c, d)
- 11/12 SC786 C Physical Sciences (Tasmanian Secondary Assessment Board, undated e, f)
- 12 PH866 C Physics (Tasmanian Secondary Assessment Board, undated g, h).

The following sections consider the extent to which the curriculum documents for each of these college science subjects, as referenced above, prescribe or advocate the use of inquiry methodologies. Each of the subject syllabus documents is accompanied by a set of standards documents. The standards documents elaborate on what is expected of students in order to obtain A, B or C ratings against a subject's criteria. As the C rating is the minimum acceptable for students to obtain a satisfactory result for the subject, in most instances it will be most appropriate to consider the standard for this rating. However, in some instances the requirements for A or B ratings show obvious ITIC links, and as teachers would have to make opportunities to attain A and B ratings available, it is relevant to consider these.

All references in the text to the syllabus or standards documents for the four subjects under consideration refer to the above references. The references are not repeated each time as it was felt that the length of the references would tend to detract from continuity in reading.

8.3 INQUIRY METHODOLOGIES IN THE COLLEGE SYLLABUS DESCRIPTIONS

Each of the syllabus documents contains a section titled ‘Subject Description’. Part of this description is reproduced below for each subject, with links to ITIC inquiry methodologies being indicated. Information from the subject description such as that pertaining to who the course is suited to and its level of difficulty is omitted as it is not relevant to the current discussions.

8.3.1 Subject Description for College Biology

The Biology subject description states in part:

> Through an *enquiry based approach*, this syllabus enables students to develop *investigative* **(F),** *interpretative* **(I)** and manipulative skills through the study of biological themes which apply to all levels of biological organisation. These themes may be studied in the contest of local biological perspectives, local biological resources or particular interest areas.

8.3.2 Subject Description for College Chemistry

The Chemistry subject description states in part:

> The syllabus provides a balanced treatment of the major topics in chemistry, emphasising understanding, the development of language skills necessary for the study of chemistry and *extensive practical work* **(F?)**.

8.3.3 Subject Description for College Physical Sciences

The Physical Sciences subject description states in part:

> It provides opportunities for students to acquire knowledge and understanding, develop skills and concepts, appreciate the applications and implications of Physics and Chemistry and their personal and social relevance.
>
> It includes study of the nature and characteristics of science as a discipline, the *principles and methodologies of scientific investigation* **(F?)** and considers scientific endeavour in its cultural and *historical context* **(S).** It focuses on the processes and products of science as a human activity, and examines its possibilities and limitations through consideration of applications of the physical sciences in society.

8.3.4 Subject Description for College Physics

The Physics subject description states in part:

> The syllabus provides a wide and detailed coverage of physics topics including Mechanics, Fields, Waves, Atomic and Nuclear models.

8.3.5 Overview of College Subject Descriptions

The subject description for Biology actually states that an enquiry based approach should be used. The Chemistry subject description may or may not allow for any behaviours relevant to the ITIC Freedom in Practical Work scale through the extensive practical work that is mandated. Similarly, it is not clear whether the study of investigations indicated in the Physical Sciences subject description allows for any behaviours relevant to the ITIC Freedom in Practical Work scale. The Physics subject description shows no links to ITIC methodologies.

8.4 LEARNING OBJECTIVES OF THE COLLEGE SCIENCE SYLLABUSES

Each of the syllabus documents includes a section titled ‘Learning objectives’. Again, these are not reproduced in their entirety, rather relevant sections are shown.

8.4.1 Learning Objectives for College Biology

Five of the six Biology Learning objectives make connections to inquiry methodologies:

- develop problem solving, practical and personal skills which allow them to function as individuals in contemporary society **(C?, I?, U?)**
- develop an understanding of biological principles and *be able to apply these in understanding the world they live in* **(I)**
- be encouraged to ask questions and to develop skills that will help them to *seek and gain information for themselves* ***(F?)***
- develop *considered opinions based on evidence* and rationality and to develop an open-minded *critical* approach to scientific and broader issues **(C, I)**
- develop an understanding of the processes occurring in biological systems and be able to *apply these to a changing world* **(I?)**.

8.4.2 Learning Objectives for College Chemistry

Of the nine learning objectives that exist for Chemistry, six make connections to inquiry methodologies. These six are reproduced below.

- develop *skills in communication, collecting, analysing and organising information*, working as an individual and in teams, and using technology, techniques and resources **(F?, C?, I)**

- acquire knowledge and understanding of a body of chemical principles and theories and acquire the ability to apply these principles to *predict and explain* the properties of substances and the interactions which take place between them **(I)**
- develop understanding of the role of chemical science in the society in which they live, and its importance in *placing in proper perspective the current conflicts between technological development and conservational restraint*, and introduce students to some of the economic considerations which influence the development of industries and the use of alternative materials and processes **(U)**
- develop understanding of the notion that chemistry is not just materialism, that *it is the product of the work and thought of many people*, and that *the history of chemical discovery and thought is closely linked with the social history of mankind* **(S)**
- use the *experimental approach to problem solving* where applicable; to develop recognition of the need to possess evidence before making judgements, and to *develop the capacity to consider evidence* contrary to established expectations **(F, I)**
- develop awareness that beyond the established facts and laws of chemistry *there are areas of uncertainty where scientists may differ on questions of interpretation*, and thereby to emphasise that chemistry is a living and still rapidly developing science, and to present the challenge of unresolved problems **(U)**.

8.4.3 Learning Objectives for College Physical Sciences

Of the 14 Physical Sciences learning objectives, ten make connections with inquiry methodologies:

- understand the aims and philosophy of science, through exploration of *the nature of scientific endeavour*, while developing *an awareness of its limitations* **(U)**

- acquire some *knowledge of the principles of scientific enquiry,* including an *understanding of the role, nature and purpose of experimentation*, processes by which we construct models, and the relationship between phenomena and these theoretical models **(F?)**
- be able to relate to contemporary science as the product of human activity which is a legitimate *part of our history and culture*, by developing an understanding of contemporary *science as the product of progressive development* **(S)**
- understand the role which science plays in the social and economic context, through examination of the *relationship of science to technology*, the responsibilities of science in creating the future, and *the ethical responsibilities of scientists* **(S)**
- *apply scientific knowledge and principles in problem solving situations*, with emphasis on real-world applications and through *extended and open-ended experimental investigations* of phenomena and ideas **(F, I)**
- *analyse issues* and *be aware of ways in which values, experiences and priorities of groups and individuals may affect their attitude to issues* **(I, U, C)**
- develop *an awareness of their own values* and a willingness to review their own attitudes in the light of new knowledge and experiences; **(C)**
- develop skills necessary to use instruments apparatus and materials correctly and safely *in order to make qualitative observations and collect quantitative data* **(F?)**
- develop an *ability to analyse and interpret data, and to solve problems by using mathematical models* **(I)**
- become familiar with the language of the physical sciences, and be able to *communicate scientific information in an appropriate manner* **(C?)**.

8.4.4 Learning Objectives for College Physics

Six of the eight Physics learning objectives listed make connections to inquiry methodologies.

- learn to *apply qualitatively and quantitatively their knowledge and understanding of physical principles* to solve problems in everyday situations **(I)**
- further develop their ability to solve physical problems *using mathematical techniques* **(I)**
- develop the appropriate process skills *to use the experimental approach to problem solving through practical work* **(F)**
- develop skills to enable the acquisition, *communication* and interpretation of information relating to physical situations using established conventions **(C?)**
- develop *awareness of the notion that established facts and laws of Physics are being constantly reevaluated and interpreted* and hence *Physics is a study of predictive models and theories* **(U)**
- develop understanding of *the impact of Physics on society and the individual*, and its contribution to technological change **(S)**.

8.4.5 Overview of Learning Objectives

The learning objectives for each of the college subjects are quite lengthy, and make a number of links to inquiry methodologies. The Biology learning objectives do not make any specific links with the Science Stories scale.

8.5 CONTENT OF COLLEGE SYLLABUS DOCUMENTS

Although teachers of the college science subjects constantly discuss and clarify the exact content to be included via twice annual statewide moderation meetings, it is that content stated in the syllabus documents which will be considered here. In the following sections, only that content which is relevant to the ITIC scales is reproduced.

8.5.1 Content of College Biology

The content section of the Biology syllabus document includes the following categories:

- Data collection and treatment
  - collection: *by experiments* using biological materials and scientific apparatus, surveying, the results of other workers **(F?)**
  - treatment: *by graphing, interpolating, extrapolating, and predicting using students' own data* or data from primary sources **(I)**.
- Field trips and excursions
  - To locations where students can experience and *work with biological systems and materials first hand* **(F?)**.
- *Decision making/problem solving exercises*
  - These can be generated through practical work, invitations to enquiry (eg BSCS), interpretive exercises, newspaper/media articles, class debate/ brain-storming activities **(I)**.
- Scientific investigations
  - Consideration of problems, *hypothesis development, experimental design, data collection and processing, analysis of results, drawing conclusions in the context of the original hypothesis, evaluation of process* **(I, F?)**.
- An investigation and presentation of a current issue in Biology
  - Students *consider a topical issue that has a biological basis* from the point of view of the biological processes and principles involved as

well as *political, economic, social and ethical considerations*. The *presentation to a group* may be a display, folio, video, debate, talk etc **(C, S, U).**

8.5.2 Content of College Chemistry

The content section of the Chemistry syllabus largely consists of chemical principles and ideas. It does include, under the heading *Electronic Structure and the Periodic Table*:

- *How did chemistry begin*? **(S)**.

8.5.3 Content of College Physical sciences

The content section of the Physical Sciences syllabus is lengthy, and includes the following:

- Prescribed Learning Activities, which includes the instruction that during this syllabus all students should undertake tasks in the following areas:
    - *open-ended problem solving and decision-making* activities **(I**)
    - *case studies of scientists* and/or scientific ideas **(S)**
    - *interpretation* of scientific literature **(I)**
    - *class/group discussion* of scientific concepts **(C).**
- *Practical Work*, which states that a minimum of 50 hours of laboratory work must have been undertaken. Every student must submit for internal assessment completed practical reports and evidence of data collection obtained during practical activities, i.e. practical notebook plus final report **(F?)**.
- The Nature and Aims of Science, including:
    - From what evidence are scientific conclusions derived?
    - *What are the limitations of science*? **(U).**

- The Methodology of Science

The study of science should include a component which addresses the methods and limitations of the various modes of scientific enquiry. The meaning of the term ‘scientific method’ is in itself controversial. More important, however, is the realisation that the notions of ‘objective’, ‘empirical’, ‘inductive’, deductive’, ‘theory’, ‘law’, ’experiment’, ‘proof’, should be understood, at least within a context which may assist to make their differences understood and useful.

  - *What are the criteria for good experiments*? **(F, I)**
  - *How can we distinguish good from bad experimental design and technique?* **(I)**
  - *When is it appropriate to discard a theory rather than modify it?* **(S, U)**
  - *What constitutes a valid experimental investigation*? **(F?)**
  - *What is ‘an experiment’*? **(I)**
  - *What is ‘proof’*? **(I)**
  - *How do we construct a hypothesis*? **(I)**
  - *What do we mean by ‘problem-solving’*? **(I?, U?)**
  - *How can we make decisions about treating data*? **(I)**
  - *With what methods can we treat data*? **(I)**
  - *Is it possible to have two satisfactory explanations for the same phenomenon*? **(U)**.

- The Historical and Cultural Context of Science
  - *How much does scientific understanding and theory-making depend on the culture and beliefs of the times*? **(S, U)**
  - *What has happened when cultural beliefs and assumptions have conflicted with new scientific theories*? **(S)**
  - *To what extent have cultures depended on scientific understanding and the associated technologies*? **(S)**

    - *To what degree has the history of science depended on wrong interpretations, earlier discoveries, serendipity, 'genius'? How much has it depended on the personality and beliefs of individuals*? **(S, U)**
    - *How is one theory replaced by another*? **(U)**.
- Science and Our Society
    - *What are the social and economic contexts for decision-making in matters with a scientific component*? **(U)**
    - *To what degree can (or should) we believe the conclusions provided by 'scientists*? **(I, U)**
    - *What is the place of science in creating the future*? **(S?)**
    - *To what extent should scientists concern themselves with ethical considerations*? **(S?, U)**
    - *Should science have other aims that depend on our values (e.g. political, religious, environmental, social)*? **(U)**
    - *How can we deal with disagreements between 'experts'*? **(U)**.
- Applications of Science
    - *To what extent should the direction of scientific research be guided by the requirements of technology - who is the servant and who should be the master*? **(C?)**.

8.5.4 Content of College Physics

The Physics syllabus document includes in the content section:

- Prescribed Learning Activities

  In studying courses derived from this syllabus, students should undertake tasks in the following areas.

  1. Data collection and treatment by *experimentation using appropriate equipment and materials* **(F?).** Activities should include observing,

measuring, classifying, recording, tabulating, graphing, *drawing inferences, developing hypotheses and predicting* **(I)**.

2. The compilation of a practical logbook and set of completed practical reports **(F?)**.
3. Class discussions on issues related to the content **(C)**.
4. A brief theoretical *or practical investigation* of an area of physics of topical interest. *Reporting* on this could take any appropriate form **(F?, C?, I)**.
5. Problem solving using interpretative exercises based on the content **(I)**.

- *Practical Work*

  All students presenting themselves for assessment must complete a course of practical work in a laboratory which has been approved after inspection by the Schools Board of Tasmania. Minimum time for practical work is 50 hours **(F?).**

8.5.5 Overview of the Content Sections

The Chemistry content section makes few links to ITIC inquiry methodologies. All other syllabus documents make a number of connections between their content and the ITIC scales.

8.6 CRITERIA FOR THE COLLEGE SCIENCE SYLLABUSES

The criteria vary between the college science subjects, although there are commonalities between some syllabuses. Each syllabus document is accompanied by a set of standards for each criterion. In the following examination of the subject criteria, parts of the standards document are reproduced under the relevant criterion where they give further insight into how the criterion relates to ITIC inquiry methodologies.

Criteria which are marked by a * are ones which are examined on the external exam, as well as by internal teacher assessments.

8.6.1 Criteria for Biology

The Biology criteria each include a list of examples. Only those relevant to ITIC inquiry methodologies are reproduced here.

1. Collect information and data from a variety of sources, correctly citing all sources when appropriate.

2. Present biological information and principles *using an appropriate and varied means of communication*.

The standards document lists oral presentation as a possible source of evidence, but does not prescribe it.

- Oral presentation of a current biological issue or a syllabus related topic **(C?)**.

3.* Demonstrate understanding and knowledge of biological principles and how they apply to the molecular and cellular levels of organisation.

The standards document includes that students have:

- The ability *to provide limited explanations for unfamiliar situations* **(I?)**.

4.* Demonstrate understanding and knowledge of biological principles and how they apply to the organism.

The standards document includes that students have:

- The ability *to provide limited explanations for unfamiliar situations* **(I?)**.

5.* Demonstrate understanding and knowledge of biological principles and how they apply to the interrelationships between organisms and environments.

The standards document includes that students have:

- The ability *to provide limited explanations for unfamiliar situations* **(I?)**.

6. Correctly, constructively, safely and ethically manipulate a variety of biological materials and scientific apparatus.

The standards document lists, as a possible source of evidence, tasks which provide opportunities for student planning, coordination and execution, with a C rating requiring:

- *plans work, uses correct apparatus and materials to conduct the experiment efficiently with some precision* to achieve most objectives within given time frame **(F?)**.

7. Work individually and cooperate with others efficiently to meet the demands of the syllabus. This includes as an example:

- *Contributing to discussions* **(C)**

The standards document lists, as a possible source of evidence, discussions of current issues.

8.* *Develop feasible hypotheses and design controlled experiments to test hypotheses*. This criterion includes as examples of achievement:

- *can propose a hypothesis appropriate to the situation* **(I)**
- *can design a controlled experiment to test a hypothesis* **(F?)**
- *devises an appropriate method of data collection and recording* **(F)**
- *an understanding of the status and limitation of conclusions* **(I).**

The standards document for criterion 8 lists proposing hypotheses and designing experiments for laboratory work as a possible source of evidence against the criterion. This implies that students may have the opportunity to do more than just design experiments on paper, so F rather than F? seems likely.

9.* *Analyse, interpret and evaluate information and data gained (from individual investigations and the investigations of others) and to evaluate the methods used and conclusions drawn from these investigations*. This criterion includes as examples:

- *open ended activities to collect and analyse data* **(F)**

- *individual research of projects including evaluation of this investigation* **(F?, I)**
- *can suggest improvements to their own and other investigations* **(I)**
- *compare own and others investigations and evaluate in teams, methodology and validity of conclusions* **(C)**.

The standards document requires that for a C rating a student:

- *Demonstrates ability to extract information from data and to analyse data presented in a variety of formats, interpreting relationships between two variables. Demonstrates ability to extrapolate and make limited predictions from graphical data. Conclusions drawn should include generalisations. Critically evaluates the design of an experiment.*

This highlights the connection to the Interpretation of Data scale of the ITIC questionnaire.

10. Demonstrate an understanding of relevant considerations (eg political, ethical, social, economic) in current biological debates.

The standards document requires that for a C rating a student:

- Demonstrates ability to present a clear summary of the issue based on accurate biological knowledge. Must be able *to present a well balanced argument* which *recognises some positive and negative elements*. *Can draw a logical conclusion.* **(C?, S, U)**.

8.6.2 Criteria for Chemistry

The assessment for *12 CH856 C Chemistry* will be based on the degree to which the student can:

1. Collect, analyse and organise information in a variety of ways when performing chemical investigations **(F?, I)**.
2. * Communicate ideas and information using appropriate chemical language and formats when undertaking chemical investigations **(C?)**.

3. *Perform practical chemical investigations* when working with others and in teams **(F?)**.

Part of the Criterion 3 checklist in the standards document states that students can:

- *Seek and respect others' opinions and viewpoints* **(C)**.

4. Use chemical information to *solve problems, develop hypotheses and design experiments to test the validity of these hypotheses* **(I)**.

Part of the criterion 4 standard states that in familiar settings a student can:

- identify, anticipate, and solve problems efficiently, *make justifiable predictions on the basis of data* and design experiments to test these predictions **(I)**.

5. Demonstrate an ability to use technology, resources and techniques in an orderly, efficient and safe manner when performing experimental work in the chemistry laboratory.

The standards for criterion 5 include that for a C rating students can:

- demonstrate some initiative to *select and use suitable resources and techniques* **(F)**.

6. Demonstrate a knowledge of *the practical applications of chemistry and its implications for society* **(S?)**.

The standards document includes that students can:

- Demonstrate *an awareness of the role of chemistry in a range of industries and of some of the implications of society* (for a C rating) or Demonstrate the ability to *advance a balanced argument on the role of chemistry in a wide range of industrial and technological applications* (for an A rating) **(C)**.

7. * Demonstrate an understanding of the fundamental principles and theories of electrochemistry.

The standards document indicates that to receive either an A or B rating students' demonstration must include:

- the ability to *provide explanations of unfamiliar situations* **(I)**.

8. * Demonstrate an understanding of the principles and theories of thermochemistry, rate of reaction and equilibrium.

The standards document indicates that to receive either an A or B rating students' demonstration must include:

- the ability to *provide explanations of unfamiliar situations* **(I)**.

9. * Demonstrate an understanding of properties and reactions of inorganic and organic matter.

The standards document indicates that to receive either an A or B rating students' demonstration must include:

- the ability to *provide explanations of unfamiliar situations* **(I)**.

10. * Apply logical processes to solve quantitative chemical problems.

The standards document indicates that to receive either an A or B rating students' demonstration must include:

- the ability to *provide explanations of unfamiliar situations* **(I)**.

8.6.3 Criteria for Physical Sciences

The assessment for *11/12 SC786 C Physical Sciences* will be based on the degree

to which the student can:

1. Collect information and data from a variety of sources.
2. * Convey scientific information and concepts *using appropriate and varied means of communication* **(C?)**.
3. *Perform practical investigations*, individually and as a member of a group **(F?)**.

The standards document states that for a C rating a student:

- *Analyses results and infers relationships* commensurate with data or observations. Possible sources of error are listed. *Makes conclusions* but may have some difficulty linking to experimental objectives **(I)**.

4. *Develop hypotheses* and models and design experiments to test their validity **(I)**.

5. Correctly and safely handle a range of apparatus and materials with minimal supervision, having proper regard for technique and working in an orderly manner.

Whilst this could be F?, cross-checking with the standards document indicates that this criterion focuses more on the use of lab equipment rather than practical design , so an ITIC connection has not been assigned to this criterion.

6. Understand the nature, *history and methodology of science* **(S)** and apply scientific understanding to *making judgements* **(I)** relating to *the role of scientific technology in society* **(S)**.

The standards document adds that for a C rating a student:

- Has a basic understanding of the impact of science on society, and some awareness of the issues that arise in this context. *Is able to make judgements* **(C)** in cases where there are relatively few conflicts of interest or variables in the arguments.

7. * Demonstrate knowledge and understanding of Physics terminology, conventions, quantities and units of measurement, definitions and laws, concepts, theories and models.

8. * *Use techniques of analysis and mathematical manipulation to solve problems* relating to Physics concepts **(I)**.

9. * Demonstrate understanding of current chemical theories explaining the structure of matter and apply this knowledge to *explain the behaviour of unfamiliar substances* **(I)**.

10. * Understand the changes that occur in various chemical reactions and use this knowledge to make qualitative and quantitative predictions of the products of reactions and *generalise to novel situations* **(I)**.

8.6.4 Criteria for Physics

The assessment for *12 PH866 C Physics* will be based on the degree to which the student can:

1. Acquire information with minimal assistance in a variety of ways from a variety of sources.

2.* *Convey information in a variety of ways* using established conventions and appropriate language **(C?)**.

3. Safely and correctly *use a range of equipment and scientific instruments to obtain data* **(F?).**

Whilst this could be F?, cross-checking with the standards document indicates that this criterion focuses more on the use of lab equipment rather than practical design , so an ITIC connection has not been assigned to this criterion.

4. Design experiments to solve problems or test hypotheses **(F?)**.
5. *Perform practical investigations* individually or as a member of a group **(F?)**.
6. *Analyse data* gained from students own practical work **(I)**.
7. * *Formulate generalisations and make realistic predictions* based on experimental data **(I)**.
8. Demonstrate *knowledge and understanding of the ways that Physics impacts on technology, society and the individual* **(S)**.

A C rating requires:

- Uses a good working knowledge *to evaluate various current scientific issues* and development. Is aware of the importance of scientific technology in society **(C?)**.

9. * Demonstrate and apply knowledge understanding of terminology; definitions laws; concepts, theories and models; and of measuring instruments of Physics.
10. * *Incorporate techniques of analysis and mathematical manipulation* (algebraic, trigonometrical, numerical and graphical) to solve complex problems **(I)**.

8.6.5 Overview of the College Subject Criteria

As was the case with the content sections, there are numerous links between the criteria for each of the college science subjects and the ITIC scales.

8.7 OVERVIEW OF INQUIRY METHODOLOGIES IN COLLEGE SCIENCE COURSES

Table 8.2 summarises the above analysis of the college science syllabus documents. It shows the number of times that a connection to the various ITIC scales is indicated in the college science syllabus documents that were considered. The results in Table 8.2, together with the preceding interrogation of the syllabus documents, indicate that there are numerous links between each of the college science subjects and the ITIC scales. Therefore, it is reasonable to expect that the results of both the student and teacher versions of the ITIC should show that inquiry methodologies are in use in science classrooms. On the basis of Table 8.2, the greatest amount of inquiry would be expected to occur in Physical Sciences, followed by Biology, and then Chemistry and Physics, these latter two being approximately equal.

Table 8.2
Number of References to Methodologies From the Various ITIC Scales in the College Science Syllabus Documents.

	Biology	Chemistry	Physical Sciences	Physics
Freedom in Practical Work	3	2	2	1
F?	7	4	6	7
Communication	4	2	4	1
C?	3	2	3	4
Interpretation of Data	10	10	15	8
I?	5	0	1	0
Science Stories	2	2	16	2
S?	0	1	2	0
Uncertainty in Science	2	2	12	1
U?	1	0	1	0
Totals	37	25	62	24

However, it may be argued that some syllabus documents are more detailed than others, allowing more references to inquiry methodologies to occur. Therefore care should be taken in interpreting the results obtained in this analysis.

The Biology subject description actually stated that an enquiry based approach should be used. Therefore results from Biology classrooms would be expected to show high levels of inquiry. The syllabus writers may have felt that having placed this initial rider in the syllabus document it was not necessary to incorporate as many further references to inquiry methodologies as would have been the case if this rider had not been there.

Examining the data for the individual ITIC scales shown in Table 8.2 some obvious trends can be seen. The Science Stories and Uncertainty in Science scales are represented much more in the Physical Sciences syllabus documents than in those for the other subjects. If the results for I and I? are combined, the Interpretation of Data scale is represented more in the Physical Sciences and Biology subject documents than in those for Chemistry and Physics. The differences between the subjects on the Freedom in Practical Work and Communication scales are not as pronounced.

8.8 INDICATION OF ITIC INQUIRY METHODOLOGIES IN SYLLABUS DOCUMENTS

All the science syllabus documents examined in this chapter showed marked links to the inquiry methodologies defined by the ITIC scales. In the case of the documentation for the four college science subjects, the greatest number of links occurred for Physical Sciences, followed by Biology, Chemistry and Physics. However, it should be reiterated at this point that care needs to be taken in attaching too much significance to the number of references found, as the length of the curriculum documentation varies considerably between subjects.

Chapter 11 will consider whether the intent of these curriculum documents is reflected by the extent to which students and teachers perceived that inquiry methodologies were actually being used in their science classrooms.

CHAPTER 9 - ANALYSIS OF 2005 TASMANIAN COLLEGE SCIENCE SYLLABUS DOCUMENTS FOR INQUIRY METHODOLOGIES

CHAPTER OVERVIEW

Chapters 9 and 10 adopt a similar approach to Chapter 8, but whereas Chapter 8 considered the science syllabus documents that were being used in Tasmania at the time that the ITIC was administered Chapters 9 and 10 consider the Tasmanian syllabus documents in use in 2005, with Chapter 9 examining college science syllabus documents and Chapter 10 examining the *Essential Learnings* curriculum documents.

Examination of these syllabus documents was carried out in order to determine the degree to which they either suggest or prescribe the use of the inquiry methodologies defined by the ITIC instrument, with the overall aim being to determine the potential usefulness of the ITIC in the contemporary Tasmanian context. The Assessment scale from the original ITIC instrument was not included in the examination of the syllabus documents, as it had not been shown to have acceptable reliability.

New college (Grade 11/12) science courses were implemented in Tasmania from 2004 onwards, replacing the documents considered in Chapter 8. The current chapter examines each of the six new Senior Secondary 5C college science syllabus documents.

Examination of the syllabus documents was carried out by considering some generic documentation, the Syllabus Descriptions for each subject and then each of the ITIC scales in turn, investigating the connections that each syllabus showed to the scale under consideration. This was slightly different to the approach taken in Chapter 8, where each syllabus was considered in turn, with the connections that it made to each of the ITIC scales then being investigated. The new approach was adopted, since if only some scales were found to be relevant to the contemporary syllabuses it could then be recommended that only this portion of the ITIC should be used in the Tasmanian context.

9.1 ITIC INQUIRY METHODOLOGIES IN GENERIC COLLEGE SCIENCE DOCUMENTATION

As was noted in the introduction to this chapter, from 2004 six college science subjects became available at what is termed Senior Secondary 5C level (level 5 denotes the highest level, and C denotes that the design time for the course is 150 hours). All level 5 syllabuses are externally assessed pretertiary (accepted for university entrance) syllabuses. For each of the college 5C science subjects the external assessment currently includes an exam that all students taking the subject must complete, and which is marked externally to the school.

The documentation for each of the college science subjects consists of a *Syllabus Document*, which includes a *Criteria Standards* section, and a separate *Syllabus Supplement* document which contains advice to assist teachers in delivering the syllabus. The latter document can be modified in response to consensus decisions arrived at in annual subject based Moderation meetings, which teachers from all schools delivering the syllabus must attend.

The six Senior Secondary 5C science syllabuses are listed below, with the Syllabus Document given as the first reference and the Syllabus Supplement as the second. As in the previous chapter, these references are not repeated each time a subject is referred to, due to their length and potential to distract from the discussion at hand. The subjects are listed in alphabetical order.

- Biology Senior Secondary 5c (Tasmanian Secondary Assessment Board, 2003a, 2003g).

- Chemistry Senior Secondary 5c (Tasmanian Secondary Assessment Board, 2003b, 2003h).

- Environmental Science Senior Secondary 5c (Tasmanian Secondary Assessment Board, 2003c, 2003i).

- Physical Sciences Senior Secondary 5c (Tasmanian Secondary Assessment Board, 2003d, 2003j).

- Physics Senior Secondary 5c (Tasmanian Secondary Assessment Board, 2003e, 2003k).
- Science of Natural Resources Senior Secondary 5c (Tasmanian Secondary Assessment Board, 2003f, 2003l).

9.1.1 Notation Used in Examination of the College Syllabus Documents

In the following discussion of the college science syllabus documents, the method of showing connections to ITIC scales that was outlined in Chapter 8 will again be employed. That is:

1. The parts of the syllabus documents that imply the use of ITIC inquiry methodologies will be reproduced in the text. Italics will be used to highlight particular connections implied by part of this text.
2. The ITIC scale/s that the reproduced statements can be taken as referring to will be shown in bold in brackets at the end of the italicised section. The key that will be used to represent the different ITIC scales is:

   (F) - Freedom in Practical Work

   (C) - Communication

   (I) - Interpretation of Data

   (S) - Science Stories

   (U) - Uncertainty in Science.

Where the connections to ITIC scales seem to be implied, but are not explicit a '**?**' will be used.

9.1.2 Examination of Some Generic College Science Documentation

The Tasmanian Qualifications Authority or TQA is the certifying body for Grade 11/12 syllabuses in Tasmania. A document on its website titled *The New and Revised Science Syllabuses* (Tasmanian Qualifications Authority, n.d.) reports that the revised TCE science syllabuses that were implemented in 2004 were designed to assist students to understand:

- *the nature of science and scientific knowledge* ***(U)***
- scientific concepts, principles, laws and theories
- *the means of developing and using evidence-based conclusions* ***(I)***
- *the importance of doubt, scepticism and questioning when applied to understanding outcomes* ***(U)***
- how to make scientific connections to a broad range of issues, ideas and technologies
- how to use these connections and questioning skills to solve problems and *make choices and decisions* ***(C)*** in the wider contexts of our lives, society and the political process
- *the limitations of scientific enquiry* ***(I, U)*****.**

The website continues on to note that the purpose of science education is to develop scientific literacy, and that this involves designing syllabuses that help students to:

- be interested in and understand the world around us
- develop manipulative skills such as measurement, use of scale and of technology, the environment and the use of these sensitively (sic)
- *engage in issues with a scientific focus or issues that use scientific findings as support arguments* ***(I, C)***
- *be curious, to question appropriately and authoritively, to be sceptical and to make informed decisions in wider contexts* ***(I, C, U)***
- act wisely and ethically when making decisions concerning the natural and constructed worlds
- desire life-long learning and seek some understanding of the big questions.

The information in this introductory document indicates that the college science syllabuses should show definite connections to inquiry methodologies as defined by the ITIC questionnaire.

The first section in each of the six college science 5C syllabus documents is titled *Learning Statement*. It is identical in the six syllabuses, with part of it being taken from the research report *The Status and Quality of Teaching and Learning of Science in Australian Schools* (Goodrum, Hackling & Rennie, 2001). This learning statement is reproduced below so that connections to inquiry methodologies can be highlighted.

> Knowledge and understanding of science, scientific literacy and scientific methods are necessary for students to develop the skills to resolve questions about their natural and constructed world.
>
> The purpose of science education is to develop scientific literacy, which is a high priority for all citizens, helping them to be interested in and understand the world around them, *to engage in discourse about science* ***(C),*** *to be sceptical and questioning of claims made by others about scientific matters* ***(U, I)***, *to be able to identify questions and draw evidence-based conclusions* ***(I)***, *and to make informed decisions* **(C, I)** about the environment and their own health and well-being.
>
> Scientifically literate students can therefore *describe, explain* ***(C)*** and *predict* ***(I)*** natural phenomena, and can *discuss the validity of their conclusions* ***(C, I).*** This enables them to identify and understand the scientific and technological aspects underlying national and local issues and *to form opinions, which are reasoned and informed* ***(C, I, U).*** It also leads *to the proper evaluation of the quality of scientific information on the basis of source and on the methods used to generate it* ***(I, U)***. The study of science raises awareness of the central role that science and technology can play both in encouraging life long learning, and in enabling a student to pursue a career path to this end.

This generic learning statement indicates that the intent of the college science syllabuses is that there should be considerable inclusion of inquiry teaching methodologies, as defined by the ITIC Communication, Interpretation of Data and Uncertainty in Science scales.

9.1.3 The Common College Science Criteria

Further important generic components of the college science syllabuses are the six common assessment criteria (out of a total of ten criteria per subject). The six common criteria are:

1. select and use technologies
2. *collect and categorise information* (**F?, I**)
3. *plan, organise and complete activities* (**F?)**
4. *develop and evaluate experiments* (**F, I**)
5. *communicate ideas and information* (**C?**)
6. demonstrate knowledge and understanding of the impact of science on society and the environment.

Connections between these common criteria and the ITIC scales will be considered in more detail in later sections, which will examine the syllabus documents by ITIC scale.

The last portion of each of the college science syllabus documents is termed *Criteria Standards,* and consists of introductory information plus a set of ten tables, one for each criterion. Each of these tables consists of three columns, one column for each of the ratings, C, B and A. The body of the table shows the outcomes, or descriptors, which describe what students need to do in order to satisfy the requirements of the criterion under consideration. Thus, there are three versions of each descriptor, one for rating C, one for rating B and one for rating A (see Table 9.1 by way of an example). In analysing the standards for connections to the ITIC scales, only the C rating descriptor was considered, as the B and A descriptors are always of similar intent to the C descriptor, and considering them as well would have artificially inflated the number of connections to a particular ITIC scale.

In the syllabus documents, bold print is used to indicate precisely where one rating is more difficult than the one that precedes it. Where descriptors are reproduced in the current chapter, this convention is maintained.

9.1.4 Connections to the ITIC - What the Generic Documents Show

The documents considered in Section 9.1 show a number of connections to the Communication, Interpretation of Data and Uncertainty in Science scales. The assessment criteria also show connections to the Freedom in Practical Work scale. There are no explicit references to the Science Stories scale.

9.2 ITIC INQUIRY METHODOLOGIES IN COLLEGE SCIENCE SYLLABUS DESCRIPTIONS

Each of the college science syllabus documents (Tasmanian Secondary Assessment Board, 2003a, b, c, d, e, f) contains a section headed *Syllabus Description*. Although some of these syllabus descriptions are rather lengthy, they are reproduced here so as to highlight any connections that they show to ITIC inquiry methodologies.

9.2.1 Biology Senior Secondary 5C Syllabus Description

The syllabus description for Biology Senior Secondary 5C states:

> Biology in the 21st century is a rapidly growing science, accumulating a vast amount of information about the living world.
>
> In this syllabus students will develop a broad understanding of the important basic biological concepts and processes. This fundamental background will enable them *to critically evaluate information, participate in debates and draw conclusions on contentious biological*

> *issues* ***(I, C, U).*** It will also provide a foundation for further studies in the Life Sciences.
>
> Biological concepts are studied at all levels of biological organisation and *are approached through problem solving* ***(I, U),*** *practical and investigative activities* ***(F)*** which involve students working as individuals as well as members of a group.

9.2.2 Chemistry Senior Secondary 5C Syllabus Description

The syllabus description for Chemistry Senior Secondary 5C states:

> Chemistry is about materials, their uses, their structures and properties and how these can be modified by chemical reactions. The study of chemistry enables students to enquire about the use that society makes of its resources, and of the impact of that use on the planet. Chemistry is a central science drawing on the principles of Physics and Mathematics and forms the basis for Agriculture, Biology, Chemical Engineering, Environmental Science, Forestry, Medicine and Pharmacy. Chemistry is used to varying extents in all other scientific disciplines.

9.2.3 Environmental Science Senior Secondary 5C Syllabus Description

The syllabus description for Environmental Science Senior Secondary 5C states:

> Environmental science explores the tension between human dependence on the natural environment for our continued survival and our significant impact on its continued functioning. Students study a range of ecosystems and explore *how human impacts on our environment are affected by our values and ethics, our sense of social responsibility, economic and political systems* ***(U),*** use of technology and scientific understanding of the natural and constructed world. There is an emphasis *on students studying local environments, where possible, and on excursions and project work* ***(F).*** The *analysis of current environmental issues in a balanced and*

> *scientific manner using critical thinking skills is an integral aspect of the syllabus* ***(I, U, C).*** Students are introduced to a range of strategies for solving environmental problems leading them to confidently meet issues in the future.

In addition to the Syllabus Description, the Syllabus Outline section of the Environmental Science document contains a number of points that imply the use of inquiry methodologies, whereas the Syllabus Outline sections for the other subjects are largely a list of content knowledge that should be covered. The relevant parts of this Syllabus Outline section will be incorporated under the ITIC scale headings. However, the last of these points is noteworthy here:

- engage students *in relevant scientific enquiry* and develop enjoyment and enthusiasm from learning in science.

9.2.4 Physical Sciences Senior Secondary 5C Syllabus Description

The syllabus description for Physical Sciences Senior Secondary 5C states:

> Physical Sciences is an integrated syllabus providing students with a rigorous introduction to the disciplines of physics and chemistry in the one course, whilst keeping all future options open with regard to further study in any area of science and technology.
>
> *It builds on the traditions of enquiry that are central to the study of science and how an understanding of the world and the universe can be explained or predicted by the development of theories and models. These theories and models can be tested objectively against gathered evidence and need to be constantly re-evaluated and modified in the light of new evidence* ***(I, U).***
>
> The Physical Sciences *syllabus requires students to work in practical ways* ***(F?)*** to gain knowledge of the theoretical concepts of the course. It provides a framework for the understanding of physical and chemical phenomena ranging in scale from sub-atomic particles to the universe itself.

> By providing the fundamental scientific background, *students will be able to participate in discussions concerning contentious current scientific issues in an informed way* ***(C, I, U)***.
>
> The development of scientific numeracy and literacy are key elements, and the basic principles that students encounter are applicable to all other scientific disciplines.
>
> The content and delivery are described through themes. The study of physical sciences focuses on the acquisition and further development of knowledge and understanding of forces and motion, structures and properties of materials, sources and properties of energy, chemical reactions and change, and on understanding the impact of science on society and the environment.
>
> *Thirty per cent of the course time is spent on practical work, completed practical reports and evidence of data collection are required* ***(F?)***.
>
> Courses based on this syllabus embrace the range of technological developments that have occurred in relation to science for data collection and analysis, and for simulation and investigative purposes.

9.2.5 Physics Senior Secondary 5C Syllabus Description

The syllabus description for Physics Senior Secondary 5C states:

> Physics Senior Secondary 5 further develops and extends the rigorous study of physics that students have experienced in Physical Sciences Senior Secondary 5.
>
> It primarily considers matter and energy and their relationship to each other. Students will begin to develop an understanding of the composition of matter and why it behaves the way it does in different situations ranging from the sub-atomic to the solar system. They will learn how energy is produced and how it is moved from one site to another and how it can be used and controlled.
>
> *Students will learn that science is an evolutionary process and that it moves forward by either developing theories and models to explain agreed*

> *observable experimental results* **(U)** or, conversely, *by devising experiments to test predictions and hypotheses* **(F?, I?)**.

9.2.6 Science of Natural Resources Senior Secondary 5C Syllabus Description

The syllabus description for Science of Natural Resources Senior Secondary 5C states:

> In this syllabus, students will develop knowledge and understanding of the management and research that allows the sustainable use of Tasmanian resources. This will be acquired through the study of sustainable resource management that integrates three or more (sic) following contexts: Agriculture, Marine/Aquaculture, Energy, Forestry and Mining. *The analysis of resource management in a balanced and scientific manner using critical thinking skills is an integral aspect of this syllabus* **(I, U)**.

9.2.7 Connections to the ITIC - What the Syllabus Descriptions Show

There is a large variation in both the length and the nature of the syllabus descriptions for the six college science subjects. This makes it difficult to draw valid comparisons between subjects, but overall it can be seen that the syllabus descriptions show extensive connections to the Freedom in Practical Work, Interpretation of Data and Uncertainty scales. There is more limited connection to the Communication scale and none to the Science Stories scale.

9.3 FREEDOM IN PRACTICAL WORK IN THE COLLEGE SENIOR SECONDARY 5C SCIENCE COURSES

This section considers the extent to which each of the college science syllabus documents prescribes or suggests an approach that includes methodologies described by items from the ITIC Freedom in Practical Work scale. Where a part of the syllabus document relates to both the Freedom in Practical Work and other scales, all connections are shown, and are not then also counted in later sections. This convention is used throughout the rest of this chapter.

The common criteria are considered first, then each college science syllabus is considered in turn. This convention will be continued in sections 9.4 through 9.7.

9.3.1 Freedom in Practical Work in the College Common Criteria

The items of the ITIC Freedom in Practical Work scale are comprehensively described by the first three descriptors from Criterion 4 - Develop and evaluate experiments - which contains a total of five descriptors. The three descriptors that relate to the Freedom in Practical Work scale are reproduced as Table 9.1.

Criterion 1 - Select and use technologies - of the six common criteria also implies that students should have some freedom in the practical work that they carry out, as this criterion requires that students develop ideas and designs and that they are able to adapt the selection and use of technologies. In science classes the technologies that that are being used would frequently relate to practical work. Table 9.2 shows the three descriptors from Criterion 1 (out of a total of five descriptors that exist for this criterion) which relate to Freedom in Practical Work scale items.

Table 9.1
The Descriptors From Common Criterion 4 - Develop and Evaluate Experiments (Tasmanian Secondary Assessment Board, 2003a-f), Which Relate to the Freedom in Practical Work scale.

Rating C	Rating B	Rating A
using an appropriate format, develop a relevant testable concept; (F)	using an appropriate format, develop a relevant testable concept;	using an appropriate format, develop a relevant testable concept;
design an experiment to test a concept using accepted elements of experimental design to demonstrate understanding of how they influence outcomes; (F)	design an experiment to test a concept using accepted elements of experimental design to demonstrate understanding of how they influence outcomes;	design an experiment to test a concept using accepted elements of experimental design to demonstrate **comprehensive** understanding of how they influence outcomes;
identify constraints including relevant safety and ethical issues which influence methodology and choice of equipment in experiments; (F)	**explain** constraints including relevant safety and ethical issues which influence methodology and choice of equipment in experiments;	explain constraints including relevant safety and ethical issues **and adopt alternative methodologies and equipment where appropriate;**

Table 9.2

The Descriptors from Common Criterion 1 - Select and Use Technologies (Tasmanian Secondary Assessment Board, 2003a-f), Which Relate to the Freedom in Practical Work Scale.

Rating C	Rating B	Rating A
consider, select and use technologies to develop ideas and designs carefully, responsibly and imaginatively; (F)	consider, select and **appropriately** use, technologies to develop ideas and designs carefully, responsibly and imaginatively;	consider, select and **competently** use technologies to develop ideas and designs carefully, responsibly and imaginatively;
identify changed conditions and adapt the selection and use of technologies to respond constructively to major changes; (F)	identify changed conditions and adapt the selection and use of technologies to respond constructively and **creatively** to major changes;	identify changed conditions and adapt the selection and use of technologies to respond constructively and **fully** to major changes;

Aspects of Criterion 3 - Plan, organise and complete activities - may also relate to the Freedom in Practical Work scale, but are not reproduced here as the links are more tenuous.

9.3.2 Freedom in Practical Work in the College Biology Senior Secondary 5C Syllabus

The Syllabus Outline section of the Biology Syllabus (Tasmanian Secondary Assessment Board, 2003a) states that:

> Students should *develop an understanding of scientific method* throughout the course.
>
> A minimum of 30% of the course is to be *spent on practical activities* ***(F?)***, which are an integral part of the course and should be used as a means of teaching and consolidating the course content.

9.3.3 Freedom in Practical Work in the College Chemistry Senior Secondary 5C Syllabus

The Syllabus Outline section of the Chemistry syllabus (Tasmanian Secondary Assessment Board, 2003b) states that:

> *Practical activities are an essential part of this course* ***(F?)***. It is recommended that 30% of class time should be spent on practical activities.

Additionally, the syllabus supplement (Tasmanian Secondary Assessment Board, 2003h) includes a schematic overview diagram which has at its centre *Practical activities* **(F?)** and *Sharing ideas* **(C)**.

9.3.4 Freedom in Practical Work in the College Environmental Science Senior Secondary 5C Syllabus

The Syllabus Outline section of the Environmental Science syllabus (Tasmanian Secondary Assessment Board, 2003c) states that:

> *Practical work* forms an important part of this science subject **(F?)**.

Additionally the syllabus prescribes a case study, with the following description:

> Students will be expected to produce *one case study of new knowledge they have generated* **(F)** in a selected area. The area of study will be selected after consultation with the teacher.
>
> *The case study should be a personal or small group investigation* carried out over the total equivalent of approximately four weeks of class time.

9.3.5 Freedom in Practical Work in the College Physical Sciences and Physics Senior Secondary 5C Syllabus

No connections not already noted.

9.3.6 Freedom in Practical Work in the College Science of Natural Resources Senior Secondary 5C Syllabus

The expanded syllabus outline in the Science of Natural Resources supplement document (Tasmanian Secondary Assessment Board, 2003l) includes a section titled *What does it mean to work scientifically in researching resources?*, which is broken down further to include:

i. *Formulate a working hypothesis based on observations of events* **(F)**.
ii. *Formulate a hypothesis which is testable* and includes an independent and a dependent variable **(F)**.
iii. *Design experiments to investigate a suitable working hypothesis* **(F)**.
iv. *Recognise controlled and uncontrolled variables in experimental design* **(F)**.
v. *Understand the need to minimize the impact of uncontrolled and sometimes unrecognised variables by the use of replicates within an experiment, repeating experiments* and the need for experiments to be repeated by different groups of workers **(F)**.
vi. *Recognise the sorts of ethical considerations that need to be taken into account in designing experiments* **(F)**.
vii. Be able to *evaluate the strengths and weaknesses of an experimental design* **(I)**.
viii. *Be able to design further investigations* related to an area of scientific investigation **(F).**
ix. Be able to *state whether the results are consistent or inconsistent with the hypothesis being tested* and if needs be *state a new hypothesis which is consistent with the results obtained* **(I).**

In addition, students must complete a Resource Investigation on a topic of their choice, which includes *collecting*, *analysing* and presenting data (**F**, **I**). Detailed information about this Resource Investigation is included in the Folio Guidelines (Tasmanian Qualifications Authority, 2004c). Whilst this document is too detailed to reproduce here, it incorporates all the items that are included on the Freedom in Practical Work scale of the ITIC.

9.3.7 Connections to the ITIC Freedom in Practical Work Scale

The above documentation shows that items from the Freedom in Practical Work scale are encompassed by every college science subject, by virtue of the common criteria. The listed descriptors from the common criteria make connections with items F2, F3, F5 and F8. Although it would seem likely that students might do this in relation to questions that they come up with, thus making links to F4, F6 and F7 this is not specified in the documents.

A number of the syllabus descriptions also refer to practical work. Environmental Science and Science of Natural Resources make particularly extensive connections to this scale, as both subjects require students to carry out their own investigation over an extended time period.

Overall, the ITIC Freedom in Practical Work scale can be considered to be very relevant to the college science syllabuses.

9.4 COMMUNICATION IN THE COLLEGE SENIOR SECONDARY 5C SCIENCE COURSES

This section considers the extent to which each of the college science syllabus documents prescribes or suggests an approach that makes connections to items from the ITIC Communication scale.

9.4.1 Communication in the College Common Criteria

Although Criterion 5 - Communicate ideas and information - seems at first glance to align with the Communication scale, closer examination of Criterion 5 shows that the descriptors within it relate to the use of methods and styles of communication, rather than to the more discussion style of items that the ITIC Communication scale contains.

One of the four descriptors for Criterion 6 - Demonstrate knowledge and understanding of the impact of science on society and the environment - relates to the ITIC Communication scale, as shown in Table 9.3.

Table 9.3

*The Descriptors from Common Criterion 6 - Demonstrate Knowledge and Understanding of the Impact of Science on Society and the Environment (Tasmanian Secondary Assessment Board, 2003a-f), Which Relate to the Communication Scale***.**

Rating C	Rating B	Rating A
demonstrate detailed understanding of the components of an issue and present a balanced discussion; (C)	demonstrate detailed understanding of the components of an issue and present a **logical**, balanced discussion;	demonstrate detailed understanding of the components of the issue and present a logical, **concise** and balanced discussion;

9.4.2 Communication in the College Biology Senior Secondary 5C Syllabus

No connections not already noted.

9.4.3 Communication in the College Chemistry Senior Secondary 5C Syllabus

As noted in section 9.3.3, the syllabus supplement (Tasmanian Secondary Assessment Board, 2003h) includes a schematic overview diagram which has at its centre Practical activities and *Sharing ideas* (**C**).

9.4.4 Communication in the College Environmental Science Senior Secondary 5C Syllabus

The Syllabus Outline section of the Environmental Science syllabus document (Tasmanian Secondary Assessment Board, 2003c) lists some of the purposes of the syllabus as:

- develop reflective and critical thinkers able to use science to *examine issues, make socially responsible choices* ***(I, C)*** and create environmentally sustainable and optimistic futures
- provide opportunities for students to reflect on their personal futures and investigate pathways into further learning and employment
- encourage students *to discuss* the local and global interdependence of issues **(C)** concerning social equity and environmental values and *to consider their personal responsibilities in these areas* **(C)**.

These purposes link to a number of items in the Communication scale.

9.4.5 Communication in the College Physical Sciences Senior Secondary 5C Syllabus

The Syllabus Supplement document (Tasmanian Secondary Assessment Board, 2003j) notes in the section titled *Introduction to the Physical Sciences*, that areas to be treated as they arise in the course structure include:

- Observation, description, recording and *communicating* **(C?)**.

This description does not specifically include items from the Communication scale.

9.4.6 Communication in the College Physics Senior Secondary 5C Syllabus

The syllabus supplement document (Tasmanian Secondary Assessment Board, 2003k) lists areas to be treated as they arise in the course structure as:

- Observation, description, recording and *communicating* **(C?)**.

This description does not specifically include items from the Communication scale.

9.4.7 Communication in the College Science of Natural Resources Senior Secondary 5C Syllabus

Part of the syllabus outline (Tasmanian Secondary Assessment Board, 2003f) for Science of Natural Resources includes a consideration of *What issues affect resource industrie*s? This syllabus component includes:

a) What values lie in using Tasmanian resources?
b) What external influences affect natural resource use?
c) What are the ethical issues associated with resource management?
d) What are some of the issues that raise public debate in:
  i. agriculture
  ii. marine resources/aquaculture
  iii energy
  iv. forestry
  v. mining.
e) What is the nature of government involvement in sustainable resource management?

The syllabus supplement (Tasmanian Secondary Assessment Board, 2003l) includes as some agricultural examples of issues that raise public debate:

- Genetically modified organisms
- Alternatives to conventional agriculture (eg Organic, permaculture, biodynamics)
- "Clean green image"
- Plantation forestry
- Pesticide use
- Salinity
- Social costs
- Soil erosion
- Biodiversity
- Animal welfare
- Urban sprawl onto productive land
- Rural Sociology eg community interactions, services available
- Change from small family farms to large corporate farming enterprises
- Forestry plantations encroaching on farms
- Decline of rural communities

Later sections of the supplement include similar examples from other resource areas. Given the nature of these topics, it is difficult to envisage them being covered without discussion and explanation of opinion, as described by the ITIC Communication scale **(C)**, or without students being presented with relevant case studies **(S)**.

9.4.8 Connections to the ITIC Communication Scale

The generic syllabus documents and the learning statement make a number of connections to the Communication scale. The syllabus descriptions for Biology, Environmental Science and Science of Natural Resources also make connections to the Communication scale. The listed descriptor from common criterion 5 makes connections with items C1, C3, C4, C7 and C8.

The Environmental Science and Science of Natural Resources documents imply substantial additional connections.

Overall, the ITIC Communication scale can be considered to be very relevant to the college science syllabuses.

9.5 INTERPRETATION OF DATA IN THE COLLEGE SENIOR SECONDARY 5C SCIENCE COURSES

This section considers the extent to which each of the college science syllabus documents prescribe or suggest an approach that makes connections to items from the ITIC Interpretation of Data scale.

9.5.1 Interpretation of Data in the College Common Criteria

As was the case with the Freedom in Practical Work scale, Interpretation of Data is represented most effectively by common Criterion 4 - Develop and evaluate experiments. The last two descriptors from Criterion 4, which contains five descriptors in total, are shown in Table 9.4.

Table 9.4
The Descriptors from Common Criterion 4 - Develop and Evaluate Experiments (Tasmanian Secondary Assessment Board, 2003a-f), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
provide evidence from experiments to support conclusions that clearly relate to the concept (I)	provide evidence from experiments to **validate** conclusions that clearly relate to the concept;	provide evidence from experiments to validate conclusions that clearly **and rationally** relate to the concept;
predict results related to observed outcomes and evaluate the experiment (I)	predict results related to observed outcomes, evaluate the experiment **including recommendations for** followup experiments.	predict results related to observed outcomes, evaluate the experiment including recommendations for followup experiments.

Criterion 6 also covers aspects of this criterion with one of its five descriptors being that shown in Table 9.5

Table 9.5
The Descriptors from Common Criterion 6 - Demonstrate Knowledge and Understanding of the Impact of Science on Society and the Environment (Tasmanian Secondary Assessment Board, 2003a-f), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
form reasoned conclusions using relevant selected evidence (I)	form reasoned and **logical** conclusions using relevant selected evidence;	form reasoned and logical conclusions using relevant selected evidence;

There is also a potential reference to Interpretation of Data from Criterion 1, in the scenario where technologies are being used in practical work. One of the five Criterion 1 descriptors is shown in Table 9.6.

Table 9.6
The Descriptors from Common Criterion 1 - Select and Use Technologies (Tasmanian Secondary Assessment Board, 2003a-f), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
evaluate effectiveness and appropriateness of selected and adapted *technologies* in specific contexts (I?)	evaluate effectiveness and appropriateness of selected and adapted *technologies* in specific contexts;	evaluate effectiveness and appropriateness of selected and adapted *technologies* in specific contexts;

9.5.2 Interpretation of Data in the College Biology Senior Secondary 5C Syllabus

Criterion 7 - Demonstrate knowledge and understanding of the chemical basis of life - includes the descriptors listed in Table 9.7 as two out of its five descriptors.

Table 9.7
The Descriptors from Biology Criterion 7 - Demonstrate Knowledge and Understanding of the Chemical Basis of Life (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
analyse data relating to the cellular basis of life, to interpret relationships between appropriate variables (I)	analyse data relating to the cellular basis of life **presented in a variety of formats** to interpret relationships between appropriate variables;	analyse data relating to the cellular basis of life presented in a variety of formats **to clearly and concisely** interpret relationships between appropriate variables;
draw appropriate conclusions from data relating to the chemical basis of life (I)	draw appropriate conclusions **and form generalisations** from data relating to the chemical basis of life.	draw **concise and logical** conclusions and form generalisations from data relating to the chemical basis of life.

The descriptors shown in Table 9.7 are effectively repeated in the remaining three Biology specific criteria, as shown in Tables 9.8 to 9.10. Criterion 8 - Demonstrate knowledge and understanding of cells - includes these as two of its five descriptors; Criterion 9 - Demonstrate knowledge and understanding of organisms - includes them as two out of its six descriptors and Criterion 10 - Demonstrate knowledge and understanding of the interaction of organisms in their environment - lists them as two out of its seven descriptors:

Table 9.8
The Descriptors from Biology Criterion 8 - Demonstrate Knowledge and Understanding of Cells (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
analyse data relating to cells to interpret relationships between appropriate variables (I)	analyse data relating to cells **presented in a variety of formats** to interpret relationships between appropriate variables;	analyse data relating to cells presented in a variety of formats to **clearly and concisely** interpret relationships between appropriate variables;
draw appropriate conclusions from data relating to cells (I)	draw appropriate conclusions **and form generalisations** from data relating to cells.	draw **concise and logical** conclusions and form generalisations from data relating to cells.

Table 9.9

The Descriptors from Biology Criterion 9 - Demonstrate Knowledge and Understanding of Organisms (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
analyse data relating to organisms to interpret relationships between appropriate variables (I)	analyse data relating to organisms **presented in a variety of formats** to interpret relationships between appropriate variables;	analyse data relating to organisms presented in a variety of formats to **clearly and concisely** interpret relationships between appropriate variables;
draw appropriate conclusions from data relating to organisms (I)	draw appropriate conclusions **and form generalisations** from data relating to organisms.	draw **concise and logical** conclusions and form generalisations from data relating to organisms.

Table 9.10

The Descriptors from Biology Criterion 10 - Demonstrate Knowledge and Understanding of the Interaction of Organisms in Their Environment (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	Rating B	Rating A
analyse data relating to interactions of organisms and their environment to interpret relationships between appropriate variables (I)	analyse data relating to interactions of organisms and their environment **presented in a variety of formats** to interpret relationships between appropriate variables;	analyse data relating to interactions of organisms and their environment presented in a variety of formats to **clearly and concisely** interpret relationships between appropriate variables;
draw appropriate conclusions from data relating to interactions of organisms and their environment (I)	draw appropriate conclusions **and form generalisations** from data relating to interactions of organisms and their environment.	draw **concise and logical** conclusions and form generalisations from data relating to interactions of organisms and their environment.

9.5.3 Interpretation of Data in the College Chemistry Senior Secondary 5C Syllabus

To a limited extent, prediction is implied by Criterion 7 - Demonstrate an understanding of the fundamental principles and theories of electrochemistry - which lists the descriptor in Table 9.11 as one of its four descriptors.

Table 9.11

The Descriptors from Chemistry Criterion 7 - Demonstrate an Understanding of the Fundamental Principles and Theories of Electrochemistry - (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	Rating B	Rating A
use the electrochemical series to predict the reactions between two species under standard conditions (I)	use the electrochemical series to predict the reactions that occur when **more than two species are present** under standard conditions;	series to predict the reactions that occur when more than two species are present under standard conditions **and suggest why some variations are observed;**

Criterion 8 - Demonstrate knowledge and understanding of the principles and theories of thermochemistry, kinetics and equilibrium - lists the descriptors shown in Table 9.12 as two of its four descriptors

Table 9.12

The Descriptors from Chemistry Criterion 8 - Demonstrate Knowledge and Understanding of the Principles and Theories of Thermochemistry, Kinetics and Equilibrium (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
interpret energy diagrams (I)	interpret energy diagrams and **explain that the enthalpy of reaction is the result of making and breaking of bonds;**	interpret energy diagrams and explain that the enthalpy of reaction is the result of making and breaking of bonds;
predict or explain the variation in reaction rates using collision theory and the concept of catalysis (I)	predict and explain the variation in reaction rates using collision theory and the concepts of catalysis **and the distribution of energy**;	predict and explain the variation in reaction rates using collision theory and the concepts of catalysis and the distribution of energy;

Criterion 9, Demonstrate knowledge and understanding of the properties and reactions of organic and inorganic matter, lists the descriptor shown in Table 9.13 as one of its six descriptors:

Table 9.13

The Descriptors from Chemistry Criterion 9, Demonstrate Knowledge and Understanding of the Properties and Reactions of Organic and Inorganic Matter - (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
identify the trends in the behaviour of elements (I)	identify **and explain** the trends in the behaviour of elements;	identify and explain the trends in the behaviour of elements;

The syllabus supplement includes a schematic overview diagram which has at two of its corners:

- *Identify patterns* of chemical reactions **(I)**
- *Predict*, and control chemical reactions **(I).**

9.5.4 Interpretation of Data in the College Environmental Science Senior Secondary 5C Syllabus

The Syllabus Outline section (Tasmanian Secondary Assessment Board, 2003c) lists the following points that relate to Interpretation of Data:

- develop reflective and critical thinkers *able to use science to examine issues, make socially responsible choices* and create environmentally sustainable and optimistic futures **(I, U)**
- enable students to *consider alternative* uses for natural resources and the *implications of such choices* **(I, U).**

It also includes the following statement under the sub-heading of ‘Analyse, interpret and draw conclusions’.

> Data is to be drawn from various content areas of the course. Students will be expected to see the relevance of data within the context of a particular environmental issue and *to relate the data to the specific environmental and scientific concepts studied* **(I)**. They will be expected *to carry out simple manipulations of the data **(I)**, be able to use graphs **(I)***, and *be able to draw appropriate conclusions* **(I)** from the data such as *revealing trends and possible cause and effect relationships **(I)***.

Criterion 10 - Analyse, interpret and draw conclusions - strongly reflects the Interpretation of Data scale, listing as its four descriptors the items shown in Table 9.14.

Table 9.14
The Descriptors from Environmental Science Criterion 10 - Analyse, Interpret and Draw Conclusions (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	Rating B	Rating A
analyse data presented in a wide variety of formats (I)	**clearly** analyse data presented in a wide variety of formats;	clearly **and concisely** analyse data presented in a wide variety of formats;
describe relationships between variables (I)	describe relationships between **multiple** variables;	**clearly** describe **complex** relationships between multiple variables;
draw relevant, detailed, logical conclusions from analysing both first and second hand data (I)	draw relevant, detailed, logical conclusions from analysing both first and second hand data;	draw relevant, **concise**, detailed and logical conclusions from analysing both first and second hand data;
draw generalisations by analysing data from multiple sources (I)	draw generalisations by analysing data from multiple sources.	draw generalisations by analysing data from multiple sources **and extrapolate.**

9.5.5 Interpretation of Data in the College Physical Sciences Senior Secondary 5C Syllabus

Criterion 7 - Demonstrate knowledge and understanding of the principles of force and motion - of the Physical Sciences syllabus (Tasmanian Secondary Assessment Board, 2003d) lists as one of its four descriptors the ones shown in Table 9.15.

Table 9.15

The Descriptors from Physical Sciences Criterion 7 - Demonstrate Knowledge and Understanding of the Principles of Force and Motion - (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
interpret linear graphs relating to force and motion (I)	interpret **and generate** linear graphs relating to force and motion;	interpret and generate linear **and parabolic** graphs, relating to force and motion;

Criterion 8 - Demonstrate an understanding of the principles of structures and properties of materials - lists as one of its three descriptors, the one shown in Table 9.16.

Table 9.16

The Descriptors from Physical Sciences Criterion 8 - Demonstrate an Understanding of the Principles of Structures and Properties of Materials (Tasmanian Secondary Assessment Board, 2003d), Which Relate to the Interpretation of Data Scale.

Rating C	**Rating B**	**Rating A**
identify similarities in the main groups of the periodic table and use them to identify bonding models (I)	identify similarities in the main groups of the periodic table and use them to identify bonding models;	identify **and explain in terms of electron configuration** similarities in the main groups of the periodic table and use them to identify bonding models;

9.5.6 Interpretation of Data in the College Physics Senior Secondary 5C Syllabus

Criterion 7 - Demonstrate knowledge and understanding of Newtonian mechanics including gravitational fields - lists the descriptor shown in Table 9.17 as one of its four. Criteria 8, 9 and 10 each contain a similar descriptor, as shown in Tables 9.18

to 9.20 as one of their four. It is the reference to demonstrating an understanding of graphs that connects these descriptors to the ITIC Interpretation of Data scale.

Table 9.17
The Descriptors from Physics Criterion 7 Demonstrate Knowledge and Understanding of Newtonian Mechanics Including Gravitational Fields - (Tasmanian Secondary Assessment Board, 2003e), Which Relate to the Interpretation of Data Scale.

Rating C	Rating B	Rating A
demonstrate understanding of graphs relating to Newtonian Mechanics (I)	demonstrate understanding of graphs, **and generate additional data from them**, relating to Newtonian Mechanics;	demonstrate understanding of graphs, generate additional data, and **make generalisations** from them relating to Newtonian Mechanics;

Table 9.18
The Descriptors from Physics Criterion 8 - Demonstrate Knowledge and Understanding of Electricity and Magnetism - (Tasmanian Secondary Assessment Board, 2003e), Which Relate to the Interpretation of Data Scale.

Rating C	Rating B	Rating A
demonstrate understanding of graphs relating to electricity and magnetism (I)	demonstrate understanding of the individual components of current electricity and magnetism**.**	demonstrate understanding of **the complex interrelationships between** current electricity and magnetism.

Table 9.19
The Descriptors from Physics Criterion 9 - Demonstrate Knowledge and Understanding of the General Principles of Wave Motion (Tasmanian Secondary Assessment Board, 2003e), Which Relate to the Interpretation of Data Scale.

Rating C	Rating B	Rating A
demonstrate understanding of graphs relating to wave motion (I)	demonstrate understanding of graphs **and generate additional data from them** relating to wave motion;	demonstrate understanding of graphs, generate additional data, and **make generalisations** from them relating to wave motion;

Table 9.20

The Descriptors from Physics Criterion 10 - Demonstrate Knowledge and Understanding of the Particle Nature of Light and Atomic and Nuclear Physics - (Tasmanian Secondary Assessment Board, 2003e), Which Relate to the Interpretation of Data Scale.

Rating C	Rating B	Rating A
demonstrate understanding of graphs relating to particle nature of light and atomic and nuclear physics (I)	demonstrate understanding of graphs **and generate additional data from them** relating to particle nature of light and atomic and nuclear physics;	demonstrate understanding of graphs, generate additional data, and **make generalisations** from them relating to particle nature of light and atomic and nuclear physics;

9.5.7 Interpretation of Data in the College Science of Natural Resources Senior Secondary 5C Syllabus

Criterion 8 - Analyse, interpret and draw conclusions - lists the descriptors shown in Table 9.21 as its four descriptors. This criterion is identical to Criterion 10 of the Environmental Science syllabus.

Table 9.21

The Descriptors from Science of Natural Resources Criterion 8 - Analyse, Interpret and Draw Conclusions (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Interpretation of Data Scale.

Rating C	Rating B	Rating A
analyse data presented in a wide variety of formats (I)	**clearly** analyse data presented in a wide variety of formats;	clearly **and concisely** analyse data presented in a wide variety of formats;
describe relationships between variables (I)	describe relationships between **multiple** variables;	**clearly** describe **complex** relationships between multiple variables;
draw relevant, detailed, logical conclusions from analysing both first and second hand data (I)	draw relevant, detailed, logical conclusions from analysing both first and second hand data;	draw relevant**, concise**, detailed and logical conclusions from analysing both first and second hand data;
draw generalisations by analysing data from multiple sources (I)	draw generalisations by analysing data from multiple sources.	draw generalisations by analysing data from multiple sources **and extrapolate.**

9.5.8 Connections to the ITIC Interpretation of Data Scale

The generic syllabus documents contain extensive connections to the Interpretation of Data scale, as do the Learning statements. All syllabus descriptions except that for Chemistry also show specific links.

The common criteria show links to Items I1, I2, I4, I5, I6, I7. They also seem to cover I8 although they do not specifically use the word hypotheses.

The documents for each of the individual syllabuses also make connections to the Interpretation of Data scale. Overall, it seems to be the ITIC scale that is most relevant to the various college science syllabus documents.

9.6 SCIENCE STORIES IN THE COLLEGE SENIOR SECONDARY 5C SCIENCE COURSES

This section considers the extent to which each of the college science syllabus documents prescribe or suggests an approach that makes connections to items from the ITIC Science Stories scale.

9.6.1 Science Stories in the College Common Criteria

Criterion 6 - Demonstrate knowledge and understanding of the impact of science on society and the environment - covers aspects of the Science Stories scale as shown in Table 9.22.

Table 9.22
The Descriptors from Common Criterion 6 - Demonstrate Knowledge and Understanding of the Impact of Science on Society and the Environment - (Tasmanian Secondary Assessment Board, 2003a-f), Which Relate to the ITIC Science Stories Scale.

Rating C	Rating B	Rating A
demonstrate understanding of the link between scientific decision making and historical context (S)	demonstrate understanding of the complexities of the link between scientific decision making and historical contexts.	demonstrate understanding of the complexities of the link between scientific decision making and historical contexts **from a range of perspectives.**

9.6.2 Science Stories in the College Biology Senior Secondary 5C Syllabus

The syllabus outline section of the syllabus document (Tasmanian Secondary Assessment Board, 2003a) notes that:

> *Case studies* can be used to engage students and integrate content from different parts of the course **(S)**.

9.6.3 Science Stories in the College Chemistry Senior Secondary 5C Syllabus

Under the Periodic Table heading the syllabus supplement (Tasmanian Secondary Assessment Board, 2003h) lists:

> Early history - Understand Mendeleev's contribution to the Periodic Table based on chemical properties and increasing atomic masses **(S?)**.

The names of scientists are mentioned in relation to models and laws eg Bohr's model of the atom, Hess's Law, Le Chatelier's Principle, but the document does not require any detail of their work or lives.

This document also notes that:

> Chemistry is a dynamic science. Teachers and students are encouraged *to discuss current research and applications of chemistry* **(C, S).**
> A most useful resource is the Australian Academy of Science website, NOVA, http://www.science.org.au/nova
>
> - Cells with non-aqueous electrolytes
> - Conducting polymers
> - Fuel Cells
> - Hydrogen powered transport
> - Droughts

Whilst this seems to imply the opportunity to include items from the Science Stories scale their use appears to be encouraged rather than mandated.

9.6.4 Science Stories in the College Environmental Science Senior Secondary 5C Syllabus

The syllabus documents do not make any reference to this scale that has not already been listed. Given the nature of the syllabus and some of the controversial areas that are covered, it is difficult to see how the content of this syllabus would be covered without Science Stories materials - although these may relate to contemporary rather than more historical/traditional science examples.

9.6.5 Science Stories in the College Physical Sciences Senior Secondary 5C Syllabus

Although the syllabus documents do not preclude these, and areas such as atomic structure and the nuclear option give considerable scope, stories and the history of science are not specifically mentioned.

9.6.6 Science Stories in the College Physics Senior Secondary 5C Syllabus

Numerous references to scientists are made in the context of references to Law's such as Ohm's Law, Kirchoff's Law, Millikan's oil drop experiment, De Broglie wavelength, but there is no mention in the syllabus of giving more details about these scientists or their work.

9.6.7 Science Stories in the College Science of Natural Resources Senior Secondary 5C Syllabus

Criterion 7 - Demonstrate knowledge and understanding of scientific ideas relevant to the resource and its development - lists the descriptor shown in Table 9.23 as one of its three descriptors:

Table 9.23
The Descriptors from Science of Natural Resources Criterion 7 - , Demonstrate Knowledge and Understanding of Scientific Ideas Relevant to the Resource and its Development - (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Science Stories Scale.

Rating C	Rating B	Rating A
identify relevant scientific research and describe in detail the impact that it has on the development of resources (S)	identify relevant scientific research and **comprehensively** describe the impact that it has on the development of resources.	identify relevant scientific research, and comprehensively describe **and prioritise** the impact that it has on the development of resources.

Criterion 10 - Demonstrate knowledge and understanding of the science of resource management - lists the descriptors shown in Table 9.24 as three of its four descriptors:

Table 9.24
The Descriptors from Science of Natural Resources Criterion 10 - Demonstrate Knowledge and Understanding of the Science of Resource Management - (Tasmanian Secondary Assessment Board, 2003a), Which Relate to the Science Stories Scale.

Rating C	**Rating B**	**Rating A**
identify and describe ways in which the management of resources will be influenced by ethical, social, cultural, economic and political factors (S)	identify and describe ways in which the management of resources will be influenced by ethical, social, cultural, economic and political factors;	identify and clearly describe ways in which the management of resources will be influenced by ethical, social, cultural, economic and political factors;
describe ways in which historical context in science may impact on the management of resources (S)	**clearly** describe ways in which historical context in science may impact on the management of resources**;**	**comprehensively** describe ways in which historical context in science may impact on the management of resources;
identify, recommend and describe scientific research needed to benefit future management of resources (S)	identify, recommend and describe scientific research needed to benefit future management of resources**.**	identify, recommend and **justify** scientific research needed to benefit future management of resources.

The following extract from the expanded syllabus outline in the syllabus supplement also implies the use of Science Stories to convey historical perspectives.

a) *How has resource use changed through history*? **(S)**
  i. As technology changes so does access and use of resource
  ii. Origins of the use of the resource
  iii. Development of the use of the resource to current uses

The syllabus supplement specifically mentions the work of research institutions and lists a number that are relevant to the Tasmanian context. Therefore there are connections to items S1, possibly S2 and S8 of the Science Stories scale.

A Research Report, which constitutes part of the folio required for this subject, requires that students complete a report on a resource *that includes historical perspectives* **(S)**.

9.6.8 Connections to the ITIC Science Stories Scale

Whilst the generic syllabus documents and the syllabus descriptions show no links with the Science Stories scale, the common criteria show links with items S3, S4, S5 and S6.

The individual subject syllabus documents make few connections to the Science Stories scale, except in the case of Science of Natural Resources. However, many opportunities for including historical stories exist.

Overall, the Science Stories scale may be said to have limited relevance to the college science syllabuses as written. However, if Science Stories type items are seen as valuable, then teachers could be encouraged to include more of them in their teaching, and the scale might be used to monitor whether this is occurring.

9.7 UNCERTAINTY IN SCIENCE IN THE COLLEGE SENIOR SECONDARY 5C SCIENCE COURSES

This section considers the extent to which each of the college science syllabus documents prescribes or suggests an approach that makes connections to items from the ITIC Uncertainty in Science scale.

9.7.1 Uncertainty in Science in the College Common Criteria

Criterion 6 - Demonstrate knowledge and understanding of the impact of science on society and the environment - covers aspects of the Uncertainty in Science scale as shown in Table 9.25.

Table 9.25
The Descriptors from Common Criterion 6 - Demonstrate Knowledge and Understanding of the Impact of Science on Society and the Environment (Tasmanian Secondary Assessment Board, 2003a-f), Which Relate to the ITIC Uncertainty in Science Scale.

Rating C	Rating B	Rating A
describe tensions between ethical, social, cultural, economic and political influences and comment on their impacts on decisions (U)	**clearly** describe tensions between ethical, social, cultural, economic and political influences and comment on their impacts on decisions;	**clearly** describe **tensions and connections** between ethical, social, cultural, economic and political influences and comment on their impacts on decisions;

9.7.2 Uncertainty in Science in the College Biology, Chemistry, Environmental Science and Science of Natural Resources Senior Secondary 5C Syllabuses

No additional connections were noted.

9.7.3 Uncertainty in Science in the College Physical Sciences and Physics Senior Secondary 5C Syllabus

The syllabus supplement document lists Uncertainty in measurements as an area to be treated as it arises in the course structure. However, this is not really in keeping with the intent of the ITIC scale.

9.7.4 Connections to the ITIC Uncertainty in Science Scale.

There are extensive connections to this scale in the generic syllabus documents. All syllabus descriptions except that for Chemistry make connections to it and common criterion 6 makes connections to items U1 and U4.

9.8 RELEVANCE OF THE ITIC TO THE TASMANIAN COLLEGE SCIENCE SUBJECTS

The information presented in this chapter indicates that that there are extensive connections between the college science syllabus documents and the ITIC scales. The data collected by examining the syllabus documents for the six college science subjects is summarised in Table 9.26. Examination of Table 9.26 shows that Interpretation of Data is the ITIC scale that has the greatest relevance to the college science syllabus documents, and that for all subjects except Science of Natural Resources, Interpretation of Data is the scale that the most connections exist for.

Table 9.26

Number of References to ITIC Inquiry Methodologies in the College Science Syllabus Documentation.

	F	F?	C	C?	I	I?	S	S?	U	U?	Total
generic	6	2	9	1	16	1	1	0	8	0	44
Biology	1	1	1	0	10	0	1	0	2	0	16
Chemistry	0	2	3	0	6	0	1	1	0	0	13
Environmental Science	2	1	4	0	13	0	0	0	4	0	24
Physical Sciences	0	2	1	1	4	0	0	0	2	0	10
Physics	0	1	0	1	4	1	0	0	1	0	8
Science of Natural Resources	8	0	1	0	8	0	7	0	1	0	25
Total	17	9	19	3	61	2	10	1	18	0	140

The number of connections that can be made from the ITIC scales to the college science documents indicate that the methodologies that the ITIC measures are valued in the college science courses. The 44 connections that the generic documents show emphasise that the Freedom in Practical Work, Communication, Interpretation of data and Uncertainty in Science scales are valued across all syllabuses. Therefore, the ITIC would be a relevant and valuable instrument to use with Tasmanians college science classes.

Whilst there are relatively few explicit references to items from the Science Stories scale shown in Table 9.26, it is difficult to envisage how teachers would not include behaviours relating to items from this scale when presenting items such as scientific decision making, historical context, case studies and the applications and impact of current research. Therefore this scale would also seem to be worthy of inclusion in any survey of college science classes. In fact, it may be of particular relevance if this is an area that teachers and syllabus writers tend to neglect, as it would allow them to specifically monitor whether they are including Science Stories type materials.

Further examination of the data in Table 9.26 indicates that Environmental Science and Science of Natural Resources are the subjects that show the most connections to the ITIC. However, it is necessary to exercise caution in making any comparison between subjects, as there is considerable variation in the amount of detail that is included in the various syllabus documents. A particular syllabus may seem to show more ITIC connections, but this may be a factor of the writers for this subject including greater detail, rather than an indication of the intent to incorporate greater amounts of the behaviours under consideration.

Overall, the number of ITIC connections that the data collected in this chapter show can be taken as indicating that inquiry methodologies, as defined by the ITIC, were valued enough for syllabus writers to specifically include either direct or indirect reference to them.

CHAPTER 10 - INQUIRY METHODOLOGIES WITHIN THE TASMANIAN *ESSENTIAL LEARNINGS* CURRICULUM DOCUMENTS

This chapter adopts a similar approach to Chapters 8 and 9, but examines a different set of curriculum documents, the Tasmanian *Essential Learnings Framework*, in order to determine whether the *Essential Learnings* either suggest or mandate the use of the inquiry methodologies defined by the ITIC. This examination was completed with a view to determining the potential usefulness of the ITIC instrument in the current Grade 7-10 context in Tasmania.

As has been mentioned previously, from 2005 all Tasmanian government schools, together with schools from the Catholic Education system and some independent schools, adopted the *Essential Learnings Framework* curriculum documents as the basis for developing courses for all students up to the end of Grade 10. Therefore, in considering contemporary Tasmanian science curriculum documents it is necessary to examine the *Essential Learnings* for Grades K-10 students and the TQA college science syllabuses for Grades 11 and 12. This chapter's examination of the *Essential Learnings* completes the examination of contemporary Tasmanian science curriculum documents that was commenced in Chapter 9. As was the case in Chapter 9, the ideas behind the Assessment scale included in the original ITIC instrument will not be considered here, as this scale did not show acceptable reliability.

10.1 INQUIRY METHODOLOGIES IN THE ESSENTIAL LEARNINGS FRAMEWORK DOCUMENTS

The *Essential Learnings Framework* (Tasmania, Department of Education, 2002, 2003) consists of five Essential Learnings (ELs), which are subdivided to 18 Key Elements. An overview of the *Essential Learnings Framework* is shown in Table 10.1. All *Essential Learnings* documents can be downloaded from http://www.ltag.education.tas.gov.au/references.htm#assessing (retrieved December 17, 2005).

Table 10.1

An Overview of Tasmania's Essential Learnings Framework.

ESSENTIAL LEARNINGS	CULMINATING OUTCOMES We want our students to be:	KEY ELEMENT OUTCOMES
THINKING	**Inquiring and reflective thinkers** able to reason, question, make decisions and solve complex problems. As reflective thinkers, they will be empathetic and able to make ethical decisions about issues, events and actions.	**Inquiry** Understands the process of inquiry and uses appropriate techniques for posing questions, defining problems, processing and evaluating data, drawing conclusions and flexibly applying findings to further learning and to creating new solutions.
		Reflective thinking Understands that reflective thinking is a deliberate process, affected by emotions and motivations, and that it is used to develop and refine ideas and beliefs and to explore different and new perceptions.
COMMUNICATING	**Effective communicators** able to create, communicate and convey ideas clearly and confidently, using the full range of symbolic systems. They will interact critically with communications created by others, interpreting linguistic, numerical and graphic information with judgement and discernment.	**Being literate** Understands, uses and critically evaluates non-verbal, spoken, visual and print communication practices of the world in which they live.
		Being numerate Understands and has the confidence and disposition to use the mathematical concepts and skills required to meet the demands of life.
		Being information literate Understands how to effectively access, interpret, transform, create, communicate, evaluate and manage information in ethical ways using a range of sources.
		Being arts literate Understands the purposes and uses of a range of arts forms – visual arts, media, dance, music, drama and literature, and how to make and share meaning from and through them. Uses with confidence and skill the codes and conventions of the art form best suited to their expressive needs.
PERSONAL FUTURES	**Self-directed and ethical people** having a positive vision for themselves and their future, acting with moral autonomy and contributing to constructive futures for themselves and others.	**Building and maintaining identity and relationships** Understands the ways in which heredity, culture, community and personal choice shape identity and relationships and is able to build and maintain resilient, productive relationships.
		Maintaining wellbeing Understands the interdependence of the physical, mental, emotional, social and spiritual dimensions of wellbeing and knows how to make wise choices and contribute positively to the overall wellbeing of self and others.
		Being ethical Understands that to be ethical requires caring about the consequences of actions of self and others and that the quality of ethical judgments is based upon reasoning and the application of ethical principles.
		Creating and pursuing goals Understands how to create, set and review goals for life and how to work with others to achieve own and shared goals.
SOCIAL RESPONSIBILITY	**Responsible citizens** prepared to participate actively in a democratic community, valuing diversity and acting for a just and equitable society.	**Building social capital** Understands the interdependence of individuals, groups and social organisations and participates positively in the building of 'good and just' communities.
		Valuing diversity Understands the interdependence of our world, values its diversity and acts for a more inclusive society.
		Acting democratically Understands and participates effectively in democratic decision-making processes and civic life.
		Understanding the past and creating preferred futures Understands that investigating the past and reflecting on the present are essential to understanding self and others and creating preferred futures.
WORLD FUTURES	**World contributors** willing to consider the consequences of scientific and technological innovations, make thoughtful decisions about their application, and act to maintain, protect and enhance local and global environments.	**Investigating the natural and constructed world** Understands how to scientifically investigate the natural and constructed world, appreciating the tentative nature of knowledge and the value of creative, imaginative and speculative thinking.
		Understanding systems Understands that the social, natural and constructed world is made up of a complex web of relationships or systems.
		Designing and evaluating technological solutions Understands how to design, make and critically evaluate products and processes in response to human needs and challenges.
		Creating sustainable futures Understands the environmental principles and ethical issues involved in creating and working towards sustainable futures.

A *Key Element Outcome* document exists for each of the 18 Key Elements. These Key Element Outcome documents describe five standards at which students can achieve, from entering school up to the end of Grade 10.

Nine of the Key Elements are currently scheduled to be calibrated. In this calibration process, each standard within a Key Element is divided to three progression levels, thus giving a total of 15 different levels that a student can achieve at on each of the calibrated Key Elements. Reporting is being phased in between 2005 and 2009, but by 2009, schools will be required to report to parents, and to the system, the progression level that each student has achieved on each of the calibrated outcomes.

The syllabus documentation for the *Essential Learnings* consists of two principal documents, which are referred to as *Essential Learnings Framework 1,* or *ELF1*, (Tasmania, Department of Education, 2002) and *Essential Learnings Framework 2, or ELF2*, (Tasmania, Department of Education, 2003).

ELF1 consists of a statement of values and purposes, a description of the learning that is recognised as essential and a set of principles to guide educational practice. It takes each of the five Essential Learnings (ELs) in turn and gives details of the territory which that EL covers, before progressing on to consider the nature of the Key Elements that sit under that EL. This gives readers an understanding of the knowledge, skills and dispositions that each Key Element aims to develop in students.

ELF2 consists of an introductory document (*Introduction to the Outcomes and Standards*), the 18 Key Element Outcome sheets and a document titled *Learners and Learning Provision*, which sets out to capture, in brief, some of the most pertinent advances in the understanding of how learning best occurs and what is known about the distinctive features of learners at different stages in their educational experience. The 18 Key Element Outcome sheets outline expectations for student achievement at Standards 1 through 5.

In the discussion of connections to the ITIC, the same methodology that was employed in the previous two chapters, and which is outlined in Section 9.1.1, will be used to highlight connections between the curriculum documents and ITIC scales. That is, text which indicates connections to ITIC scales will be italicised and the letter/s representing the corresponding ITIC scale will be shown at the end of the relevant text.

The documents that will be considered in the following discussion are the *ELF1* booklet and the 18 Key Element Outcome sheets contained in *ELF2*. As was the case when considering syllabus documents in the two previous chapters, the full author reference will not always be given when discussing *ELF1* and *ELF2,* as its continual inclusion can detract from readability. Where a particular Key Element or its outcome sheet shows no connections to the ITIC a separate section will not be included for that Key Element.

For the standards sections of the Key Element Outcome documents, ITIC connections, are only shown at the end of Standard 5. The intent of the documents is that Standard 5 encompasses all the preceding standards as well as what is written for Standard 5 itself, so the documentation for the lower standards was taken into consideration when drawing these connections. Coding each standard separately may have resulted in an over representation of some ITIC scales.

In considering the *Essential Learnings* documents a more general interpretation of the ITIC scale items was made, particularly in the case of the Science Stories and Uncertainty in Science scales. For example, item U7, *We learn that scientific information can change*, was regarded more as, *We learn that information can change*. This approach was taken as the Essential Learnings documents are written to encompass all disciplines rather than with just the discipline of Science in mind. If this approach had not been employed then Essential Learnings syllabus material that reflected the intent of the ITIC scales might have been disregarded due to it not including the word *science* as a qualifier.

10.1.1 General Connections Between the Essential Learnings and the ITIC

A brochure published for parents (Tasmania, Department of Education, undated) notes the following under the heading *Why redevelop curriculum?*:

> Nationally and internationally, there has been a growing recognition that young people are going to need new knowledge, skills and dispositions to enable them to deal successfully with a rapidly changing world. Not only are we faced with massive economic, political and social change, but also

> the pace of change itself has increased, so that knowledge learned today is likely to be superseded by new findings tomorrow. Knowing how to learn throughout life and being adaptable and confident are essential requirements for learners who can participate in and contribute to a globally connected world.

Under the heading *What is essential?* the brochure goes on to add:

> To be able to learn new things as they arise and to learn throughout life, learners need to develop high-level skills in thinking, communicating, investigating, deliberating, reflecting and making judgements.
>
> It is not sufficient to give learners knowledge and skills; education should also foster attitudes, beliefs and a preparedness to take action. Living and working in a complex future world, learners will need to be adaptable and have the confidence and fundamental skills to take on new learning throughout their lives.

In brief, this statement can be looked on as the justification behind the implementation of the new Tasmanian curriculum. It lends support to the use of inquiry methodologies, as defined by the ITIC, across all areas of learning, including Science.

10.2 CONNECTIONS TO ITIC SCALES WITHIN THE THINKING ESSENTIAL LEARNING

The Thinking EL contains two Key Elements:

- Inquiry.
- Reflective Thinking.

10.2.1 Description of Thinking from *ELF1*

The description of the Thinking EL contained in *ELF1* includes the following:

> Inquiry includes *identifying* and clarifying issues, *and gathering* **(F)**, *organising, interpreting and transforming information* **(I).** It encompasses

> the processes of creatively, imaginatively and inquisitively thinking about possibilities; *analysing,* synthesising and evaluating proposed solutions; and *explaining and justifying decisions* **(I, C)**. The skills of inquiry can be used to clarify meaning, draw appropriate comparisons and make considered decisions . . . Imaginative, caring and empathetic thinkers *listen to others, share ideas, explore areas of disagreement and generate constructive solutions to issues* **(C, I)**. Such thinkers bring an altruistic and ethical dimension to considering alternatives and making decisions, being prepared to address human problems that face us as global citizens . . . It is also necessary to understand, however, that inquiry and reflection are usually more effective *when undertaken with a group* **(C)** (Tasmania, Department of Education, 2002, p. 14).

10.2.2 Description of the Inquiry Key Element from *ELF1*

The information that *ELF1* contains about the Inquiry Key Element includes:

> Effective learners need the capacity to *ask good questions, persevere in a line of inquiry* **(F?),** be systematic, set goals, and *plan and follow a course of action* (**F**). They need the skills to organise timeframes and time usage, *to conduct their own investigations* **(F)** and to *predict and explore possible consequences* **(I)** and outcomes. Through experience with others, learners come to understand that *undertaking the process of inquiry collaboratively* **(C)** is likely to result in more effective learning and the achievement of more appropriate solutions. Learners need to understand the value of inquiry in dealing with issues, events and actions, and the importance of *developing criteria to evaluate* quality, relevance, reliability, truth, accuracy and effectiveness **(I)**. These are essential skills for learners in an age of consumerism and ready access to vast amounts of information. In addition, learners need to understand *how society and culture affect information and its sources* **(S?, U)**. The ability *to communicate what has been learnt and thought about* **(C?)**, and to do so in a consistent, coherent, relevant and persuasive way, is essential in enabling learners to participate

> fully in schools, communities and workplaces. (Tasmania**,** Department of Education, 2002, p. 14-15)

ELF1 goes on to give further information about the Inquiry Key Element under five sub-headings.

Under the *Posing problems* sub-heading, *ELF1* includes:

> Learners need *to identify why there is a problem, what the problem is, what the present context* is **(F, S?)** and *what purpose, interest or need makes it desirable to improve the present situation* (**U?).** Learning is more effective, interesting and relevant when *learners consciously choose and use particular methodologies, devise their own strategies to deal with challenges, solve problems* (**F**), and *apply their understandings to real-life contexts* (**I**) (Tasmania, Department of Education, 2002, p. 15).

Under the *Gathering information* sub-heading, *ELF1* includes:

> The learner's ability to *transform, synthesise and evaluate the data obtained* (**I**), and to *make judgements about its authenticity and relevance* (**U**), is a critical aspect of dealing with information (Tasmania, Department of Education, 2002, p. 15).

Under the *Thinking about possibilities* sub-heading, *ELF1* includes:

> Learners need to *seek* (**F?**), *analyse and evaluate evidence on the basis of careful reasoning* (**I**) when considering possible solutions. At the same time, however, learners need to recognise that being curious, creative and imaginative enables them to see new ways of doing things and helps them to deal flexibly with changing contexts. Learners who *explore alternatives* (**U**) and recognise possibilities, who are open to new ideas, and who actively problem-seek and set challenges when planning their own learning, are able to generate constructive and creative solutions to problems and use their learning for a variety of new purposes (Tasmania, Department of Education, 2002, p. 15).

Under the *Making decisions* sub-heading, *ELF1* includes:

> Learners need to *consider the results of proposed solutions, and understand how to evaluate benefits, uncover underlying assumptions and*

> *assess risks and limitations* (**I**, **U**). They need to learn how to judge the importance of consequences, *think about the merits of various options and decide which option is best in the light of likely outcomes. They also need to understand that investigations and analyses are influenced by personal points of view, biases and emotions* (**I**, **U**) (Tasmania, Department of Education, 2002, p. 16).

Under the *Justifying conclusions* sub-heading, *ELF1* includes:

> Understanding how to *reach, explain and justify conclusions in a fair-minded way* (**I**) helps learners to *work cooperatively and collaboratively with others* (**C**) in seeking optimum solutions to shared problems. Achieving this goal includes: *being able to present ideas accurately, clearly and persuasively; understanding how to identify and frame questions, giving reasons for opinions, distinguishing good reasons from bad ones* (**C, I**); *and establishing effective criteria to evaluate arguments and information* (**I, U**). It also involves learners developing skills to *assess the reasonableness of ideas and the accurate use of evidence* (**I**) (Tasmania, Department of Education, 2002, p. 16).

10.2.3 Connections to ITIC Scales from the Inquiry Key Element Outcome

The Key Element Outcome descriptor for Inquiry contained in *ELF2* states:

> Understands the process of inquiry and *uses appropriate techniques for posing questions, defining problems* (**F?**), *processing and evaluating data, drawing conclusions* (**I**) and *flexibly applying findings* (**U**) to further learning and to creating new solutions.

The Performance Guidelines, which form part of the Inquiry Key Element Outcome document, state that: students who are inquiring thinkers:

- Understand that inquiry processes are based on skills, methodologies and key concepts from the disciplines.
- Understand *how to pose and define a problem, clarify the issues involved and select and monitor the most effective process to use* (**F**).

- Understand *how to decide information needs, and collect, organise and evaluate data* (**F, I**).
- Understand *how to consider new possibilities and create new solutions* (**I**).
- Understand how to *evaluate benefits of proposed solutions, uncover underlying assumptions and assess risks and limitations* (**I, U**).
- Understand *how to explain and justify conclusions in a fair-minded way* (**I, C)**.

Table 10.2 lists the five standards statements from the Inquiry Key Element Outcome. As was mentioned earlier, connections to ITIC methodologies are shown only at the end of Standard 5. Standard 5 is the endpoint that all earlier work scaffolds students toward, and the intent of the Key Element Outcome documents is that Standard 5 encompasses the descriptors for all previous standards.

Table 10.2

The Five Standard Statements for Inquiry From ELF2 (Tasmania, Department of Education, 2003)

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that observation and inquiry can be used to guide action and solve problems in deliberate ways.	Understands that investigations need to be conducted through logical processes for collecting information, drawing conclusions and arriving at solutions.	Understands how to plan and carry out investigations relevant to questions that have been identified using inquiry strategies and processes.	Understands the processes of issues identification, data collection, selection of strategies, evaluation of findings and creation of solutions .	Understands how to *design and conduct investigations* through deliberate research, drawing on the understanding processes and skills derived from disciplines *and reflecting upon the quality of conclusions and methodologies used* (**F, I, U**).

10.2.4 Description of the Reflective Thinking Key Element from *ELF1*

The information that *ELF1* contains about the Reflective Thinking Key Element is divided to three sub-headings.

Under the *Thinking about thinking and learning* sub-heading, *ELF1* states in part:

> Reflective learners *compare their thinking with that of others* (**C**), to select appropriate mental processes, to relate experience to prior learning and to see personal relevance (Tasmania, Department of Education, 2002, p. 17)

Under the *Understanding and caring about different perspectives* sub-heading, *ELF1* states in part:

> *Appreciating what part emotions, beliefs and cultural perspectives play in colouring opinions and judgements assists learners to understand their views and those of others. In order to deal successfully with the complexities of living and working in the present and future world, learners need to accept and value differences based on culture, race, gender, (dis)ability and appearance, and need to be willing to explore alternative views to assess their validity and usefulness* (**U)**. . . . *Respecting others and their viewpoints, acknowledging different perspectives, listening carefully and attentively, being willing to share ideas* (**C**), and being prepared to canvass areas of disagreement are fundamental to effective working and learning together (Tasmania, Department of Education, 2002, p. 17).

Under the *Ethical reasoning* sub-heading, *ELF1* states in part:

> There will be many encounters for each learner that will require them to think ethically about issues, events and actions. Learners need to be able to *identify the foundations upon which they and others base judgements about what is right and wrong and to analyse and evaluate principles that underpin ethical standpoints and values* (**I, U**). They can then *argue an ethical position with sound logic and reasoning* (**C**). They need to be able to *evaluate ethical dilemmas in their lives or in the world, take a stand that reflects their personal value systems, and explain and defend their position* (**U, C**) (Tasmania, Department of Education, 2002, p. 18).

10.2.5 Connections to ITIC Scales from the Reflective Thinking Key Element Outcome

The Key Element Outcome descriptor for Reflective Thinking contained in *ELF2* states:

> Understands that reflective thinking is a deliberate process, *affected by emotions and motivations, and that it is used to develop and refine ideas and beliefs and to explore different and new perceptions* (**U**).

The Performance Guidelines for the Reflective Thinking Key Element Outcome document state that reflective students understand:

- That *decisions about right and wrong choices are based on an agreed set of ethical principles* (**U**).
- How to think about, describe and improve own thinking and learning.
- *In what ways experiences, emotions, beliefs and cultural perspectives affect thinking and create differences between self and others* (**U**).
- The importance of being open to new possibilities and perceptions pertaining to the ideas of self and others.
- That *dialogue is essential* in developing fair-minded positions (**C**).

Table 10.3 lists the standards from the Reflective Thinking Key Element Outcome.

Table 10.3

The Five Standard Statements for Reflective Thinking From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands how to use simple strategies that assist in organising thoughts, and how to modify their own actions in the light of reflection.	Understands that they can solve problems in ways that are particular to them or their group, and can use tools provided.	Understands how to use particular thinking and problem-solving strategies, recognising that emotions, motivations and beliefs of themselves and others influence the process of making choices.	Understands how to choose from a range of thinking strategies and use them to solve problems, make personal and group decisions and evaluate their effectiveness.	Understands how to deliberately select and apply thinking strategies to the *consideration of alternative perceptions and value positions,* and *evaluate the quality* of personal choices about such issues **(U, I)**.

10.2.6 ITIC Inquiry Methodologies in the Thinking EL

The above consideration shows that the Thinking EL contains extensive reference to inquiry methodologies as defined by the ITIC. This is perhaps not surprising given that one of the Key Elements of the Thinking EL is termed Inquiry.

The ITIC scale that the Thinking EL makes the most connections to is Interpretation of Data, followed by Uncertainty in Science and then Communication and Freedom in Practical Work. There is very limited connection to the Science Stories scale.

The connections that the Thinking EL shows to ITIC items are summarised below:

- Freedom in Practical Work scale - connections to all items except F1 (We carry out practical investigations that take more than one lesson), but it is difficult to envisage how students would complete research such as that referred to without taking more than one lesson, so item F1 seems to be implied.
- Communication - connections to all scale items.
- Interpretation of Data - connections to all scale items.
- Science Stories - connections to S3 and S4, possible connections to S5 and S6.
- Interpretation of Data - definite connections to items U1, U3, U4, U5, U6, U7, with less connection to U2 and no real connection to U8 (Our teacher questions some scientific theories), although the type of behaviour implied by U8 would seem to be valuable in developing the skills referred to in the Thinking EL.

Taking into consideration both the number of connections that the Thinking EL makes to ITIC methodologies and the number of ITIC items that these connections relate to, the above data indicate that the ITIC would be a valuable instrument to use to assess the extent to which the intent of the Thinking EL is being met by the methodologies used in science classrooms. As there are few connections to the Science Stories scale, researchers may wish to omit this scale when collecting data. However, given that behaviours from the Science Stories scale may be useful in setting contexts for students, it is recommended that consideration be given to including this scale.

10.3 CONNECTIONS TO ITIC SCALES WITHIN THE COMMUNICATING ESSENTIAL LEARNING

The Communicating EL contains four Key Elements:

- Being Literate.
- Being Numerate.
- Being Information Literate.
- Being Arts Literate.

10.3.1 Description of Communicating from *ELF1*

The description of the Communicating EL contained in *ELF1* includes the following:

> Communicating, in this instance, focuses on how symbol systems are used to communicate meaning and *influence opinion* (**U**) . . .
>
> . . . Richer forms of symbol use *enable more complex and flexible ways of thinking and of relating with others*. *Language is essential to being able to reflect on, accommodate and refine what has been learnt* and how it was learned (**C, I?**).
>
> *Symbolic representation is not neutral. It can be constructed in certain ways for particular effects* (**U**). In contemporary education it is vital to provide learners with *the skills to interpret critically the images and messages that are part of their lives* (**I**) (Tasmania, Department of Education, 2002, p. 20).

10.3.2 Description of the Being Literate Key Element from *ELF1*

The information that *ELF1* contains about the Being literate Key Element includes:

> Learners develop the basic skills of *listening, speaking* (**C**), reading, viewing and writing for a range of purposes . . . Learners need to be able to use language to compose creatively and to *comprehend critically* (**I**). They need to recognise its impact on them and make judgements about what is said and shown to them (Department of Education, 2002, p. 20).

10.3.3 Connections to ITIC Scales from the Being Literate Key Element Outcome

The Key Element Outcome descriptor for Being Literate contained in *ELF2* states:

> *Understands, uses and critically evaluates* non-verbal, *spoken, visual and print communication practices of the world in which they live* (**C, I, U**).

One of the seven Performance Guidelines for the Being Literate Key Element Outcome states:

> *Apply evaluative criteria to the selection, interpretation, analysis, reorganisation and synthesis of information from a variety of sources and formats* (**I, U**).

Table 10.4 lists the standards from the Being Literate Key Element Outcome.

Table 10.4

The Five Standard Statements for Being Literate From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands some of the ways that communication works and how non-verbal, spoken, written and visual forms carry messages.	Understands how to use basic structures, features and strategies to communicate in a variety of contexts for a range of purposes.	Understands how to select and use communications for different audiences, purposes and contexts.	Understands how to construct and deconstruct communications designed for particular effects.	Understands the *sophisticated ways in which communications may be varied and combined to fulfil a range of requirements* for learning, life and work (**I, U**).

10.3.4 Description of the Being Numerate Key Element from *ELF1*

The information that *ELF1* contains about the Being Numerate Key Element includes:

> Being numerate not only includes numeracy skills and understandings, but it also involves the critical and life-related aspects *of being able to interpret information thoughtfully and accurately when it is represented in numerical and graphic form* (**I**). This aspect of numeracy is akin to critical literacy – *being able to recognise that information can be constructed to influence the reader or viewer* (**U**). Developing the critical skills to

> *analyse quantitative and spatial information when it is presented in various forms – for example graphs, tables, spreadsheets, charts and comparative models* (**I**) – enables young people to make more informed decisions, personally in everyday life, as consumers and as citizens (Tasmania, Department of Education, 2002, p. 21).

10.3.5 Connections to ITIC Scales from the Being Numerate Key Element Outcome

The Key Element Outcome descriptor for Being Numerate contained in *ELF2* states:

> Understands and has the confidence and disposition to *use the mathematical concepts and skill*s required to meet the demands of life (**I**).

Table 10.5 lists the standards from the Being Numerate Key Element Outcome.

Table 10.5

The Five Standard Statements for Being Numerate From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that mathematical language and ideas can be used to describe situations encountered through play and interaction with the environment.	Understands how to purposefully use and explain informal ways of thinking and acting mathematically in familiar situations.	Understands how to explore, refine and communicate more effective ways of thinking and acting mathematically in familiar situations.	Understands how to consistently select and justify effective mathematical strategies and choose the most effective strategy for communicating information and solving problems in a variety of situations.	Understands how and when to use mathematical ideas *effectively and critically when interpreting and communicating information* and solving problems encountered in life **(I)**.

10.3.6 Description of the Being Information Literate Key Element from *ELF1*

The information that *ELF1* contains about the Being Information Literate Key Element includes:

> *Information is not neutral* (**U**) and it is essential that learners select sources wisely, interact critically with multimedia communications and develop insight into their intentions, constructions and effects. *Only then*

> *will they be able to make decisions about the authenticity and safe use of materials* (**I, U**).
>
> With relatively open access to information on a global scale, especially outside school, young people need help to develop discernment, judgement and discrimination, so that they challenge assumptions, *question validity and test ideas and beliefs against their personal and community codes of values* (**I, U**) (Tasmania, Department of Education, 2002, p. 22).

10.3.7 Connections to ITIC Scales from the Being Information Literate Key Element Outcome

The Key Element Outcome descriptor for Being Information Literate contained in ELF2 states:

> Understands how to effectively access, *interpret, transform*, create, communicate, evaluate and manage information in ethical ways, using a range of sources (**I, U**).

Table 10.6 lists the standards statements for Being Information Literate.

Table 10.6

The Five Standard Statements for Being Information Literate From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that interesting, entertaining and useful information can be obtained and generated through communication technologies, and begins to explore technology in appropriate ways.	Understands that there is a range of information sources and technology tools for specific purposes. Selects and responsibly uses appropriate information and technology tools to meet learning needs.	Understands why information is useful and valuable and why it should be used responsibly. Locates, organises and synthesises information and uses technology tools to create a product which effectively communicates their understanding.	Understands how to use advanced search techniques and critically evaluate information sources. Structures and manages personal collections of information. Synthesises information and creatively uses it and technology in responsible and ethical ways.	Understands own information needs. Uses technology as a tool to solve problems. *Critically, collaboratively and ethically engages in local and global learning communities*. Applies prior understandings to effectively use new software and hardware tools **(I, C)**.

10.3.8 Description of the Being Arts Literate Key Element from *ELF1*

The information that *ELF1* contains about the Being Arts Literate Key Element includes:

> The arts are important ways of coming to know and understand through direct, intimate, intuitive experience. They provide a particular way of looking*, thinking, describing, recording and analysing* (**I?**). . . The opportunity to communicate through arts forms gives voice to less empowered groups in society, thereby *conveying minority points of view* (**U?**) to wider audiences. Understanding how the arts reflect, challenge and sometimes shape the values and beliefs of a society, *and how their forms vary across times and cultures* (**S?**), helps learners to enjoy and engage with them as a life-enhancing part of personal and social experience (Tasmania, Department of Education, 2002, p. 23).

10.3.9 Connections to ITIC Scales from the Being Arts Literate Key Element Outcome

The Key Element Outcome descriptor for Being Arts Literate contained in *ELF2* states:

> Understands the purposes and uses of a range of arts forms – visual arts, media, dance, music, drama and literature - *and how to make and share meaning from and through them* (**I**). Uses with confidence and skill the codes and conventions of the art form best suited to their expressive needs.

Two of the four Performance Guidelines for Being Arts Literate state:

- Understanding that arts works are intentional and that personal meanings can be derived from them, shared and moderated with others (**U?, C?**).
- Understanding the role of the arts in *reflecting, challenging and shaping the values and understandings of a society* (**U?, C?**).

Table 10.7 lists the standards from the Being Arts Literate Key Element Outcome.

Table 10.7

The Five Standard Statements for Being Arts Literate From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that there are different arts forms through which enjoyment is gained and meanings expressed and derived.	Understands how the basic elements of arts forms are used to communicate meanings in everyday life.	Understands the ways in which arts forms communicate for different purposes, audiences and contexts.	Understands how to construct and deconstruct arts works designed with particular intentions.	Understands the sophisticated ways in which the art form most suited to their expressive needs may be used to *reflect, challenge and shape values* and understanding of a society (**I**, **U**).

10.3.10 Overview of ITIC Inquiry Methodologies in the Communicating EL

The Communicating EL contains a number of connections to the Interpretation of Data and Uncertainty (in Science) ITIC scales. These references largely relate to students being critical consumers of knowledge, recognizing that communications are created for particular purposes by authors with particular interests. There are no connections to the Freedom in Practical Work scale, one questionable one to the Science Stories scale and limited connections to the ITIC Communication scale.

The connections that the Communicating EL shows to ITIC items are summarised below:

- Freedom in Practical Work - no connections.
- Communication - connections exist to all scale items, largely resulting from the collaborative sharing of ideas required by the Communicating EL.
- Interpretation of Data - definite connections to I1, I2, I3, I5 and I6; no connections to I4 and I7; connections to I8 are implied in the form of creating ideas, although the term *hypothesis* is not used in the Communicating EL.

- Science Stories - a potential connection to S5 through Being Arts Literate, but no definite connections to any items.
- Uncertainty in Science - connections to U3 and U4; connections to U2, U5 and U6 seem to be implied; no connections to U1, U7 or U8.

Taking into account both the number of connections that the Communicating EL shows to ITIC methodologies and the number of ITIC scale items that these connections relate to, the above data indicates that the ITIC would be useful in determining the extent to which the requirements to interpret information, acknowledge uncertainty and share ideas with others were being met in science classes. The Freedom in Practical Work and Science Stories scales would not be useful from the viewpoint of the Communicating EL, so if data were only being collected about the Communicating EL researchers may wish to omit these scales.

10.4 CONNECTIONS TO ITIC SCALES WITHIN THE PERSONAL FUTURES ESSENTIAL LEARNING

The Personal Futures EL contains four Key Elements:

- Building and Maintaining Identity and Relationships.
- Maintaining Wellbeing.
- Being Ethical.
- Creating and Pursuing Goals.

10.4.1 Description of Personal Futures from *ELF1*

The description of the Personal Futures EL contained in *ELF1* includes the following:

> . . . Operating with autonomy requires a willingness to *develop a personal ethical position*, in order *to act on informed conscience* (**U**, **C?**, **I**?).

> . . . *Being able to communicate sensitively in a range of contexts, using both verbal and non-verbal means, is essential* in establishing and sustaining all these (**C**).
>
> . . . Acting autonomously involves *being aware of choices, being able to judge what one can or should do, being able to select suitable options,* persist and take responsibility for the consequences of decisions and behaviour (**I**). *Operating with moral autonomy requires an ethical code that guides right behaviour towards others and the independence to behave with personal integrity in challenging situations* (**U**).
>
> . . . It includes *being able to reflect on experience and to identify and solve problems* (**I**) . . . Through recognising and utilising our strengths and *imagining possibilities* (**I**), we can set, pursue and review achievable goals and make perceptive choices about work, leisure and life. (Tasmania, Department of Education, 2002, p. 25).

10.4.2 Description of the Building and Maintaining Identity and Relationships Key Element from *ELF1*

The information that *ELF1* contains about the Building and Maintaining Identity and Relationships Key Element includes:

> Learners develop understandings about the *social and cultural construction of identities and evaluate the impact of these constructs on their views of themselves and others* (**U**) . . . Learning how to *communicate flexibly and creatively in personal, recreational and vocational contexts is essential* (**C**) in developing and maintaining effective relationships (Tasmania, Department of Education, 2002, p. 26).

10.4.3 Connections to ITIC Scales from the Building and Maintaining Identity and Relationships Key Element Outcome

One of the four Performance Guidelines for the Building and Maintaining Identity and Relationships Key Element Outcome states:

> Have the personal qualities, skills and understandings required to *communicate appropriately and effectively* in a range of contexts (**C?**).

Table 10.8 lists the standards from the Building and Maintaining Identity and Relationships Key Element Outcome.

Table 10.8

The Five Standard Statements for the Building and Maintaining Identity and Relationships From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that they have characteristics, strengths, talents, interests and preferences and relates to others in socially functional ways.	Understands common and unique characteristics of self and others and that relationships with others are a basic human need.	Understands that behaviours, attitudes and choices affect identity and relationships.	Understands that identity is constructed, and evaluates key ways in which experiences, groups, and cultures contribute to identity.	Understands how to build on strengths and address challenges through individual and *group action*, recognising that *identity is open to change* (**C, U**).

10.4.4 Description of the Being Ethical Key Element from *ELF1*

The information that *ELF1* contains about the Being Ethical Key Element includes:

> To develop moral autonomy, learners *debate different points of view* (**C, U**) and come to understand the values implicit in the situations being studied. They are helped to understand the complexity of ethical decision-making, to *evaluate* moral dilemmas in their lives and in the world, and *to take a stand that reflects their values* (**C**, **I**) (Tasmania, Department of Education, 2002, p. 27).

10.4.5 Connections to ITIC Scales from the Being Ethical Key Element Outcome

The descriptor for the Being Ethical Key Element Outcomes states:

> Understands that to be ethical requires caring about the consequences of actions of self and others and that the quality of ethical judgements *is based upon reasoning* (**I**) and the application of ethical principles.

Two of the five Performance Guidelines that *ELF2* contains for the Being Ethical Key Element Outcome state:

- Uses ethical values and ethical decision-making frameworks *to analyse and evaluate the actions of themselves and others* (**I, U**).
- *Articulate their ethical reasons and justify ethical positions held by themselves* (**C**) and others.

Table 10.9 lists the standards statements for Being Ethical.

Table 10.9

The Five Standard Statements for Being Ethical From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that self and others have needs and rights, and can describe actions in simple ethical terms.	Understands that values can be applied to describe behaviour and acts within rules and norms.	Understands how to use values and emerging ethical principles when choosing to act and when exploring the behaviour of self and others.	Understands how to use valid ethical principles to make choices in developing a personal position. Demonstrates ethical behaviour by caring about their actions and those of others.	Understands that *emotional response and social contexts influence evaluation of the actions of others* and the modification of personal actions and beliefs **(U?)**.

10.4.6 Description of the Creating and Pursuing Goals Key Element from *ELF1*

The information that *ELF1* contains about the Creating and Pursuing Goals Key Element includes:

> They learn *how to work cooperatively with others to achieve their own and shared goals* (**C**).

10.4.7 Connections to ITIC Scales from the Creating and Pursuing Goals Key Element Outcome

The Key Element Outcome descriptor for Creating and Pursuing Goals contained in *ELF2* states:

> Understands how to create, set and review goals for life and *how to work with others* to achieve own and shared goals (**C**).

Table 10.10 lists the standards statements for Creating and Pursuing Goals.

Table 10.10

The Five Standard Statements for Creating and Pursuing Goals *From ELF2 (Tasmania, Department of Education, 2003).*

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands how to set and achieve a simple goal within an individual or group activity and describes some of the steps involved.	Understands how to implement and record the steps involved in setting and achieving personal and small-group goals.	Understands how and why we work collaboratively to achieve goals. Understands the strengths and weaknesses of plans and how this affects the implementation and realisation of goals.	Understands how to set personal and group goals, justifying choices in selecting and following plans and evaluating the effectiveness of the choices they have made.	Understands how *to effectively prioritise, implement and adjust plans* in ways that *reflect changing world views* and the impact these have on self and others (**F?, C, I**).

10.4.8 ITIC Inquiry Methodologies in the Personal Futures EL

The Personal Futures EL contains limited connections to the ITIC scales. These relate largely to the Communication scale of the ITIC, with some connections to the Uncertainty (in Science) and Interpretation of Data scales.

The Maintaining Wellbeing Key Element did not show any connections to the ITIC, so no discussion of it has been included.

The connections through the Communication scale tend to relate to debating different points of view and working with others to determine and achieve their own and group goals. The links to the Uncertainty in Science scale are through acknowledging that different points of view exist.

The connections that the Personal Futures EL shows to ITIC items are summarised below:

- Freedom in Practical Work - connections to F2, if it is read as plans rather than experiments; no definite connections to other items.
- Communication - connections to all scale items through the requirement to communicate flexibly and creatively and to debate different points of view.

- Interpretation of Data - connections to items I1, I5, I6, I8 and possibly I7; no connections to I2, I3, and I4.
- Science Stories - no connections to any items.
- Uncertainty in Science - connections to items U3 and U4; connections to items U1 and U6 seem to be implied by the fact that differences in opinion exist; no connections to items U2, U5, U7 or U8.

Taking into account both the number of connections that the Personal Futures EL shows to ITIC methodologies and the number of ITIC scale items that these connections relate to, the above data indicates that the ITIC would be useful in determining the extent to which the Personal Futures behaviours relating to developing a point of view and sharing ideas with others occurs in science classes. The Freedom in Practical Work and Science Stories scales provide little information pertaining to the Personal Futures El, so researchers may wish to omit these scales if they are only investigating Personal Futures.

10.5 CONNECTIONS TO ITIC SCALES WITHIN THE SOCIAL RESPONSIBILITY ESSENTIAL LEARNING

The Social Responsibility EL contains four Key Elements:

- Building Social Capital.
- Valuing Diversity.
- Acting Democratically.
- Understanding the Past and Creating Preferred Futures.

10.5.1 Description of Social Responsibility from *ELF1*

The description of the Social Responsibility EL contained in *ELF1* includes the following:

> Learning from the past plays a significant part in making wise decisions for the present and the future. *Understanding the historical and cultural*

> *foundations of societies and peoples* (**U**) assists the constructive resolution of social conflicts and tensions. *Being able to reflect on the range of points of view around issues and events and to make personal, ethical judgements* (**I**, **C, U**) is an essential component of social responsibility (Tasmania, Department of Education, 2002, p. 30).

10.5.2 Description of the Building Social Capital Key Element from *ELF1*

The information that *ELF1* contains about the Building Social Capital Key Element includes:

> Learners need *opportunities to canvass alternative views about issues* (**U**) that matter to them in their own communities and to *build shared values through thoughtful discussion and respectful deliberation* (**C**) (Tasmania, Department of Education, 2002, p. 31).

10.5.3 Connections to ITIC Scales from the Building Social Capital Key Element Outcome

The Key Element Outcome descriptor for Building Social Capital contained in ELF2 states:

> *Understands the interdependence of individuals, groups and social organisations* (**I?**) and participates positively in the building of ‘good and just’ communities.

Two of the four Performance Guidelines for Building Social Capital are:

- Act ethically to relate and reconcile *diverse views and interests* (**U**).
- *Engage effectively with others* (**C**) in collective action to develop ‘good and just’ communities.

Table 10.11 lists the standards statements for Building Social Capital.

Table 10.11

The Five Standard Statements for Building Social Capital From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands the everyday ways in which self and others are connected.	Understands the need for constructive personal and social relationships.	Understands the processes through which individuals and groups work together to achieve a personal and shared goal.	Understands the social systems and networks people participate in; and can evaluate the effects of personal and collaborative action .	Understands the interdependence of individuals, groups and social organisations and *participates collaboratively with diverse others* in the building of 'good and just' communities **(C, I, U)**.

10.5.4 Description of the Valuing Diversity Key Element from *ELF1*

The information that *ELF1* contains about the Valuing Diversity Key Element includes:

> The more we understand the growing interdependence of our world the more we need to appreciate *the diversity of cultures, races, opinions, religions, beliefs, languages and world views* (**U**) (Tasmania, Department of Education, 2002, p. 31).

10.5.5 Connections to ITIC Scales from the Valuing Diversity Key Element Outcome

The Key Element Outcome descriptor for Valuing Diversity contained in ELF2 states:

> Understands the interdependence of our world, *values its diversity* and acts for a more inclusive society (**U**).

Three of the five Performance Guidelines for Valuing Diversity are:

- *Acknowledge and celebrate diversity and difference in self and others* (**U**).
- Have the courage *to promote difference* (**C?**) when achieving personal and shared goals.

- Develop *understanding of causes and consequences* (**I**) of discrimination and inequities based on difference.

Table 10.12 lists the standards statements for Valuing Diversity.

Table 10.12

The Five Standard Statements for Valuing Diversity From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that self and others have unique characteristics.	Understands that individuals have differences and similarities.	Understands that whilst difference enriches culture, it may lead to misunderstandings which can be resolved by individual and group action.	Understands the value of diversity, recognises interdependence and sources of inequity, and takes informed action.	Understands global interdependence; *values and celebrates diversity*; and uses strategies to create a more inclusive world. (**I, U**)

10.5.6 Description of the Acting Democratically Key Element from *ELF1*

The information that *ELF1* contains about the Acting Democratically Key Element includes:

> The more we understand the growing interdependence of our world the more we need to appreciate *the diversity of cultures, races, opinions, religions, beliefs, languages and world views* (**U**). (Tasmania, Department of Education, 2002, p. 31).

10.5.7 Connections to ITIC Scales from the Acting Democratically Key Element Outcome

The Key Element Outcome descriptor for Acting Democratically contained in ELF2 states:

> Understands and *participates effectively in democratic decision-making processes* (**C**) and civic life.

The four Performance Guidelines for Acting Democratically are:

- *Explain and defend their own beliefs* (**C**) about democratic values (e.g. fairness, freedom, equality).

- *Explain and evaluate* (**I**) the operation of formal and informal decision-making processes, including processes they have designed themselves.
- *Participate as active, informed and responsible citizens to pursue their own rights and interests* (**C?**).
- *Participate as ethical and responsible citizens for the 'public good', including acting to enhance and protect democratic values and institutions* (**C?**).

Table 10.13 lists the standards statements for Acting Democratically.

Table 10.13

The Five Standard Statements for Acting Democratically From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that there are helpful rules and ways of making decisions, and behaves in acceptable ways.	Understands that decision-making can be a group process and participates responsibly.	Understands how to use a range of democratic processes and participates responsibly in school and community groups.	Understands how to apply democratic processes and ideas, and participates actively and responsibly in a range of school and community groups.	Understands how *to participate actively* and responsibly in a range of communities and acts to embed democratic values and processes in civic life. (**C**)

10.5.8 Description of the Understanding the Past and Creating Preferred Futures Key Element from *ELF1*

The information that *ELF1* contains about the Understanding the Past and Creating Preferred Futures Key Element includes:

> Changes have often resulted from people moving against perceived injustices, with a determination to make life better for all. While some of these changes have been intentional and predictable, others have been unintended or had unexpected consequences. *Understanding why events have occurred, and how decisions have been made* **(S)**, is a necessary foundation for recognising the mistakes of the past and creating preferred futures.

10.5.9 Connections to ITIC Scales from the Understanding the Past and Creating Preferred Futures Key Element Outcome

The Key Element Outcome descriptor for Understanding the Past and Creating Preferred Futures contained in *ELF2* states:

> Understands that *investigating the past and reflecting on the present* (**S**) are essential to understanding self and others and creating preferred futures.

Table 10.14 lists the standards statements for Understanding the Past and Creating Preferred Futures.

Table 10.14

The Five Standard Statements for Understanding the Past and Creating Preferred Futures From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that everyday events have causes, relationships and consequences.	Understands how to use evidence to reflect on the past, to sequence events, and to make decisions.	Understands the value of evidence and uses a range of perspectives to gain insights into the past and present, and to make predictions for the future.	Understands how to evaluate evidence, viewpoints and decisions through investigating past, present and future contexts.	Understands how *to make predictions* and take actions for preferred futures *based on historical investigations, recognising the influence of evidence, perspective and context.* (**I, S, U**)

10.5.10 ITIC Inquiry Methodologies in the Social Responsibility EL

The Social Responsibility EL shows particular connections to the ITIC Communication and Uncertainty (in Science) scales. There are some links to the Interpretation of Data scale and a few to the Science Stories scale. As was the case with the Personal Futures EL, many of the connections arise from the recognition that there are diverse points of views and opinions on issues.

The connections that the Social Responsibility EL shows to ITIC items are summarised below:

- Freedom in Practical Work - no connections to any ITIC items.

- Communication - connections exist to all scale items through the requirements to build shared values through thoughtful discussion , and to participate effectively.
- Interpretation of Data - connections to items I1, I2, I5, I6 and possibly I8; no connections to items I3, I4 or I7.
- Science Stories - connections to items S3, S4, S5 and S6; no connections to items S1, S2, S7 or S8.
- Uncertainty in Science - connections of items U1, U3, U4 and U6; no connections to U2, U5, U7 or U8.

Taking into account the number of connections that the Social Responsibility EL shows to ITIC methodologies, and the number of ITIC items that these connections relate to, the above data indicate that the ITIC would be useful in determining the extent to which science classes provide opportunities for issues to be presented as uncertain, and for students to discuss these issues collaboratively, evaluating evidence for different alternatives.. Researchers may wish to omit the Freedom in Practical Work scale if only collecting information for the Social Responsibility EL.

10.6 CONNECTIONS TO ITIC SCALES WITHIN THE WORLD FUTURES ESSENTIAL LEARNING

The World Futures EL contains four Key Elements:

- Investigating the Natural and Constructed World.
- Understanding Systems.
- Designing and Evaluating Technological Solutions.
- Creating Sustainable Futures.

10.6.1 Description of World Futures From *ELF1*

The description of the World Futures EL contained in *ELF1* includes the following:

> Investigative approaches seek *to identify questions* (**F**), generate new ideas and solve problems about real-world issues. Through these investigations we come to appreciate *the provisional nature of knowledge* (**U)** and to acknowledge, with a sense of humility, that there is much we do not understand. The *history of scientific thought* (**S**) amply demonstrates how conceptualisations about the world are properly recast in the light of new knowledge, insights, evidences and understandings (Tasmania, Department of Education, 2002, p. 35).

10.6.2 Description of the Investigating the Natural and Constructed World Key Element from *ELF1*

As the Investigating the Natural and Constructed World EL contained in *ELF1* seems particularly relevant to the ITIC, the description from *ELF1* is reproduced below in its entirety:

> Learners are assisted and challenged to observe, *describe and analyse their world in a variety of ways* (**I**). Focused observation and attention to environments may be informed by artistic, scientific and mathematical ways of thinking.
>
> The essence of a scientific approach lies in *the way questions are generated and investigations framed, conducted* (**F**) and *evaluated* (**I**). This includes *identifying those questions that may be answered by scientific investigation – hypothesising, gathering, presenting* (**F**) and *analysing data, drawing inferences, interpreting evidence and estimating risk and probabilities* (**I, U**).
>
> Contemporary understandings of science *acknowledge the provisional and tentative nature of knowing* (**U**) and recognise how the creative, imaginative and speculative qualities of scientific thought can take us to new conceptualisations about the world and how it works. Accordingly, learners are encouraged to apply an inquisitive, creative and imaginative

> approach to *posing, identifying and solving problems and undertaking investigations* (**F**, **I)**. They are asked to describe their observations accurately and to *assess the adequacy, accuracy and worth of data before making tentative judgements based on the evidence available* (**I**). By *learning about the history of human ideas* (**S**) they can appreciate both the wealth of knowledge we have access to, and *the fact that theories are always subject to the challenge of contrary evidence* (**U**).
>
> Since *information is never 'value-free'* (**U**), learners are assisted to *think critically* about where, when, how, by whom and for what purposes information is being presented (**I**). They also come to *understand how their beliefs, assumptions and personal ways of knowing will affect what they observe and the judgements they make* (**U**). They are encouraged to think ethically about issues and events, to challenge claims and *to present reasoned arguments for their conclusions* (**I, C***)*. (Tasmania, Department of Education, 2002, p. 36).

10.6.3 Connections to ITIC Scales from the Investigating the Natural and Constructed World Key Element Outcome

The Key Element Outcome descriptor for Investigating the Natural and Constructed World contained in *ELF2* states:

> Understands *how to scientifically investigate the natural and constructed world* (**F**), *appreciating the tentative nature of knowledge* (**U**) and the value of creative, imaginative and speculative thinking.

The Performance Guidelines for the Investigating the Natural and Constructed World Key Element Outcome state that students who are investigating the natural and constructed world:

- Understand that *all people bring ways of knowing, beliefs and understanding to their investigations* (**U**).
- *Use direct experience and observation, wonder why, ask questions, formulate possible hypotheses and suggest possibilities* (**F, I**).

- *Describe and record observations* through various means (artistic, scientific, mathematical, technological) (**I**).
- *Design investigations using appropriate methodology, show awareness of ethical considerations, anticipate results and make predictions* (**F**, **I**).
- *Complete practical tasks, record, analyse, critically question and evaluate results, drawing justifiable conclusions* (**F, I**).
- *Reflect on investigation and identify problems which occurred and further questions which could be explored* (**I**).
- *Communicate investigations to a wider audience* (**C**), selecting from a range of presentation styles including written, oral, online, graphic and artistic modes.

Table 10.15 lists the five standards statements from the Investigating the Natural and Constructed World Key Element Outcome.

Table 10.15

The Five Standard Statements for Investigating the Natural and Constructed World From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands how to use a variety of direct experiences and play to collect information about the natural and constructed world.	Understands how to use a variety of techniques to collect information and resources to answer questions.	Understands how to pose questions, actively investigates them, and evaluates the findings against the explanations and observations of others.	Understands principles of fair testing and controlling variables. Compares their findings with those of others and evaluates against current scientific knowledge. Chooses appropriate questions for a variety of scientific investigations.	Understands how to *select appropriate methods to investigate collaboratively – formulated,* testable models, taking into consideration current scientific knowledge. *Critically evaluates own results, and also those of others, and modifies ideas in the light of new information* (**F, I, U**).

10.6.4 Description of the Understanding Systems Key Element from *ELF1*

The information that *ELF1* contains about the Understanding Systems Key Element includes:

> They are introduced to the uncertainty and unpredictability of systems and to concepts such as side-effects or the potential for positive and negative feedback within and between systems.
>
> This involves developing a strong sense of place and an understanding of the particular and unique character of the local environment. It includes *recognition of Indigenous knowledge and experience of, and spiritual connection with, a particular environment* (**U?**), and understanding of Indigenous management of natural ecosystems

10.6.5 Connections to ITIC Scales from the Understanding Systems Key Element Outcome

The Key Element Outcome descriptor for Understanding Systems contained in *ELF2* states:

> Understands that the social, natural and constructed world is made up of a complex web of relationships or systems.

The seven Performance Guidelines for Understanding Systems are:

- *Recognise interconnections* (**I**) within and between systems.
- *Understand the connections* between local and global environments (social, natural and constructed) (**I**).
- Develop the capacity to operate and modify systems (**F?, C?**).
- Examine how systems operate to achieve particular outcomes (**I**).
- Explore the forms, functions and performance of systems (**F?**).
- *Examine the functioning of natural systems* (**F?**) and *explore how understandings developed may be used in design of constructed systems* (**I**?).
- *Investigate whether constructed systems are appropriate, depending on the ethical, technical, environmental and cultural consequences of their application* (**U**).

Table 10.16 lists the standards statements for Understanding Systems

Table 10.16

The Five Standard Statements for Understanding Systems From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands simple connections in systems.	Understands how some of the parts of social, natural and constructed systems work together.	Understands causal relationships in systems, including some of their effects on Tasmanian people and their environment.	Understands the interdependency of systems and their function within local and national communities.	*Understands principles, structures, organisation and control of systems, and their impact on local, national and global environments.* (**I**)

10.6.6 Description of the Designing and Evaluating Technological Solutions Key Element from *ELF1*

The information that *ELF1* contains about the Designing and Evaluating Technological Solutions Key Element includes:

> Learners are encouraged to develop their capacity for *designing and making processes and products* (**F**) in response to human needs or problems. . . . Learners may adapt existing models or *devise and create new designs and solutions that meet identified needs, circumstances and opportunities* (**F**). In the process, they apply previously learnt concepts and skills to new situations, *appraise the applications against value-based, aesthetic and practical criteria, and make judgements* (**I**) about such things as appropriateness, benefits, limitations, risk and impact.
>
> Scientific and technological applications and processes impact on cultural, political, social, environmental and economic systems. Increasingly we are being challenged to *make hard ethical choices because of innovations* (**U**). Learners must develop *the capacity to critically evaluate the consequences of scientific and technological innovation and make informed and ethical decisions about their impact on people and the environment* (**I, U, C**) . . . To act responsibly, *learners need to identify the information needed to make wise decisions, estimate its accuracy, adequacy and bias, and make*

> *judgements about alternative courses of action* (**I**) (Tasmania, Department of Education, 2002, p. 38).

10.6.7 Connections to ITIC Scales from the Designing and Evaluating Technological Solutions Key Element Outcome

The Key Element Outcome descriptor Designing and Evaluating Technological Solutions contained in *ELF2* states:

> Understands how to *design, make and critically evaluate products and processes in response to human needs and challenges* (**F**, **I***)*.

The Performance Guidelines for this Key Element Outcome state that students who design and evaluate technological solutions:

- *Devise creative ways of generating and applying ideas* (**F?**).
- *Develop and produce appropriate technological solutions using problem-solving systems and strategies* (**F**).
- Use the arts, *mathematics and science in design, production and evaluation* (**F**, **I**).
- Modify ideas in the face of adversity and *consider alternatives, dealing with uncertainty in an informed way* (**U**).
- *Evaluate proposed and established technological and scientific solutions for their economic, social, environmental, aesthetic and ethical impact* (**I**, **U**).

Table 10.17 lists the standards statements for Designing and Evaluating Technological Solutions.

Table 10.17

The Five Standard Statements for Designing and Evaluating Technological Solutions From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands that everyday products have particular characteristics suited to their uses.	Understands simple production processes, including the need for care and safety.	Understands how to plan and carry out the steps of production processes, making safe and efficient use of resources. Explores the contribution of technology to cultures.	Understands the characteristics of materials and relates them to the functional and aesthetic requirements of designs for their own constructions and those of others. Evaluates alternative technological solutions.	*Understands how to create and prepare design and production proposals that demonstrate consideration of functional, aesthetic, social, environmental and ethical issues, critically evaluating the consequences of their own and others' innovations.* (**F**, **I**, **U**)

10.6.8 Description of Creating Sustainable Futures from *ELF1*

The information that *ELF1* contains about the Creating Sustainable Futures Key Element includes:

> Ecological sustainability is an approach to making environmental decisions that focuses on a responsible and sustainable world future. It *involves individuals, communities and nations in making careful choices, and it increasingly requires governments to take an international perspective* (**U**). Learners are helped to see how ecological sustainability can be translated into personal action and how public laws and policies are developed within the context of the choices that must be made by citizens (Tasmania, Department of Education, 2002, p. 38).

10.6.9 Connections to ITIC Scales from the Creating Sustainable Futures Key Element Outcome

The Key Element Outcome descriptor Creating Sustainable Futures contained in *ELF2* states:

> Understands the environmental principles *and ethical issues involved in creating and working towards sustainable futures* (**U**).

Table 10.18 lists the standards statements for Creating Sustainable Futures

Table 10.18

The Five Standard Statements for Creating Sustainable Futures From ELF2 (Tasmania, Department of Education, 2003).

Standard 1	Standard 2	Standard 3	Standard 4	Standard 5
Understands some of the actions needed to care and show concern for people and the natural environment.	Understands their connections to and responsibility for the local environment.	Understands the uniqueness of local ecosystems and takes responsible action to sustain them.	Understands how to investigate and plan for sustainable practices to reduce environmental impacts on biodiversity.	Understands the consequences of human activity on local and global systems and understands how to act as a responsible global citizen. **(C?, U)**

10.6.10 ITIC Inquiry Methodologies in the World Futures EL

The World Futures EL shows extensive links to the Freedom in Practical Work, Interpretation of Data and Uncertainty in Science ITIC scales. There are limited connections to the Communication scale and only two from the Science Stories scale. Overall the World Futures Key Elements seem to be indicating many of the methodologies that the ITIC is measuring.

The connections that the World Futures EL shows to ITIC items are summarised below:

- Freedom in Practical Work - connections exist to items F2, F3, F4, F5, F6, F7 and F8; connection to F1 (We carry out practical investigations that take more than one lesson) seem to be implied, as it would be difficult to meet the stated outcomes if investigations did not occur over an extended period.
- Communication - connections exist to items C1, C2, C3, C6, C7 and C8; it seems unlikely that C4 and C5 would not be desirable during practical work.
- Interpretation of Data - there are connections to all scale items.
- Science Stories - connections exist to all scale items through the reference to *the history of scientific thought.*

- Uncertainty in science - connections exist to all scale items except U8 (Our teacher questions some scientific theories); item 8 seems to represent a behaviour that is in line with the intent of the World Futures EL.

Taking into account both the number of connections that the World Futures EL shows to ITIC methodologies and the number of ITIC scale items that these connections relate to, the ITIC would be an extremely valuable tool to use to assess the extent to which the behaviours that the World Futures EL indicates are occurring in science classes.

10.7 OVERVIEW OF ITIC CONNECTIONS TO THE *ESSENTIAL LEARNINGS*

The preceding discussion has highlighted the connections that exist between Tasmania's *Essential Learnings* curriculum and the ITIC scales. These connections are summarised in Tables 10.19 and 10.20.

Table 10.19

Number of References to ITIC Inquiry Methodologies in the Essential Learnings Documentation.

	F	F?	C	C?	I	I?	S	S?	U	U?	Total
Thinking	8	3	12	1	22	0	0	2	16	1	65
Communicating	0	0	4	2	15	2	0	1	11	3	38
Personal Futures	0	1	9	2	8	0	0	0	6	1	27
Social Responsibility	0	0	7	3	6	1	3	0	11	0	31
World Futures	14	4	3	2	23	1	2	0	18	1	68
Total	22	8	35	10	74	4	5	3	62	6	229

The data in Table 10.19 show that the ITIC scales that have the most connections to the Essential Learnings curriculum documents are Interpretation of Data and Uncertainty in Science. There are also a number of connections to the

Communication and Freedom in Practical Work scales. There are a very limited number of connections to the Science Stories scale.

If the connections are examined by Essential Learning, Table 10.19 shows that the most connections to ITIC methodologies occur from the Thinking and World Futures ELs. There are just over half as many connections from the Communicating EL, approximately half as many from the Social Responsibility EL, and under half as many from the Personal Futures EL. Close examination of the five ELs reveals that the content of most traditional science courses would sit under the Thinking and World Futures ELs, so it is perhaps not surprising that these are the areas that a questionnaire designed to measure the extent to which inquiry methodologies are employed in science classes makes the mot connections.

While the data in Table 10.19 may be taken as an indication of the number of connections that exist between inquiry methodologies, as described by the ITIC, and the five Essential Learnings that constitute the Tasmanian curriculum, it must be remembered that whilst a single phrase in a curriculum document may only be represented by one number in Table 10.19, that phrase may imply close connections to a number of scale items. The number of ITIC items that connect to each of the ELs is summarised in Table 10.20.

Table 10.20

Number of ITIC Scale Items Connecting to Each Essential Learning (Maximum of 8 Possible).

	Freedom in Practical Work	Communicat-ion	Interpretat-ion of Data	Science Stories	Uncertainty in Science
Thinking	7-8	8	8	2-4	6-7
Communicating	0	8	5-6	1	2-5
Personal Futures	1	8	4-5	0	2-4
Social Responsibility	0	8	4-5	4	4
World Futures	7-8	6-8	8	8	7-8

The data in Table 10.20 indicate that virtually all ITIC items connect to the World Futures EL and that many ITIC items connect to the Thinking EL. The data in Table 10.20 also show that all items from the Communication scale are relevant to all five ELs.

Overall, the data collected in this chapter show that inquiry methodologies, as defined by the ITIC, are valued by the Essential Learnings curriculum, particularly from the perspective of the Thinking and World Futures ELs. Therefore, the ITIC would be a valuable instrument to use when studying the extent to which behaviours mandated by these two ELS are occurring in Tasmanian Grade 7-10 science classes, or indeed across all classes.

Additionally, all eight of the Communication scale items are connected to all five ELs. Therefore the Communication scale would provide valuable information across the whole ELs curriculum.

CHAPTER 11 - DISCUSSION OF THE ITIC RESEARCH PROJECT

CHAPTER OVERVIEW

The research objectives of the current study, as outlined fully in Section 1.3, have been met through the design, administration and analysis of the *Is This an Inquiring Classroom?* or ITIC questionnaire. The results of the various analyses that were conducted have been discussed in earlier chapters, but the overall research findings, together with their significance and implications will be considered here.

The ITIC is a new contribution to the field of classroom environment research outlined in Section 4.1, adding to the repertoire of instrument from which researchers can select when measuring classroom environments. As it was designed specifically to measure the extent to which inquiry methodologies are used in science classes it is relevant to the thinking behind many contemporary science curricula.

11.1 WHAT IS INQUIRY TEACHING?

Chapter 2 considered the historical development of the term inquiry as used in the science education literature, looking at the ideas and influences of its major proponents. Chapter 3 distilled the ideas of various influential authors as to what constituted, or indeed did not constitute, inquiry teaching, culminating in the identification of six scales which could be used to define inquiry teaching as referred to in the science education literature. A number of items were developed against each of these scales to form the Preliminary Version of the ITIC questionnaire, an instrument designed to assess the extent to which inquiry teaching methodologies were employed in science classes. Following analysis of the data from the Preliminary Version of the ITIC, a number of items were deleted or rewritten to give the final Student and Teacher Versions of the ITIC.

Statistical analysis showed the Student and Teachers ITICs, Actual and Preferred Forms, to be valid and reliable instruments with five scales. The complete instrument is presented in Table 11.1

Table 11.1

The 40 Items Comprising the Is This an Inquiring Classroom (ITIC) Questionnaire.

ITIC Scale 1 - Freedom in Practical Work

F1 We carry out practical investigations that take more than one lesson.
F2 We are asked to design our own experiments.
F3 We are allowed to extend the practical work and do some experimenting.
F4 We carry out experiments to answer questions that come up in class discussions.
F5 All students do exactly the same experiments.
F6 We carry out experiments to answer questions that interest us.
F7 We carry out experiments to test ideas which ***we*** come up with.
F8 We decide the best way to do things during practical work.

ITIC Scale 2 - Communication

C1 Most students take part in discussions.
C2 We talk to other students about our work.
C3 We explain our ideas to each other.
C4 We comment on other students' opinions.
C5 We talk with other students about how to solve problems.
C6 We discuss the results we have obtained with others.
C7 Our ideas and opinions are listened to during classroom discussions.
C8 The teacher listens to our ideas.

ITIC Scale 3 - Interpretation of Data

I1 We have to try to explain the results of our experiments.
I2 We are asked to make generalisations from data.
I3 We are asked what diagrams and graphs mean.
I4 We are asked to predict the results of experiments.
I5 We use information from our experiments to predict what will happen in a different situation.
I6 We are asked to justify our conclusions (to say why we think what we do).
I7 We are asked how we could improve the experiments we have done.
I8 We are asked to form our own hypotheses.

ITIC Scale 4 - Science Stories

S1 We learn about scientists.
S2 The names of scientists are mentioned during lessons.
S3 We learn about the history of science.
S4 The teacher tells us stories about science.
S5 As we study different topics we talk about the history of how science ideas have developed.
S6 When we study a topic we are told about the trouble which scientists have had working in this area.
S7 We are told personal information about what scientists were like.
S8 We look at what people who are working as scientists do.

ITIC Scale 5 - Uncertainty in Science

U1 We learn that science *cannot* provide perfect answers to problems.
U2 We learn that science has changed over time.
U3 We learn that people can have different theories to explain the same thing.
U4 We learn that science is influenced by people's values, opinion and beliefs.
U5 We learn that science is about coming up with ideas.
U6 Scientific knowledge is presented as being incomplete - there are things that are still not understood.
U7 We learn that scientific information can change.
U8 Our teacher questions some scientific theories.

The scale titled Assessment was not found to be valid, and is therefore omitted from the final version of the ITIC presented here. On this basis, inquiry teaching in science classes is defined as teaching that is characterised by the behaviours indicated by the 40 ITIC items shown in Table 11.0. Item F5 is a reverse score item, so the presence of this type of behaviour is indicative of an absence of inquiry teaching.

The development and validation of the ITIC instrument meets Research Objectives 1-3 of this study, as it:

- is a description of what constitutes inquiry teaching and learning
- has been found to be a valid and reliable instrument for measuring the extent to which students and teachers both perceive there to be, and would prefer there to be, an inquiry-based approach in use in their science classes.

11.2 INQUIRY TEACHING IN TASMANIAN SCIENCE CLASSROOMS

The ITIC was administered to a group of 2,207 Tasmanian students from 122 science classes in 16 Tasmanian schools, ranging from Grades 7 through to 12. It was also administered to a group of 65 teachers from 15 different schools. As reported in earlier chapters, respondents rated each questionnaire item on a scale of 1 to 5.

Over the five ITIC scales the mean actual scores for the students varied from 2.41 to 3.37 and for teachers from 2.54 to 3.89. Chapters 6 and 7 presented this information in detail. These values acknowledge that inquiry teaching is occurring in Tasmanian science classes. Statistical comparison of the teacher and student mean scores on each of the ITIC Actual Form scales indicated that teachers perceived there to be significantly more inquiry occurring than did students on the Communication scale. There were no statistically significant differences in the perceptions of the two groups on the Freedom in Practical Work, Interpretation of Data, Science Stories and Uncertainty in Science scales. Therefore, the ITIC appears to be useful for measuring the extent to which inquiry methodologies are actually being employed in science classes, as it reflects teacher and student perceptions similarly.

When the mean teacher and student preferred scores were examined, student mean preferred scores were seen to range from 2.96 to 3.73 across the five ITIC scales and teacher preferred scores from 3.42 to 4.47. Given that these values were assigned on a scale of 1 to 5, they can be regarded as implying that both teachers and students favour relatively high levels of inquiry, indicating that inquiry methodologies are valued in Tasmanian science classes. Teachers would prefer there to be more inquiry than would students across all scales. When the means scores for the two groups were examined statistically, there were found to be significant differences between the preferred scores of the two groups on the Communication, Interpretation of Data and Uncertainty in Science scales. In all cases, teachers indicated that they would prefer higher levels of inquiry than did students.

In addition to examining the overall means scores of the teacher and student groups, various sub-groups within these main groups were examined. Consequently, the ITIC has provided data about:

- similarities and differences in the perceptions and preferences of male and female students and male and female teachers

- similarities and differences in perceptions and preferences between students in different grade levels

- similarities and differences in perceptions and preferences between students in different college science subjects

- similarities and differences in perceptions and preferences between high school students with different predicted Grade 10 achievement levels

- similarities and differences in perceptions and preferences between high school and college teachers

- the influence of inquiry methodologies on student and teacher attitude towards science.

All of these factors have been discussed in more detail in earlier chapters.

The data summarised here meet Research Objective 4 and 5 of this study, by providing an assessment of the extent to which inquiry methodologies are used in Tasmanian science classes, and also of the extent to which both teachers and students would prefer them to be used.

11.3 INQUIRY TEACHING IN THE TASMANIAN SYLLABUS DOCUMENTS

The examination of the Tasmanian science syllabus documents carried out in Chapters 8, 9 and 10 showed that the use of inquiry teaching methodologies, as defined by the ITIC scales, is implied in virtually all of the syllabus documents considered. Some of the documents examined specifically included the term inquiry, but did not define the types of behaviours and strategies that inquiry implied. Other documents did not mention the term inquiry, but suggested the inclusion of many of the behaviours and strategies indicated by the ITIC scales. The various groups of documents examined are considered in the sections below.

11.3.1 College Syllabus Documents in Use When the ITIC Was Administered

Chapter 8 examined the syllabus documents which were in use at the time that teachers and students completed the ITIC. Each of the college science syllabus documents, Biology, Chemistry, Physical Sciences and Physics, contained a number of references to inquiry teaching methodologies, as defined by the ITIC. These are summarised in Table 8.2.

The Physical Sciences documents contained approximately twice as many references as did the others. This may have been because the Physical Sciences syllabus writers visualised this syllabus as being more inquiry based than the other syllabuses, or it may have been that inquiry represented more of a new approach in this subject, prompting the syllabus writers to specify the types of methodologies that they deemed desirable in some detail.

The Biology syllabus actually specified that an inquiry approach should be used, but did not spell out in the syllabus documents what this entailed. It may have been that the syllabus writers for Biology presumed that teachers would be able to interpret the types of behaviours that the term inquiry indicated, as the Grade 11/12 Biology syllabus has long been regarded as being an inquiry-based or discovery course. This perception probably stems from the use of the *BSCS Web of Life* texts and support materials in Tasmanian Biology classes from around the 1960s. As acknowledged earlier, these texts were rather innovative in the manner in which they presented materials to students. Consequently, their use gave Biology the reputation of being an inquiry-based subject. This perception persisted amongst teachers through a number of syllabus revisions and changes, although the data gathered by the ITIC suggests that this perception may need to be revisited.

The ITIC scale that the college syllabus documents made the most connections to was Interpretation of Data. This is perhaps not surprising as this scale could be regarded as the one that contains items most commonly associated with science courses. In the case of the Freedom in Practical Work and Communication scales, if the number of definite and tentative references to ITIC inquiry behaviours are combined, there can be seen to be a number of references to these types of inquiry behaviours for each of the college science subjects.

The ITIC Science Stories scale received relatively few mentions in the syllabus documents, except in the case of Physical Sciences, where it received 18, the highest number received by any scales in any subject. A similar situation exists for the Uncertainty in Science scale, with there being far more references to these items for Physical Sciences.

In summary, the college science syllabuses documents were found to support the use of inquiry teaching methodologies, as defined by the ITIC. The Physical Sciences syllabus document offered the strongest support, but as noted this may be an artefact of the amount of explanation provided by this syllabus document rather than a true reflection that the Physical Sciences syllabus was intended to contain more inquiry than the other college syllabuses.

11.3.2 Grade 9/10 Syllabus Documents in Use When the ITIC was Administered

References to inquiry methodologies in the Grade 9/10 syllabuses in use at the time that the ITIC was administered were discussed in Section 8.1 of this thesis. It was found that the syllabus documents made links to most of the items contained in the five ITIC scales.

These links were least explicit in the case of the Science Stories scale, where most of the links were implied rather than explicit, and where it was necessary to refer back to the national statement document - referenced in the Grade 9/10 syllabus - to draw some of these links.

The ITIC Freedom in Practical Work, Communication and Interpretation of Data scales all showed links with at least two of the 9/10 assessment criteria, as well as with other parts of the syllabus documents. Links to the Uncertainty in Science scale were only reflected in one of the assessment criteria.

Overall, the Grade 9/10 syllabus documents were found to support the use of inquiry teaching methodologies, as defined by the ITIC scales, in teaching Grade 9 and 10 Science in Tasmania.

11.3.3 New Tasmanian College Science Syllabus Documents

The six college science syllabus documents that came into use from 2004 onwards were considered in detail in Chapter 9. Consideration of the generic components of these documents indicated that there were a number of connections to the Freedom in Practical work, Communication, Interpretation of Data and Uncertainty in Science scales of the ITIC. The generic documents contained no explicit references to the Science Stories scale.

In addition to the links to ITIC scales indicated by generic syllabus documents, there are links via the six common assessment criteria that exist for the college science subjects, and also through subject specific documentation. The number of connections to ITIC inquiry methodologies that existed for each syllabus are summarised in Table 9.26.

The Freedom in Practical Work scale shows links to all the college science syllabus documents, through common assessment criteria numbers 1 and 3 in particular.

The Communication scale shows links to all the college science syllabus documents, through common assessment criterion number 6. Additionally, the Environmental Science and Science of Natural Resources documents imply substantial additional links.

The Interpretation of Data scale shows connections to all the college science syllabus documents through common assessment criteria 1, 4 and 6, as well as through subject specific criteria. It is the scale which shows the most links to the various syllabus documents.

The Science Stories scale shows links to the college science syllabus documents through common assessment criterion 6. Only the Science of Natural Resources syllabus documents make any other real links to this scale, although the potential for more use of behaviours from this scale exists.

The Uncertainty in Science scale shows links to the college science syllabus documents through common assessment criterion 6.

Overall, the ITIC can be seen to be of considerable relevance to the six college science syllabuses. As such it would be a useful instrument for teachers to employ to investigate their classroom behaviours.

11.3.4 New Tasmanian K-10 Syllabus Documents - The *Essential Learnings*

The *Essential Learnings* syllabus documents that came into use in Tasmanian schools from 2005 onwards were considered in detail in Chapter 10. This consideration indicated that the *Essential Learnings* documents show numerous connections to the inquiry methodologies defined by the ITIC. These connections were summarised in Table 10.19, and further examined in Table 10.20, which shows the number of items from each ITIC scale that make connections to each Essential Learning.

Items from the Interpretation of Data, Uncertainty in Science and Communication scales showed connections to all five Essential Learnings. Items from the Freedom in Practical Work scale connected largely to the Thinking and World Futures Essential Learnings. The Science Stories scale showed the least number of connections to the Essential Learnings, although the reference that the World Futures Essential Learning makes to the history of scientific thought means that all items from the Science Stories scale are relevant to this Essential Learning.

Overall, the ITIC was found to be of considerable relevance to the Essential Learnings curriculum, in particular to the World Futures, Thinking and Communication Essential Learnings. Therefore, the ITIC would be a useful instrument for teachers to employ to assess the extent to which their classrooms are providing the types of inquiry behaviours indicated.

11.3.5 Summary of Tasmanian Curriculum Links

The examination of the various Tasmanian curriculum documents indicated that the inquiry methodologies defined by the ITIC were valued by the syllabus documents in use at the time that the ITIC was administered, and also by the current syllabus documents for both high school and college students.

This examination of the syllabus documents meets research objective 6 of this study, by providing an analysis of the extent to which Tasmanian syllabus documents either indicate or dictate the use of an inquiry-based approach, with the extent to which an inquiry approach is indicated being measured by the number of connections that the syllabus documents make to each ITIC scale.

11.4 CLASSROOM REALITY COMPARED TO SYLLABUS INTENT

This section will examine whether the extent to which inquiry methodologies, as defined by the ITIC, were actually employed in Tasmanian science classrooms at the time that the ITIC was administered was in line with the intent of the then Tasmanian syllabus documents.

11.4.1 Inquiry in the College Science Subjects

On the basis of the data contained in Table 8.2, which shows the number of connections that were made to items from the ITIC scales by each of the college syllabus documents, the Physical Sciences syllabus documents can be seen to contain by far the most connections to inquiry methodologies (62), followed by Biology (37) and then Chemistry and Physics with approximately equal numbers (25 and 24). Table 11.2 considers the number of connections on a scale by scale basis, showing which syllabus documents indicated the most inquiry. Connections that were listed as tentative in Table 8.2 are included in Table 11.2. It should be noted that in some instances the difference in the number of connections that different subjects show are negligible. The numbers in brackets indicate the number of connections that the syllabus documents for the subject in question made to the ITIC scale under consideration.

Table 11.2

Relative Amounts of Inquiry in the College Science Subjects, as Indicated by the Syllabus Documents.

	Freedom in Practical Work	Communication	Interpretation of Data	Science Stories	Uncertainty in Science
Most inquiry	Biology (10)	Biology/ Physical Sciences (7)	Physical Sciences (16)	Physical Sciences (18)	Physical Sciences (13)
↓	Physics/ Physical Sciences (8)	Physics (5)	Biology (15)	Chemistry (3)	Biology/ Chemistry (2)
	Chemistry (6)	Chemistry (4)	Chemistry (10)	Physics (2)	Physics (1)
Least inquiry			Physics (8)	Biology (1)	

The data have been presented in this manner in order to facilitate comparing it with the amount of inquiry that students perceived to be actually occurring in their college science classes, as described in Chapter 6. The amount of inquiry perceived by students will be taken as an indication of the amount of inquiry that was actually occurring in each of the college science subjects. It is not possible to consider the teacher data in a similar way, as there were too few teachers to divide them up according to the subject/s that they taught.

Table 11.3 shows which of the college science subjects students perceived that the greatest amount of inquiry behaviours, as defined by the ITIC Freedom in Practical Work, Communication and Science Stories scales, were occurring in. There were no statistically significant differences between college science subjects, with respect to the levels of inquiry behaviours that students perceived, on the Interpretation of Data and Uncertainty in Science scales, so these are not included in Table 11.3. Table 11.3 does not indicate which subjects there were significant differences between, but this information is given in Chapter 6, in the discussion of Table 6.16.

Table 11.3

Relative Amounts of Inquiry in the College Science Subjects, as Perceived by Students.

	Freedom in Practical Work	Communication	Science Stories
Most inquiry	Physics	Chemistry	Physics
↓	Chemistry	Physics	Chemistry
	Physical Sciences	Physical Sciences	Physical Sciences
Least inquiry	Biology	Biology	Biology

Table 11.3 shows that although Physical Sciences had by far the most inquiry indicated in the syllabus documents, this did not translate into what students perceived to actually be occurring in their classrooms, as whilst the Physical Sciences syllabus documents showed the most connections to inquiry methodologies, Physical Sciences ranked third on each of the three inquiry scales where significant differences existed between college science subjects. Table 11.2 shows that in the case of the Interpretation of Data scale, the Physical Sciences syllabus documents indicated that Physical Sciences would be expected to have a similar amount of inquiry to Biology and more than Chemistry or Physics. The fact that analysis of the student data showed that there was no significant difference in the amount of inquiry that students perceived to actually be occurring between the college science subjects on this scale indicates that the expectations set by the syllabus documents were not being met. The same is true for the Uncertainty in Science scale. Therefore, overall, Physical Sciences classrooms are not showing higher levels of inquiry than those of the other college science subjects.

As noted in Chapter 8, the Biology syllabus documents actually stated that an inquiry approach should be used. However, on the basis of the data in Table 11.3 it is the subject where students perceived there to be the least amount of inquiry occurring, based on the three scales where there were significant differences between the subjects.

Hence, what was actually occurring in college science classes at the time that the ITIC was administered does not appear to be in line with what the then syllabus documents were advocating. Whilst it is not possible to give an exact measure of how much inquiry the syllabus documents indicated, it can be seen that in a relative sense the subjects whose documents specified the greatest amount of inquiry did not have the greatest amount of inquiry occurring in the classroom.

A possible explanation for Physics and Chemistry classes actually having the highest amount of inquiry, at least as perceived by students, is that Chemistry and Physics classes are largely composed of Grade 12 students. This has two major implications which may be of importance here. The first is that teachers would see these students as being more experienced in the laboratory situation and may hence allow them more freedom - in both practical work and other areas. Secondly, teachers are more likely to know the students and the students to know each other - remembering that the nature of Grade 11/12 college education in Tasmania means that students change schools at the end of Grade 10, so that Grade 11 classes are largely composed of students who do not know each other. This is likely to lead to both teachers and student being more comfortable with the types of behaviours specified by the Communication scale, and so both programming and engaging in more of them.

A limitation of this data is that it was not the same group of students commenting on each subject, although a number of students would have been studying more than one college science subject. A possible further limitation is that variation in the length and depth of the syllabus documents for the different college science subjects may have impacted on the amount of inquiry that they were judged to show. However, as these are the only documents that were available to teachers it was considered valid to examine them in the manner outlined.

As indicated earlier, it was not possible to analyse the teacher data in the same way as the student data, as there were not sufficient teacher responses.

11.4.2 Inquiry in the High School Science Classes

The inclusion of inquiry methodologies in the Grade 9/10 science syllabus documents was considered in section 8.1. The analysis conducted in this section showed that there were clear connections between the syllabus documentation and each of the ITIC scales, with each ITIC scale being relevant to at least one assessment criterion. More specifically, the Communication scale connected to three assessment criteria, the Freedom in Practical Work and Interpretation of Data scales to two and the Science Stories and Uncertainty in Science scales to one criterion each. This indicates that inquiry methodologies were valued by the Grade 9/10 syllabus documents.

The classroom reality of the extent to which inquiry methodologies were incorporated into Grade 9/10 science classes can be gauged from student perceptions of their actual classroom environment, as shown in Table 6.14 and teacher perceptions of their actual classroom environment, as shown in Table 7.7. In the case of the student data, Grade 9/10 students have been separated out from the other grades. However, it was not feasible to separate out teachers of Grade 9/10 classes in the same manner, as the overall number of teachers was not high enough.

Examination of the student data shows that the mean response for the level of inquiry that is occurring in science classes ranges from 2.16 for Science Stories in Grade 9 to 3.29 for Interpretation of Data in Grade 10. Examination of the teacher data shows that mean response for the level of inquiry that is occurring in science classes ranges from 2.57 for Freedom in Practical Work to 3.59 for Communication.

On the basis of this data, it is not possible to make a definitive statement as to whether or not the amount of inquiry that is occurring in Grade 9/10 science classes is in line with the stated intent of the syllabus documents. However, it is possible to say that the syllabus documents indicate that inquiry should be occurring.

11.4.3 Teacher and Student Preferred Environments

As the ITC questionnaire asked respondents to assess both their actual and preferred classroom environments, this data can be used to comment on whether the amount of inquiry that is occurring in classrooms is in line with student and teacher preferences.

Table 7.5 shows that teacher preferred scores were significantly higher than actual scores across all ITIC scales. Table 7.7 shows that there were significant differences between the actual classroom environments of college and high school teachers, but that there were no significant differences in their preferred environments. These data indicate that teachers did not perceive their classrooms as being as inquiry based as they would have preferred them to be. This seems to have been particularly the case for high school teachers, as Table 7.7 shows that there was significantly more inquiry occurring in college science classes than in high school ones.

Table 6.2 shows that there were significant differences between students' actual and preferred classroom environments on four of the ITIC scales. Examining different subgroups within the student population showed that these differences were largely perpetuated. This has been considered in greater detail in Chapter 6. Overall, it can be said that science classes at both the high school and college level were not as inquiry based as students would have liked them to be.

11.4.4 Summary of Classroom Reality

The above consideration of whether or not the extent to which inquiry methodologies were actually being used in Tasmanian high school and college science classes was in line with the appropriate syllabus documentation, the beliefs of teachers and the preferences of students meets research objective 7 of the current study.

In summary, both teachers and students would prefer that there were more inquiry behaviours in their science classes. Both the syllabus documents that were in use at the time that the ITIC was administered and the current syllabus documents, which were examined in Chapters 9 and 10, support the use of inquiry methodologies. Whilst it is difficult to quantify whether or not the amount of inquiry that is occurring is in line with the curriculum documents, it is possible to state that these documents support the use of inquiry methodologies, and that both students and teachers believe that there should be more inquiry occurring in science classes than was the case at the time of this study.

11.5 SIGNIFICANCE OF AND RECOMMENDATIONS FROM THE ITIC RESEARCH

The research presented in this thesis indicates that it is desirable to use inquiry methodologies, as defined by the ITIC, in Tasmanian science classes. It would be desirable for there to be higher levels of inquiry methodologies in science classes than currently exist. This conclusion is drawn on the basis of the following findings:

- Students expressed a preference to experience significantly more inquiry methodologies, as defined by the ITIC Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science scales, in their science classes.

- Teachers expressed a preference for their science classes to experience significantly more inquiry methodologies as defined by all five ITIC scales.

- The correlations between both student attitude and teacher attitude and the ITIC scales showed that there was a significant correlation between the extent to which inquiry methodologies were used in science classes and both student and teacher attitude.

- The correlations between the ITIC scales and predicted student achievement level at Grade 10 showed that there was a significant correlation between the extent to which inquiry methodologies were used in science classes and predicted student achievement levels at the end of Grade 10.

- The science syllabus documents which are currently being used in Tasmania show extensive connections to ITIC methodologies, at both high school and college level.

When sub-sets of the student population were examined in further detail, the preference for significantly greater levels of inquiry, as defined by the Freedom in Practical Work, Communication, Science Stories and Uncertainty in Science scales, in their science classes held for males, females, Grade 7, Grade 8, Grade 9, Grade 10, Physical Sciences, Biology, and Chemistry students. Physics student preferences were similar to the groups mentioned, with the exception that they did not wish to experience significantly more Science Stories type activities. Grade 7 and 8 students expressed an additional preference, that there be significantly more inquiry methodologies as defined by the Interpretation of Data scale. Possible reasons for these preferences have been discussed in more detail in Chapter 6.

In light of the identified desirability of increasing the extent to which inquiry methodologies are used in science classes, the ITIC can be seen as a potentially useful instrument for achieving this aim. Its usefulness stems from two possible uses:

1. as a checklist for teachers to identify the type of methodologies that they should be aiming to implement or extend in their science classes

2. as a monitoring instrument to assess the extent to which inquiry methodologies are being used in science classes.

As the ITIC was formulated by distilling what the science education literature identified as inquiry methodologies, the items of the ITIC can be taken as describing inquiry in science classes. Therefore, by ensuring that they provide students with opportunities to experience the types of activities described by the ITIC items, teachers can move toward a more inquiry based science class.

The data that have been collected and presented in this thesis is baseline data that could be used as a comparison for future studies. As the syllabus documents for both high school and college science courses in Tasmania changed shortly after the ITIC was administered, the data that has been collected will be useful in analysing any impact that the syllabus changes have had on inquiry methodologies. This is a fortuitous situation, as no deliberate attempt has been made by the implementing bodies to collect data that any potential change could be measured against. Consequently, the ITIC data is likely to be valuable to future researchers. This is likely to be of particular interest, as Tasmania is now using its *Essential Learnings* curriculum up to the end of Grade 10 and various persons are making claims for and against the perceived effectiveness of this curriculum.

If individual schools or teachers did not wish to use the baseline data provided by the current study, but to assess the extent to which deliberate change affects the level of inquiry in their science classes, they could use the ITIC to collect their own baseline data and then readminister the ITIC a specified amount of time later - after there had been time for the changes that they implemented to take effect.

In the case of any future changes to either high school or college syllabuses, the ITIC could be administered before and after the changes in order to assess the impact of the change on levels of inquiry.

One reason, which has been alluded to earlier, for teachers, schools or education systems to be concerned about the levels of inquiry that are occurring in science classes is that fewer students seem to be choosing to enter science related careers. As this is becoming a matter of national and international concern, any change which increases the likelihood of students being engaged by science is worth considering. Given that the analysis of the ITIC data showed that the use of inquiry methodologies had a significant positive effect on student attitude, it would seem sensible to aim to increase the use of inquiry methodologies in science classes.

Apart from increasing the overall amount of inquiry methodologies, as defined by the ITIC scales, in science classes, the current study also identified a number of other desirable changes. These changes have been discussed in earlier chapters, but in brief include:

- providing male students with more opportunities for freedom in the practical work that they undertake, than female students are provided with, as although both males and females wanted more freedom in the practical work that they undertook, males wanted higher levels

- providing female students with more opportunities to engage in communication related activities, as, again, although both male and female students wanted higher levels of communication, females wanted significantly higher levels than males
- providing Grade 7 and 8 students with increased opportunities to participate in Interpretation of Data activities
- providing female students with similar levels of Science Stories activities to male students.

The analysis of the *Essential Learnings* curriculum documents undertaken in Chapter 10 indicated that all ITIC scales were relevant to this curriculum, but that the documents made fewest connections to the Science Stories scale. The analysis of the college science syllabuses undertaken in Chapter 9 showed a similar situation. Therefore, it seems that Science Stories related activities are ones that might easily be overlooked in developing and delivering materials for science classes. Hence, if teachers consider that exposure to historical perspectives and what scientists do is important they may need to make a conscious effort to incorporate such materials into their science courses.

11.6 RESEARCH LIMITATIONS OF THE ITIC STUDY

As with any study of this nature the data presented here have limitations, many of which were beyond the control of the researcher. These limitations have largely been commented on in earlier sections of this thesis, and include issues relating to sample size and to the administration and validation of the questionnaire.

The size of two of the sample populations, the teacher population and the population of Grade 10 students, should be noted as limiting the interpretation of data gathered in this study to some extent. The size of the teacher population (65 teachers) completing the questionnaire was relatively small as compared to the student population (2,207 students). Limitations that arise from the relatively small size of the teacher population are, firstly, that the results are less likely to be representative of the teaching population as a whole, and, secondly, that the statistical comparisons with the student population must be interpreted with caution. The smaller number of Grade 10 students completing the questionnaire, as compared to other high school grade levels also means that the data for this grade group may not be as representative of the population of Grade 10 students as a whole as would be desired. However, the results obtained do not seem to indicate that the data obtained for this grade group is anomalous.

Limitations that relate to the administration of the questionnaire include the questionnaire not being administered by the researcher, low student literacy levels and item interpretation. The fact that the questionnaire was administered to classes by their science teachers rather than by the researcher meant that the instructions and amount of assistance given to different classes may have varied. However, as the intent of the questionnaire was to ascertain students' opinions about their classroom environment rather than to test their critical literacy skills it is unlikely that this would have had an adverse effect on the results obtained. The low literacy level of some students is a limitation in the administration of the questionnaire, as low literacy may have prevented them from interpreting items and giving the response that most closely matched their opinion. A number of questionnaires were discarded during data entry, and it is likely that a number of these belonged to students with low literacy levels. A limitation that this places on the data is that the opinions of low ability students may be under represented.

Item interpretation must always be regarded as a potentially limiting factor in a study such as this, as if respondents do not interpret items in the way that the researcher intended the responses will not give the information that the researcher was seeking. Observations during the administration of the preliminary questionnaire did not indicate that any particular items appeared to cause a great enough problem with interpretation to warrant removing them. However, before using the ITIC in a different cultural context it would be desirable to trial it with at least a small group of teachers and students in case there are any items whose meaning does not transfer easily. A particular example may be in the case of Scale 1, Assessment in Practical Work. Whilst the term 'practical work' is the one commonly used in Tasmania, literature from the U.S. indicates that the term 'laboratory work' is more common there.

Perhaps the greatest problem in the development of the ITIC as an instrument to measure the extent to which inquiry methodologies are used in science classes was that although the type of assessment used was identified as an inquiry characteristic in the survey of the science education literature, this study did not successfully develop and validate an assessment scale.

Despite these potential limitations, the ITIC seems to have delivered useful data which can be used both as the basis of further research and to assist teachers in identifying changes that they may wish to make to their science teaching.

11.7 FUTURE RESEARCH DIRECTIONS

The first and most obvious direction for future research to emerge from this study is the need to develop and validate a scale that measures the extent to which assessment activities in science classes are inquiry based. The current study attempted to develop such a scale, but it was not found to be a valid and reliable scale in the preliminary questionnaire. Despite the scale undergoing a considerable amount of modification it was still not found to be valid and reliable when incorporated as part of the final questionnaire. As the need for an Assessment scale was identified through analysis of the available literature, it is highly desirable that a valid Assessment scale is developed.

With respect to the Tasmanian context, this study has shown that the ITIC is relevant to the *Essential Learnings* curriculum that has just been implemented in that state. As this new curriculum is based on five Essential Learnings rather than traditional subject areas but has a heavy emphasis on inquiry, it would be valuable to modify the ITIC for use in Tasmanian classrooms, with both science and non-science classes. This could often be achieved by replacing specific references to science classes with more generic qualifiers.

The ITIC is a potentially valuable tool for use in science teacher professional learning sessions. Examining the nature of the ITIC items would allow teachers to develop a better idea of what is meant by the term inquiry. Once they had clarified their understanding of the requirements of inquiry teaching, teachers could set out to deliberately modify aspects of the pedagogies that they use, in order to achieve a more inquiry based science class. They could monitor the success of the changes that they made by administering the ITIC to their classes both before and after they made changes to their teaching methodologies.

The time at which the ITIC was administered to Tasmanian science classes was a somewhat fortuitous one, as it coincided with a period when new curriculum documents were being introduced, both in high schools and colleges. Consequently, the data collected in the current study serves as baseline data against which the impact of the new curriculum documents can be measured. In order to monitor any changes that occur with regard to the amount of inquiry teaching that is occurring in Tasmanian science classes (or potentially in a wider group of classes), the ITIC should be administered to a representative group of Tasmanian science classes at intervals following the introduction of the new curriculum. Every two years would seem to be a realistic period of time for the ITIC to be administered.

In any future large scale administration of the ITIC, consideration should be given to improving its format by removing all reverse score items, and adopting a process where the scales are rotated, so that every student does not complete the items in the same order, in a similar manner to that in which electoral parties are rotated on Australian electoral papers. This would have the benefit of avoiding a fatigue factor where respondents are less conscientious about their responses to later items.

The current research study could be taken further by conducting teacher and student interviews which ask individuals from both groups why they prefer an inquiry based approach - which the data collected in this study indicate to be the case. This may give unexpected insights into factors that encourage or deter students from pursuing their science studies. In the case of teachers, it would be valuable to ask individuals why, given that they have expressed a preference for more inquiry to occur in their science classes, they do not attempt to make this a reality themselves. It is possible that there are systemic factors which need to be addressed to allow greater amounts of inquiry teaching to occur. In addition, interviews may assist in shedding more light on some of the findings of the student questionnaire, including:

- why female students perceived there to be significantly less inquiry learning experiences relating to the Science Stories scale than did male students
- what the factors are that inhibit teachers from using Interpretation of Data activities to a greater extent with Grade 7 students, and what strategies teachers need to be encouraged to use so that Grade 7 students experience more of these
- why Physics students do not want to experience more Science Stories type activities - is it because they feel there is already an adequate amount, or because they do not enjoy them
- whether Biology teachers are aware that, on the basis of student perceptions, Biology may now be regarded as being less inquiry based than the other college science subjects, and whether they perceive this to be problematic
- why lower ability students do not want to experience as high a level of Uncertainty in Science behaviours, and if strategies can be found to overcome this tendency.

The current study could also be extended by adding a qualitative component. This could involve classroom observation sessions, in which an observer records the frequency with which the behaviours listed in the ITIC occur.

11.8 WHY ENCOURAGE THE USE OF THE ITIC?

It is interesting to note that the review of the literature presented in Chapter 2 of this thesis identified the threat of declining U.S. world leadership in the area of science as the impetus for the development of numerous inquiry based science education resources in the 1960s, and that as the current study concludes the identification of school science education as a factor contributing to future economic problems in the U.S. has arisen yet again. This was seen in the release of a February 2005 report issued by the U.S. Business-Higher Education Forum (BHEF), titled *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education*.

This report (Business-Higher Education Forum, 2005) maintained that if America was to sustain its international competitiveness, its national security, and the quality of life for its citizens, then it must move quickly to achieve significant improvements in the participation of all students in mathematics and science. It urged all business, education and policy leaders to come together all across the country during the next five years, to ensure that current and future generations acquire the core mathematics and science skills needed to achieve success in the new century, adding that America cannot afford to lose ground in preparing all students in these key areas.

The report commented that America has failed to comprehend that in the highly competitive global economy of the 21st century mathematics and science are no longer pursuits for the few, but requirements for *all*. Again, this is not new ground - as noted in Chapter 2, Schwab, Dewey and Armstrong were of the same opinion. The report also commented that other countries have not only noted, but have acted on this fact.

A noteworthy comment from the report is the idea that skill in integrating ideas is needed, in addition to (not in place of) discipline-specific expertise, and that the current secondary school, and indeed college, curriculum compartmentalises science concepts into courses such as Biology A or Algebra II, so working against an understanding of the connections within or between the broader fields of science and mathematics. The use of inquiry methodologies seems to be a mechanism that would help to promote such connections.

The BHEF report acknowledged that the national and personal economic security crises attributed to American students' inadequate performance and flagging interest in mathematics and science have been widely reported for decades, and that during the last four years a number of reports have been published that address the urgent need to improve mathematics and science education in the United States, and that initiatives were undertaken to try to solve the problem - but considered that these have served to provide information about what does not work rather than solving the problem.

Whilst the report did not recommend particular pedagogies, inquiry or otherwise, its existence indicates that debate over the most appropriate manner for teaching school science continues. The report did recommend the provision of experiences designed to increase student understanding of, and interest in, mathematics and science, and stated that these experiences should include laboratory-based investigations; extended problem-solving activities that promote understanding of key concepts and their application in the real world; the use of technology tools in doing mathematics and science; and introduction to mathematics and science related careers. In discussing assessment, the report recommended that in addition to test results, performance in portfolios of work on extended tasks and written and oral presentation of research should be considered. Therefore, the BHEF report seems to be supporting the use of the type of inquiry methodologies that the ITIC measures. Consequently, the ITIC can be viewed as a useful tool for groups interested in implementing the type of changes that the BHEF report calls for.

A still more recent report was prepared for the U.S. Congress in response to the questions:

> What are the top ten actions, in priority order, that federal policy makers could take to enhance the science and technology enterprise so the United States can successfully compete, prosper, and be secure in the global community of the 21st Century? What implementation strategy, with several concrete steps, could be used to implement each of those actions? (Committee on Science, Engineering, and Public Policy, p. 1).

It identified as one of its four recommendations, to

> increase America's talent pool by vastly improving K-12 mathematics and science education (Committee on Science, Engineering, and Public Policy, p. 3).

The actions identified to make this a reality were to recruit 10,000 new teachers, strengthen 250,000 teachers' skills and to *enlarge the pipeline*, which referred to creating opportunities and incentives for middle and high school students to pursue advanced work in science and mathematics. The report also identified two approaches that were already in use and which should be expanded. These were statewide specialty high schools and inquiry-based learning. In relationship to inquiry-based learning, the report recommended that laboratory experience should be available to all students and that summer internships and research opportunities should be expanded to serve at least 2000 middle school and high school students each year. It also commented that experiences designed to stimulate low-income and minority student participation should be particularly encouraged. This report would seem to indicate the inquiry methodologies that the ITIC reports on are seen as valuable in the current world climate.

In the Australian context, inquiry ideas and methodologies are contained in the curriculum documents that have been developed in all states and territories. A common theme amongst these documents seems to be that they have been formulated in response to the fact that twenty first century workers live in a time of rapid technological change, significant changes in society and changed local and global economic structures. Students attending school now will need to be lifelong learners, have the ability to problem solve, to occupy different positions and to work in teams. These are qualities that the inquiry teaching methodologies measured by the ITIC value seem to promote.

In the Tasmanian context, where the current study was based, the use of inquiry teaching methodologies has been shown to be relevant to the teaching of science and, in fact, to the broader curriculum, particularly sitting within the Thinking Essential Learning. Whilst it is beyond the scope of this thesis to consider the curriculum documents for the other Australian states in the same manner that the Tasmanian ones were considered, it is worth pointing out some key features which seem to imply that inquiry methodologies are valued within the various curricula.

In the Australian Capital Territory (ACT), the new curriculum, to be implemented from 2008, is outlined in the document *Every Chance to Learn Future Directions in ACT Curriculum Renewal (ACT Australian Capital Territory Department of Education and Training, 2005).* The curriculum contains 36 Essential Learning

Achievements, a number of which show close links to the type of inquiry methodologies measured by the ITIC. These include:

- the student applies methods of inquiry
- the student makes considered decisions
- the student uses problem solving strategies
- the student recognises patterns and draws out generalisations
- the student makes plans and carries them out
- the student applies scientific understandings
- the student understands change.

The extended descriptions for each of these Essential Learning Achievements make the links clearer.

Whilst the New South Wales curriculum documents remain more traditional than those of the other states and territories of Australia, the curriculum description for 7-10 Science show that ITIC inquiry methodologies are valued. Under the heading *What will students learn?* the Science document states:

> Students work individually and in teams in planning and conducting investigations. They evaluate issues and problems, identify questions for inquiry and draw evidenced-based conclusions from their investigations. Through this problem-solving process they develop their critical thinking skills and creativity. They are provided with experiences in making informed decisions about the environment, the natural and technological world and in communicating their understanding and viewpoints. (New South Wales, Board of Studies, 2004, p. 30)

The *Course Requirements* section adds that practical experiences which emphasise hands-on activities will occupy a substantial amount of time. Therefore, the ITIC must be seen as being relevant to the New South Wales context.

The Northern Territory Curriculum Framework contains what are termed *EsseNTial Learnings*, which are central to all teaching and learning. These EsseNTial

Learnings are developmentally mapped to achieve culminating outcomes. The outcomes are developed through the content of the learning areas, of which Science is one. Examination of the Working Scientifically strand of the Science learning area, in particular, shows marked connections to ITIC methodologies. The Northern Territory Curriculum Framework document gives the following description of this strand:

> Working Scientifically is an effective way to generate understanding, test ideas and creatively solve problems. This strand has five elements:
>
> - Planning - learners plan to test ideas about the natural and technological world.
> - Investigating - learners collect and record a variety of information relevant to their investigation, translate and analyse the information to find patterns and draw conclusions to share and extend their investigations.
> - Evaluating - learners reflect on their investigations, evaluate the process and generate further ideas.
> - Acting Responsibly - learners make decisions and take responsible action in their society.
> - Science in Society - learners examine and use the relationship between the nature and direction of science and society's perspectives and values. (Northern Territory, Department of Employment, Education and Training, n.d., p. 342).

These elements can be seen to show clear connections to ITIC inquiry methodologies.

Queensland is in the process of developing the Queensland Curriculum, Assessment and Reporting Framework for P-10 students (Queensland, Department of Education and the Arts, 2005). Whilst the framework has yet to be developed, a preliminary paper notes that the essential learnings will encompass knowledge, skills and attributes that are:

- specific to content areas such as English, maths, and science

- required for complex, real-life challenges such as higher-order thinking skills, and social and personal competence
- needed for good communication and ongoing learning such as literacy, numeracy, life skills, information and communication technologies, and cultural skills.

Hence, whilst it is not possible to second guess what the framework will contain, it seems very likely that ITIC inquiry methodologies will be relevant here. An expert paper (Freebody, 2005) prepared for the Department of Education and the Arts in relation to the new curriculum noted that the desirable attributes of Queensland school students at the end of Year 10 reflect their commitments to:

- personal competence, success, security and wellbeing
- fostering an attitude of active lifelong inquiry, innovativeness and creativity
- social and cross-cultural inclusion, participation and cohesion.

The second dot point above seems to reinforce the position that ITIC inquiry methodologies will be relevant in the Queensland context.

The South Australian Curriculum, Standards and Accountability (SACSA) Framework describes curriculum Key Ideas and Outcomes upon which education from birth to Year 12 is to be built. The Curriculum Scope is organised around Learning Areas through which Essential Learnings, Equity Cross-curriculum Perspectives and Enterprise and Vocational Education are interwoven. The Essential Learnings describe the values, dispositions, skills and understandings that are considered crucial, and to which all learning areas should contribute (South Australia, Department of Education and Children's Services, n.d.). The Essential Learnings are:

- Futures - Learners develop the flexibility to respond to change, recognise connections with the past and conceive solutions for preferred futures.

- Identity - Learners develop a positive sense of self and group, accept individual and group responsibilities and respect individual and group differences.

- Interdependence - Learners develop the ability to work in harmony with others and for common purposes, within and across cultures.

- Thinking - Learners become independent and critical thinkers, with the ability to appraise information, make decisions, be innovative and devise creative solutions.
- Communication - Learners develop their abilities to communicate powerfully using literacy, numeracy and information and communication technologies.

Without examining the Science learning area documents in depth, it can be seen that these suggest connections to a number of ITIC scales - Communication, Interpretation of Data, Science Stories and Uncertainty in Science.

Victoria will implement its new curriculum framework for P-10 students, the Victorian Essential Learning Standards (VELS), in 2006. These standards are developed within three core interrelated strands:

- Physical, Personal and Social Learning.
- Discipline-based Learning.
- Interdisciplinary Learning.

The Science learning domain of the VELS is divided to two dimensions. The *Science at work* dimension seems to imply significant connections to the ITIC inquiry methodologies, with its description including:

> This dimension focuses on students experiencing and researching how people work with and through science. Students learn to be curious and to use scientific understanding and processes to find answers to their questions. They design and pursue investigations; generate, validate and critique evidence; analyse and interpret ideas and link them with existing understanding; work and reason with scientific models and communicate their findings and ideas to others. They identify and practise the underlying values, skills and attributes of science.
>
> Through their investigations, they gain insight into science as a human activity and the relationship between science, technology and society and possible futures. They explore how science is used in multiple contexts

> throughout their lives and its pervasiveness throughout the workplace. (Victorian Curriculum and Assessment Authority, 2005, p. 6-7)

This description suggests close links with ITIC methodologies.

Phase 2 of Western Australia's Curriculum Improvement Project (CIP2) has seen the development of an Outcomes and Standards Framework which is mandated in the new Curriculum, Assessment and Monitoring Policy released in 2005 (Western Australia, Department of Education and Training, 2005). Science has five learning outcomes relating to working scientifically and four to conceptual understandings. The progress map for Science contains *Investigating* as one of the five process outcomes. The Investigating outcome and all the conceptual outcomes are sequenced within eight levels in the Outcomes and Standards framework. The descriptor for the Investigating outcome states:

> Students investigate to answer questions about the natural and technological world, using reflection and analysis to prepare a plan: to collect, process and interpret data: to communicate conclusions: and to evaluate their plan, procedures and findings (Western Australia, Department of Education and Training, 2005 p. 62).

This descriptor indicates that the Western Australian curriculum documents are supportive of ITIC inquiry methodologies.

In summary, examination of contemporary Australian curriculum documents and reports published in the U.S. indicate that although at the commencement of this study some may have argued that inquiry teaching was a passé methodology, events have shown it to have stood the test of time and that the ideas and methodologies that the term encompasses can be seen in a number of Australian and international curriculum documents, albeit not necessarily under the heading of inquiry. Therefore, the use of the ITIC should be encouraged, as it measures skills that are currently valued in curriculum initiatives that are being both suggested and implemented.

11.9 THE CURRENT STUDY IN SUMMARY

The methodologies that characterise inquiry in the science education literature have been identified and categorised into six scales, Freedom in Practical Work, Communication, Assessment, Interpretation of Data, Science Stories and Uncertainty in Science. Five of these scales have been validated to give a new classroom environment instrument, the *Is This an Inquiring Classroom?* or ITIC questionnaire. This instrument can be used to give teachers a measure of how inquiry based their science classes are, and also to assist teachers to identify pedagogies that will make their classrooms more inquiry oriented.

Whilst it is likely that tensions between teaching science using an inquiry approach and teaching it by more transmissionist methods will continue, fuelled by numerous factors, this study has found that current Tasmanian curriculum documentation supports the use of the inquiry methodologies measured by the ITIC. It also found that Tasmanian teachers and students from Grades 7 through 12 were supportive of the use of inquiry methodologies, with both teachers and students expressing a preference for the inclusion of more inquiry in their science classes. Whilst this support for the use of more inquiry methodologies in their science classes tended to be consistent, regardless of which grade students were in, whether they were male or female or of their predicted achievement level, there were some differences between these sub-groups with respect to which categories of inquiry methodologies they would like to experience more frequently.

Given that the decades old propensity to blame at least some of a country's economic woes on inadequacies in the science and mathematics education of its citizens seems to be continuing into the 21st Century, the use of inquiry methodologies in science classes is an area that should be given increased attention. This is particularly so as teachers' responses to the ITIC indicated that they were supportive of the idea of there being greater amounts of inquiry methodologies in their science classes. The production of the ITIC provides an appropriate means of measuring inquiry levels, and is also an analysis of what inquiry teaching and learning in the area of science education involves.

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Appendix 1 - The initial version of the *Is this an inquiring classroom?* Questionnaire, as given to critiquing teachers. The copies given to the teachers had the actual scale names deleted.

Is This an Inquiring Classroom? Questionnaire

When you are answering this questionnaire, use the numbers to indicate these frequencies.

Almost Always	Often	Sometimes	Seldom	Almost Never
5	**4**	**3**	**2**	**1**

		ACTUAL					PREFERRED				
	Scale 1 - Open-endedness										
	In this class . . .										
1	We carry out laboratory investigations to test ideas which we come up with.	5	4	3	2	1	5	4	3	2	1
2	All students do exactly the same experiments.	5	4	3	2	1	5	4	3	2	1
3	There is opportunity for us to pursue our own science interests.	5	4	3	2	1	5	4	3	2	1
4	In our laboratory sessions, the teacher decides the best way for us to carry out the laboratory experiments.	5	4	3	2	1	5	4	3	2	1
5	We are required to design our own experiments for a given problem.	5	4	3	2	1	5	4	3	2	1
6	We are allowed to go beyond the regular laboratory exercise and do some experimenting.	5	4	3	2	1	5	4	3	2	1
7	We carry out laboratory investigations to answer questions which arise in class discussions.	5	4	3	2	1	5	4	3	2	1
8	In laboratory work students collect different data from each other for the same problem.	5	4	3	2	1	5	4	3	2	1

9	The teacher tells us which equipment to use for practical work.	5	4	3	2	1	5	4	3	2	1
10	We carry out investigations to answer questions which puzzle us.	5	4	3	2	1	5	4	3	2	1
11	In our laboratory sessions some students do different experiments to others.	5	4	3	2	1	5	4	3	2	1
12	We decide the best way to proceed during laboratory experiments.	5	4	3	2	1	5	4	3	2	1
	Scale 2 - Discussion										
	In this class . . .										
13	Most students take part in discussions.	5	4	3	2	1	5	4	3	2	1
14	We talk to other students about our work.	5	4	3	2	1	5	4	3	2	1
15	We explain our ideas to each other.	5	4	3	2	1	5	4	3	2	1
16	We comment on other students' opinions.	5	4	3	2	1	5	4	3	2	1
17	We talk with other students about how to solve problems.	5	4	3	2	1	5	4	3	2	1
18	We discuss the results we have obtained with each other.	5	4	3	2	1	5	4	3	2	1
19	We discuss things which people have different opinions about.	5	4	3	2	1	5	4	3	2	1
20	Our ideas and opinions are used during classroom discussions.	5	4	3	2	1	5	4	3	2	1
21	We sit and listen to the teacher without asking or answering questions.	5	4	3	2	1	5	4	3	2	1
22	We pay attention to what other students are saying.	5	4	3	2	1	5	4	3	2	1
23	We ask the teacher questions.	5	4	3	2	1	5	4	3	2	1
24	The teacher talks rather than listens.	5	4	3	2	1	5	4	3	2	1
	Scale 3 - Assessment										
	In this class . . .										
25	Our tests have questions where we have to interpret data.	5	4	3	2	1	5	4	3	2	1
26	Our tests only have questions which we can memorise the answers to.	5	4	3	2	1	5	4	3	2	1

27	We are allowed to use textbooks or notes when we are doing tests.	5	4	3	2	1	5	4	3	2	1
28	We have to really understand the work which we have done in order to answer the test questions.	5	4	3	2	1	5	4	3	2	1
29	We can find the answers to most of the assignment questions we are set in library books.	5	4	3	2	1	5	4	3	2	1
30	If you want to do well, the most important thing is to memorise information for tests.	5	4	3	2	1	5	4	3	2	1
31	We have to memorise a lot of information.	5	4	3	2	1	5	4	3	2	1
32	We do assignments where we have to think things out.	5	4	3	2	1	5	4	3	2	1
33	The teacher will mark different answers to a question as being equally correct.	5	4	3	2	1	5	4	3	2	1
34	There is usually only one right answer which our teacher will accept to questions.	5	4	3	2	1	5	4	3	2	1
35	Our teacher is more interested in checking that we have the right answer than in our thinking and reasoning.	5	4	3	2	1	5	4	3	2	1
36	We take a lot of theory notes.	5	4	3	2	1	5	4	3	2	1
	Scale 4 - Scientific Method										
	In this class . . .										
37	We have to try to explain the results of our investigations.	5	4	3	2	1	5	4	3	2	1
38	We are asked to make generalisations from data.	5	4	3	2	1	5	4	3	2	1
39	We are asked to explain the meaning of statements, diagrams and graphs.	5	4	3	2	1	5	4	3	2	1
40	We are asked to predict the results of experiments.	5	4	3	2	1	5	4	3	2	1
41	We draw conclusions from investigations.	5	4	3	2	1	5	4	3	2	1
42	We are asked to apply ideas to new situations.	5	4	3	2	1	5	4	3	2	1
43	We are asked to think about the evidence for statements.	5	4	3	2	1	5	4	3	2	1

44	We are asked to suggest how we could improve the investigations which we have carried out.	5	4	3	2	1	5	4	3	2	1
45	We are asked to suggest further research which could be carried out.	5	4	3	2	1	5	4	3	2	1
46	We are asked to form our own hypotheses.	5	4	3	2	1	5	4	3	2	1
47	We have to analyse data.	5	4	3	2	1	5	4	3	2	1
48	We are asked to criticise the investigations which we have carried out.	5	4	3	2	1	5	4	3	2	1

	Scale 5 - Historical Perspectives / Stories										
	In this class . . .										
49	We learn about scientists.	5	4	3	2	1	5	4	3	2	1
50	The names of scientists are mentioned during lessons.	5	4	3	2	1	5	4	3	2	1
51	We learn about the history of science.	5	4	3	2	1	5	4	3	2	1
52	The teacher tells us stories about science.	5	4	3	2	1	5	4	3	2	1
53	As we study different topic we talk about the history of how these ideas have developed.	5	4	3	2	1	5	4	3	2	1
54	When we study a topic we are told about the trouble which scientists have had working things out.	5	4	3	2	1	5	4	3	2	1
55	We learn about how people came to make scientific discoveries.	5	4	3	2	1	5	4	3	2	1
56	We are told personal information about what scientists were like.	5	4	3	2	1	5	4	3	2	1
57	We watch videos about the work and lives of scientists.	5	4	3	2	1	5	4	3	2	1
58	We look at what people who are working as scientists do.	5	4	3	2	1	5	4	3	2	1
59	We talk about scientists and researchers who have worked in the area which we are studying.	5	4	3	2	1	5	4	3	2	1
60	We learn that modern science is different from the science of long ago.	5	4	3	2	1	5	4	3	2	1

	Scale 6 - Uncertainty										
61	We learn that scientists do not know how some things work.	5	4	3	2	1	5	4	3	2	1
62	We learn that science *cannot* provide perfect answers to problems.	5	4	3	2	1	5	4	3	2	1
63	We learn that science has answers for everything.	5	4	3	2	1	5	4	3	2	1
64	We learn that science has changed over time.	5	4	3	2	1	5	4	3	2	1
65	We learn that once scientists have proven something their ideas will not change.	5	4	3	2	1	5	4	3	2	1
66	We learn about alternative theories for the same scientific idea.	5	4	3	2	1	5	4	3	2	1
67	We learn that people can have different theories to explain the same thing.	5	4	3	2	1	5	4	3	2	1
68	We learn that science is influenced by people's values and opinions.	5	4	3	2	1	5	4	3	2	1
69	We learn that science is about *inventing* theories.	5	4	3	2	1	5	4	3	2	1
70	Scientific knowledge is presented as being incomplete - there are things which are still not understood.	5	4	3	2	1	5	4	3	2	1
71	We learn that scientific information can change.	5	4	3	2	1	5	4	3	2	1
72	Our teacher expresses their own uncertainty about whether some scientific ideas are correct.	5	4	3	2	1	5	4	3	2	1

Appendix 2 - Statement of Research interest area as supplied to critiquing teachers

The concept of inquiry as a teaching methodology appropriate to science classrooms seems to be one which continues to recur in the literature since its common usage was proposed in the 1960's. Although inquiry as a teaching methodology now seems to be largely looked on as something which is passe, the question may be raised as to whether or not it is in fact a technique which is very much indicated by the science syllabus statements and documents which are in use in Australia today.

Classroom environment questionnaires have come to be regarded as useful instruments in the field of learning environment research. The proposed study aims to develop, validate and use a new questionnaire to investigate the extent to which inquiry is in fact being used as a teaching methodology in science classrooms - even if the term inquiry is not being expressly used. The study will also investigate the opinions of teachers and students as to whether or not inquiry teaching strategies are desirable. This research will focus particularly on the situation in Tasmanian grade 9 to 12 classrooms.

Appendix 3 - Preliminary Questionnaire and student information sheet.

Is this an Inquiring Classroom? Preliminary Questionnaire.

Background information.

- Your name:..

Please circle the appropriate information.

- Grade: 7 8 9 10
- Sex: female male
- How would you rate your performance in your Science class?

1	2	3	4	5
Bottom group		Middle group		Top group

Instructions for completing the questionnaire.

- Please answer all the items.
- There are no right or wrong answers. The questionnaire is asking what you think about things in your Science class.
- When you are answering this questionnaire, the numbers mean these things:

5	**4**	**3**	**2**	**1**
Almost Always	**Often**	**Sometimes**	**seldom**	**Almost Never**

- In the 'actual' column, put a circle around how often this thing ***actually*** happens in your Science class.
- In the 'preferred' column, put a circle around how often ***you would like*** this thing to occur in your Science class.

Thank you for your assistance in completing this questionnaire.

Is this an Inquiring Classroom? Preliminary questionnaire

When you are answering this questionnaire, the numbers mean these things:

5	**4**	**3**	**2**	**1**
Almost Always	**Often**	**Sometimes**	**seldom**	**Almost Never**

Scale 1 - Freedom in practical work

		ACTUAL					PREFERRED				
	In this class . . .										
1	In our practical lessons some students do different experiments to others.	5	4	3	2	1	5	4	3	2	1
2	The teacher tells us which equipment to use for practical work.	5	4	3	2	1	5	4	3	2	1
3	There is opportunity for us to find out about things that interest us in Science.	5	4	3	2	1	5	4	3	2	1
4	In our practical lessons, the teacher decides the best way for us to carry out the experiments.	5	4	3	2	1	5	4	3	2	1
5	We are asked to design our own experiments.	5	4	3	2	1	5	4	3	2	1
6	We are allowed to extend the practical work and do some experimenting.	5	4	3	2	1	5	4	3	2	1
7	We carry out experiments to answer questions that come up in class discussions.	5	4	3	2	1	5	4	3	2	1
8	In practical work students collect different data from each other about the same problem.	5	4	3	2	1	5	4	3	2	1
9	All students do exactly the same experiments.	5	4	3	2	1	5	4	3	2	1
10	We carry out experiments to answer questions that interest us.	5	4	3	2	1	5	4	3	2	1
11	We carry out experiments to test ideas which ***we*** come up with.	5	4	3	2	1	5	4	3	2	1
12	We decide the best way to do things during practical work.	5	4	3	2	1	5	4	3	2	1

Scale 2 - Communication

		Actual					Preferred				
	In this class . . .										
13	Most students take part in discussions.	5	4	3	2	1	5	4	3	2	1
14	We talk to other students about our work.	5	4	3	2	1	5	4	3	2	1
15	We explain our ideas to each other.	5	4	3	2	1	5	4	3	2	1

PTO

Is this an Inquiring Classroom? Preliminary questionnaire

When you are answering this questionnaire, the numbers mean these things:

5	**4**	**3**	**2**	**1**
Almost Always	**Often**	**Sometimes**	**seldom**	**Almost Never**

	Communication (cont)	**Actual**					**Preferred**				
16	We comment on other students' opinions.	5	4	3	2	1	5	4	3	2	1
17	We talk with other students about how to solve problems.	5	4	3	2	1	5	4	3	2	1
18	We discuss the results we have obtained with each other.	5	4	3	2	1	5	4	3	2	1
19	We discuss things which people have different opinions about.	5	4	3	2	1	5	4	3	2	1
20	Our ideas and opinions are listened to during classroom discussions.	5	4	3	2	1	5	4	3	2	1
21	We sit and listen to the teacher without asking or answering questions.	5	4	3	2	1	5	4	3	2	1
22	We pay attention to what other students are saying.	5	4	3	2	1	5	4	3	2	1
23	We ask the teacher questions.	5	4	3	2	1	5	4	3	2	1
24	The teacher listens to our ideas.	5	4	3	2	1	5	4	3	2	1

Scale 3 - Assessment

		Actual					**Preferred**				
	In this class . . .										
25	Our tests have questions where we have to interpret data.	5	4	3	2	1	5	4	3	2	1
26	Our tests only have questions that we can memorise the answers to.	5	4	3	2	1	5	4	3	2	1
27	We are allowed to use textbooks or notes when we are doing tests.	5	4	3	2	1	5	4	3	2	1
28	We have to really understand the work that we have done in order to answer questions on tests.	5	4	3	2	1	5	4	3	2	1
29	We can find the answers to most of the assignment questions we are set in library books.	5	4	3	2	1	5	4	3	2	1
30	If you want to do well, the most important thing is to learn off by heart for tests.	5	4	3	2	1	5	4	3	2	1

Assessment (cont) **Actual** **Preferred**

PTO

When you are answering this questionnaire, the numbers mean these things:

5	4	3	2	1
Almost Always	**Often**	**Sometimes**	**seldom**	**Almost Never**

31	We have to remember a lot of information.	5	4	3	2	1	5	4	3	2	1
32	We do assignments where we have to think things out.	5	4	3	2	1	5	4	3	2	1
33	The teacher will mark different answers to a question as being equally correct.	5	4	3	2	1	5	4	3	2	1
34	There is usually only one right answer for each question.	5	4	3	2	1	5	4	3	2	1
35	Our teacher is more interested in checking that we have the right answer than in our thinking and reasoning.	5	4	3	2	1	5	4	3	2	1
36	We take a lot of notes.	5	4	3	2	1	5	4	3	2	1

Scale 4 - Interpretation of data

		Actual					**Preferred**				
	In this class . . .										
37	We have to try to explain the results of our experiments.	5	4	3	2	1	5	4	3	2	1
38	We are asked to make generalisations from data.	5	4	3	2	1	5	4	3	2	1
39	We are asked what diagrams and graphs mean.	5	4	3	2	1	5	4	3	2	1
40	We are asked to predict the results of experiments.	5	4	3	2	1	5	4	3	2	1
41	We draw conclusions from experiments.	5	4	3	2	1	5	4	3	2	1
42	We use information from our experiments to predict what will happen in a different situation.	5	4	3	2	1	5	4	3	2	1
43	We are asked to justify our conclusions.	5	4	3	2	1	5	4	3	2	1
44	We are asked how we could improve the experiments we have done.	5	4	3	2	1	5	4	3	2	1
45	We are asked to suggest further research that could be carried out.	5	4	3	2	1	5	4	3	2	1
46	We are asked to form our own hypotheses.	5	4	3	2	1	5	4	3	2	1
47	We have to interpret data.	5	4	3	2	1	5	4	3	2	1
48	We are asked to criticise the experiments that we have carried out.	5	4	3	2	1	5	4	3	2	1

Is this an Inquiring Classroom? Preliminary questionnaire

When you are answering this questionnaire, the numbers mean these things:

5	4	3	2	1
Almost Always	**Often**	**Sometimes**	**seldom**	**Almost Never**

Scale 5 - Science Stories

		Actual					Preferred				
	In this class . . .										
49	We learn about scientists.	5	4	3	2	1	5	4	3	2	1
50	The names of scientists are mentioned during lessons.	5	4	3	2	1	5	4	3	2	1
51	We learn about the history of science.	5	4	3	2	1	5	4	3	2	1
52	The teacher tells us stories about science.	5	4	3	2	1	5	4	3	2	1
53	As we study different topics we talk about the history of how science ideas have developed.	5	4	3	2	1	5	4	3	2	1
54	When we study a topic we are told about the trouble which scientists have had working in this area.	5	4	3	2	1	5	4	3	2	1
55	We learn about how people made scientific discoveries.	5	4	3	2	1	5	4	3	2	1
56	We are told personal information about what scientists were like.	5	4	3	2	1	5	4	3	2	1
57	We watch videos about the work and lives of scientists.	5	4	3	2	1	5	4	3	2	1
58	We look at what people who are working as scientists do.	5	4	3	2	1	5	4	3	2	1
59	We talk about people who have worked in the area which we are studying.	5	4	3	2	1	5	4	3	2	1
60	We learn that modern science is different from the science of long ago.	5	4	3	2	1	5	4	3	2	1

Don't miss the next page – it's the last one.

Is this an Inquiring Classroom? Preliminary questionnaire

When you are answering this questionnaire, the numbers mean these things:

5	**4**	**3**	**2**	**1**
Almost Always	**Often**	**Sometimes**	**seldom**	**Almost Never**

Scale 6 - Uncertainty in science

		Actual					**Preferred**				
	In this class . . .										
61	We learn that scientists do not know how some things work.	5	4	3	2	1	5	4	3	2	1
62	We learn that science *cannot* provide perfect answers to problems.	5	4	3	2	1	5	4	3	2	1
63	We learn that science has answers for everything.	5	4	3	2	1	5	4	3	2	1
64	We learn that science has changed over time.	5	4	3	2	1	5	4	3	2	1
65	We learn that once scientists have come up with an idea this idea will *not* change.	5	4	3	2	1	5	4	3	2	1
66	We learn about different theories for the same scientific idea.	5	4	3	2	1	5	4	3	2	1
67	We learn that people can have different theories to explain the same thing.	5	4	3	2	1	5	4	3	2	1
68	We learn that science is influenced by people's values, opinion and beliefs.	5	4	3	2	1	5	4	3	2	1
69	We learn that science is about coming up with ideas.	5	4	3	2	1	5	4	3	2	1
70	Scientific knowledge is presented as being incomplete - there are things which are still not understood.	5	4	3	2	1	5	4	3	2	1
71	We learn that scientific information can change.	5	4	3	2	1	5	4	3	2	1
72	Our teacher questions some scientific theories.	5	4	3	2	1	5	4	3	2	1

Thanks again for your help!

The End!

PTO

Appendix 4 - The following four pages constitute the final student version of the Is this an inquiring classroom? Questionnaire, as used to collect data for this research project. The questionnaire was presented as an A3 sheet folded in half.

Nb Margins were set up differently on the version of the questionnaire that students worked with.

Is this an Inquiring Classroom? Student Questionnaire.

Background information *(please circle where needed)*

- Grade: 7 8 9 10
- Sex: female male
- What level science result do you predict that you will get in grade 9/10?

  bottom middle top

Instructions for completing the questionnaire.

- Please answer all the items.
- There are no right or wrong answers. The questionnaire is asking what you think about things in your science class.
- When you are answering this questionnaire, the numbers mean these things:

1	**2**	**3**	**4**	**5**
almost never	**seldom**	**sometimes**	**often**	**almost always**

	Attitude to Science					
1.	I look forward to science lessons.	1	2	3	4	5
2.	Science lessons are fun.	1	2	3	4	5
3.	I enjoy the activities we do in science.	1	2	3	4	5
4.	The things we do in science are among the most interesting things we do at school.	1	2	3	4	5
5.	I want to find out more about the world in which we live.	1	2	3	4	5
6.	Finding out about new things is important.	1	2	3	4	5
7.	I enjoy science lessons in this class.	1	2	3	4	5
8.	I like talking to my friends about what we do in science.	1	2	3	4	5
9.	We should have more science lessons each week.	1	2	3	4	5
10.	I feel satisfied after a science lesson.	1	2	3	4	5

Instructions for the rest of the questionnaire

- In the ‘actual’ column, put a circle around how often this thing ***actually*** happens in your Science class.
- In the ‘preferred’ column, put a circle around how often ***you would like*** this thing to occur in your Science class.

Is this an Inquiring Classroom? Student questionnaire

When you are answering this questionnaire, the numbers mean these things:

1	**2**	**3**	**4**	**5**
almost never	**seldom**	**sometimes**	**often**	**almost always**

Scale 1 - Freedom in practical work		**Actual**	**Preferred**
	In this class . . .		
F1	We carry out practical investigations that take more than one lesson.	1 2 3 4 5	1 2 3 4 5
F2	We are asked to design our own experiments.	1 2 3 4 5	1 2 3 4 5
F3	We are allowed to extend the practical work and do some experimenting.	1 2 3 4 5	1 2 3 4 5
F4	We carry out experiments to answer questions that come up in class discussions.	1 2 3 4 5	1 2 3 4 5
<u>F5</u>	All students do exactly the same experiments.	1 2 3 4 5	1 2 3 4 5
F6	We carry out experiments to answer questions that interest us.	1 2 3 4 5	1 2 3 4 5
F7	We carry out experiments to test ideas which ***we*** come up with.	1 2 3 4 5	1 2 3 4 5
F8	We decide the best way to do things during practical work.	1 2 3 4 5	1 2 3 4 5

Scale 2 - Communication		**Actual**	**Preferred**
	In this class . . .		
C1	Most students take part in discussions.	1 2 3 4 5	1 2 3 4 5
C2	We talk to other students about our work.	1 2 3 4 5	1 2 3 4 5
C3	We explain our ideas to each other.	1 2 3 4 5	1 2 3 4 5
C4	We comment on other students' opinions.	1 2 3 4 5	1 2 3 4 5
C5	We talk with other students about how to solve problems.	1 2 3 4 5	1 2 3 4 5
C6	We discuss the results we have obtained with others.	1 2 3 4 5	1 2 3 4 5
C7	Our ideas and opinions are listened to during classroom discussions.	1 2 3 4 5	1 2 3 4 5
C8	The teacher listens to our ideas.	1 2 3 4 5	1 2 3 4 5

PTO

Is this an Inquiring Classroom? Student questionnaire

When you are answering this questionnaire, the numbers mean these things:

1	**2**	**3**	**4**	**5**
almost never	**seldom**	**sometimes**	**often**	**almost always**

Scale 3 - Assessment

		Actual	**Preferred**
	In this class . . .		
A1	Our tests mainly have questions that you can memorise the answers to.	1 2 3 4 5	1 2 3 4 5
A2	We are allowed to use our notes or textbooks in tests.	1 2 3 4 5	1 2 3 4 5
A3	There can be more than one correct answer to test or assignment questions.	1 2 3 4 5	1 2 3 4 5
A4	In tests (or assignments) we are given the results of an experiment or investigation and asked what these show.	1 2 3 4 5	1 2 3 4 5
A5	It is important to explain your answers carefully.	1 2 3 4 5	1 2 3 4 5
A6	We have to really understand the work to do well on tests.	1 2 3 4 5	1 2 3 4 5
A7	We can copy the answers to assignment questions straight from books or the internet.	1 2 3 4 5	1 2 3 4 5
A8	Test or assignment questions ask us what our opinion is and why we think this.	1 2 3 4 5	1 2 3 4 5

Scale 4 - Interpretation of data

		Actual	**Preferred**
	In this class . . .		
I1	We have to try to explain the results of our experiments.	1 2 3 4 5	1 2 3 4 5
I2	We are asked to make generalisations from data.	1 2 3 4 5	1 2 3 4 5
I3	We are asked what diagrams and graphs mean.	1 2 3 4 5	1 2 3 4 5
I4	We are asked to predict the results of experiments.	1 2 3 4 5	1 2 3 4 5
I5	We use information from our experiments to predict what will happen in a different situation.	1 2 3 4 5	1 2 3 4 5
I6	We are asked to justify our conclusions (to say why we think what we do).	1 2 3 4 5	1 2 3 4 5
I7	We are asked how we could improve the experiments we have done.	1 2 3 4 5	1 2 3 4 5
I8	We are asked to form our own hypotheses.	1 2 3 4 5	1 2 3 4 5

PTO

When you are answering this questionnaire, the numbers mean these things:

1	2	3	4	5
almost never	**seldom**	**sometimes**	**often**	**almost always**

Scale 5 - Science Stories

	In this class . . .	Actual					Preferred				
S1	We learn about scientists.	1	2	3	4	5	1	2	3	4	5
S2	The names of scientists are mentioned during lessons.	1	2	3	4	5	1	2	3	4	5
S3	We learn about the history of science.	1	2	3	4	5	1	2	3	4	5
S4	The teacher tells us stories about science.	1	2	3	4	5	1	2	3	4	5
S5	As we study different topics we talk about the history of how science ideas have developed.	1	2	3	4	5	1	2	3	4	5
S6	When we study a topic we are told about the trouble which scientists have had working in this area.	1	2	3	4	5	1	2	3	4	5
S7	We are told personal information about what scientists were like.	1	2	3	4	5	1	2	3	4	5
S8	We look at what people who are working as scientists do.	1	2	3	4	5	1	2	3	4	5

Scale 6 - Uncertainty in science

	In this class . . .	Actual					Preferred				
U1	We learn that science *cannot* provide perfect answers to problems.	1	2	3	4	5	1	2	3	4	5
U2	We learn that science has changed over time.	1	2	3	4	5	1	2	3	4	5
U3	We learn that people can have different theories to explain the same thing.	1	2	3	4	5	1	2	3	4	5
U4	We learn that science is influenced by people's values, opinion and beliefs.	1	2	3	4	5	1	2	3	4	5
U5	We learn that science is about coming up with ideas.	1	2	3	4	5	1	2	3	4	5
U6	Scientific knowledge is presented as being incomplete - there are things that are still not understood.	1	2	3	4	5	1	2	3	4	5
U7	We learn that scientific information can change.	1	2	3	4	5	1	2	3	4	5
U8	Our teacher questions some scientific theories.	1	2	3	4	5	1	2	3	4	5

Thanks again for your help!

Appendix 5 - Letter to high school coordinators of the *Is this an inquiring classroom?* Questionnaire.

27/8/02

Dear

Thank you very much for assisting my research by agreeing to run the ‘Is this an inquiring classroom?’ questionnaire in your school.

Just to remind you:

- Where possible, could you give the questionnaire to 3 classes at each grade level. The questionnaires are in envelopes in class sets of 30.
- Completed questionnaires can either be mailed back to me, or left at your school office for me to collect. Please let me know when they are ready to be collected.
- I do not need student or teacher names, but need to be able to tell which school the questionnaires are from, so there is a number on each envelope. Schools will not be named in the write up.
- I have included a teacher version of the questionnaire, and would appreciate it if you would ask all science teachers who are prepared to do so to fill it in.

Please contact me if you have any questions or concerns. Thanks again!

Regards

Denise Devitt

TELI
GPO Box 919
Hobart 7001
Ph: 6233 5677
Fax: 62333 6982
denise.devitt@education.tas.gov.au

Appendix 6 - Letter to college coordinators of the *Is this an inquiring classroom?* questionnaire

2/9/02

Dear

Thank you very much for assisting my research by agreeing to run the 'Is this an inquiring classroom?' questionnaire in your school.

Could you please give the questionnaire to the following pretertiary classes at your school, plus science teachers:

Biology	class/es
Chemistry	class/es
Physical Sciences	class/es
Physics	class/es
Teachers	As many science teachers as possible

Just to remind you:

- Completed questionnaires can either be mailed back to me, or, if you are in the Hobart area, left at your school office for me to collect. Please let me know when they are ready to be collected.
- I do not need student or teacher names, but need to be able to tell which school the questionnaires are from, so there is a number on each envelope. Schools will not be named in the write up.

Please contact me if you have any questions or concerns. Thanks again!

Regards

Denise Devitt

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denise.devitt@education.tas.gov.au

Appendix 7 - Instructions to high school teachers administering the Is this an inquiring classroom? Questionnaire.

Is this an inquiring classroom? Questionnaire

Instructions to administering teachers.

Please ask students to:

1. complete all details on the information page – names are not required
2. circle 2 responses to each item, one in the actual column and one in the preferred column.
3. answer all items – don't miss the back page!.

If students are unsure of any terms please feel free to clarify them – the intent of the questionnaire is to find out what students think, not test their literacy skills. Similarly, if students have literacy problems please feel free to read items to them.

Many thanks for your assistance.

Denise Devitt

TELI
GPO Box 919
Hobart 7001
Ph: 6233 5677
Fax: 62333 6982
denise.devitt@education.tas.gov.au

Appendix 8 - Instructions to college teachers administering the *Is this an inquiring classroom?* questionnaire

Grade 11/12 Classes

Is this an inquiring classroom? Questionnaire

Instructions to administering teachers.

Depending on which classes at your school are given this questionnaire, some students may be asked to complete it more than once. This is not a problem from the point of view of the questionnaire, as students will be offering responses about a different subject.

Please ask students to:

1. Complete relevant details on the information page
    - names are not required
    - grade is not required for college students as questionnaires will have already been coded (CB=college biology, CP=college physics, CC=college chemistry, CPS=college physical sciences)
    - the item asking about predicted grade 9/10 result can be omitted.
    - the ‘attitude to science’ scale refers to students’ attitude to the subject in which they are completing the questionnaire - physical sciences, biology, chemistry or physics. It was not practical to print questionnaires with different cover pages for each subject.
2. Complete the items on pages 1-3 by circling 2 responses to each item, one in the actual column and one in the preferred column.
3. Answer all items – don’t miss the back page!

If students are unsure of any terms please feel free to clarify them – the intent of the questionnaire is to find out what students think, not test their literacy skills. Similarly, if students have literacy problems please feel free to read items to them.

Many thanks for your assistance.

Denise Devitt

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Appendix 9 - The teacher version of the *Is this an inquiring classroom?* Questionnaire, as used in data collection for the current research. Changes that have been made form the student version of the questionnaire can be seen by comparing the teacher version with the final student version of the questionnaire, as shown in Appendix 4.

Nb Margins and Scale 3 and cover page font size were set up differently on the version of the questionnaire that teachers worked with.

Is this an Inquiring Classroom? Teacher Questionnaire.

Background information (please circle one or more, as appropriate)

- **Sex:** female male
- **School type:** high district high college
- **Taught in Curriculum Consultation Project School in:** 2001 2002 neither
- **No of years teaching experience:** less than 5 5-10 over 10
- **Age:** 25 or under 26-40 over 40
- **Grades taught:** 7 8 9 10 11 12

  If grades 11/12, please specify subject ....
- **Teaching qualifications:** B Sc B Ed Dip Ed B Teach M Ed

  Other (please specify) ....
- **Major degree area:** biological sciences physics chemistry earth sciences

  environmental sciences other ....

Instructions for completing the questionnaire.

- *Please answer all the items.*
- *When you are answering this questionnaire, the numbers mean these things:*

1	**2**	**3**	**4**	**5**
Almost never	**seldom**	**Sometimes**	**often**	**almost always**

	Attitude to Science & Science classes					
1.	I enjoy teaching my science classes.	1	2	3	4	5
2.	I feel satisfied after a science lesson.	1	2	3	4	5
3.	The things we do in science are among the most interesting things done at school.	1	2	3	4	5
4.	I like talking to others about what we do in my science classes.	1	2	3	4	5
5.	I like talking to others about science related topics.	1	2	3	4	5
6.	I am interested to hear about new science ideas and discoveries.	1	2	3	4	5

Instructions for the rest of the questionnaire

- *In the 'actual' column, put a circle around how often this thing* ***actually*** *happens in your Science class.*
- *In the 'preferred' column, put a circle around how often* ***you would like*** *this thing to occur in your Science class.*

IF you would be willing to be interviewed for this study please complete the following:

Name: ....

School:... **Phone:** ....

Email:..

Thank you for your help

Denise Devitt
GPO Box 919
Hobart 7001

Is this an Inquiring Classroom? Teacher questionnaire

When you are answering this questionnaire, the numbers mean these things:

1	**2**	**3**	**4**	**5**
almost never	**seldom**	**sometimes**	**often**	**almost always**

Scale 1 - Freedom in practical work

	In my Science classes . . .	**Actual**	**Preferred**
F1	Students carry out practical investigations that take more than one lesson.	1 2 3 4 5	1 2 3 4 5
F2	I ask students to design their own experiments.	1 2 3 4 5	1 2 3 4 5
F3	Students are allowed to extend the practical work and do some experimenting.	1 2 3 4 5	1 2 3 4 5
F4	Students carry out experiments to answer questions that come up in class discussions.	1 2 3 4 5	1 2 3 4 5
F5	All students do exactly the same experiments.	1 2 3 4 5	1 2 3 4 5
F6	Students carry out experiments to answer questions that interest them.	1 2 3 4 5	1 2 3 4 5
F7	Students carry out experiments to test ideas which ***they*** come up with.	1 2 3 4 5	1 2 3 4 5
F8	Students decide the best way to do things during practical work.	1 2 3 4 5	1 2 3 4 5

Scale 2 - Communication

	In my Science classes . . .	**Actual**	**Preferred**
C1	Most students take part in discussions.	1 2 3 4 5	1 2 3 4 5
C2	Students talk to other students about their work.	1 2 3 4 5	1 2 3 4 5
C3	Students explain their ideas to each other.	1 2 3 4 5	1 2 3 4 5
C4	Students comment on other students' opinions.	1 2 3 4 5	1 2 3 4 5
C5	Students talk with other students about how to solve problems.	1 2 3 4 5	1 2 3 4 5
C6	Students discuss the results they have obtained with others.	1 2 3 4 5	1 2 3 4 5
C7	Students' ideas and opinions are listened to during classroom discussions.	1 2 3 4 5	1 2 3 4 5
C8	I listen to students' ideas.	1 2 3 4 5	1 2 3 4 5

Is this an Inquiring Classroom? Teacher questionnaire

When you are answering this questionnaire, the numbers mean these things:

1	**2**	**3**	**4**	**5**
almost never	**seldom**	**sometimes**	**often**	**almost always**

Scale 3 - Assessment

		Actual					Preferred				
	In my Science classes . . .										
A1	My tests mainly have questions that students can memorise the answers to.	1	2	3	4	5	1	2	3	4	5
A2	Students are allowed to use notes or textbooks in tests.	1	2	3	4	5	1	2	3	4	5
A3	There can be more than one correct answer to test or assignment questions.	1	2	3	4	5	1	2	3	4	5
A4	In tests (or assignments) I give students the results of an experiment or investigation and ask what these show.	1	2	3	4	5	1	2	3	4	5
A5	It is important that students explain their answers carefully.	1	2	3	4	5	1	2	3	4	5
A6	Students have to really understand the work to do well on tests.	1	2	3	4	5	1	2	3	4	5
A7	Students can copy the answers to assignment questions straight from books or the internet.	1	2	3	4	5	1	2	3	4	5
A8	Test or assignment questions ask students what their opinion is and why they think this.	1	2	3	4	5	1	2	3	4	5

Scale 4 - Interpretation of data

		Actual					Preferred				
	In my Science classes										
I1	Students have to try to explain the results of their experiments.	1	2	3	4	5	1	2	3	4	5
I2	Students are asked to make generalisations from data.	1	2	3	4	5	1	2	3	4	5
I3	Students are asked what diagrams and graphs mean.	1	2	3	4	5	1	2	3	4	5
I4	Students are asked to predict the results of experiments.	1	2	3	4	5	1	2	3	4	5
I5	Students use information from their experiments to predict what will happen in a different situation.	1	2	3	4	5	1	2	3	4	5
I6	Students are asked to justify their conclusions (to say why they think what they do).	1	2	3	4	5	1	2	3	4	5
I7	Students are asked how they could improve the experiments they have done.	1	2	3	4	5	1	2	3	4	5
I8	Students are asked to form their own hypotheses.	1	2	3	4	5	1	2	3	4	5

Is this an Inquiring Classroom? Teacher questionnaire

When you are answering this questionnaire, the numbers mean these things:

1	2	3	4	5
almost never	**seldom**	**sometimes**	**often**	**almost always**

Scale 5 - Science Stories		**Actual**					**Preferred**				
	In my Science classes										
S1	Students learn about scientists.	1	2	3	4	5	1	2	3	4	5
S2	The names of scientists are mentioned during lessons.	1	2	3	4	5	1	2	3	4	5
S3	Students learn about the history of science.	1	2	3	4	5	1	2	3	4	5
S4	I tell stories about science.	1	2	3	4	5	1	2	3	4	5
S5	As we study different topics we talk about the history of how science ideas have developed.	1	2	3	4	5	1	2	3	4	5
S6	When we study a topic students are told about the trouble which scientists have had working in this area.	1	2	3	4	5	1	2	3	4	5
S7	Students are told personal information about what scientists were like.	1	2	3	4	5	1	2	3	4	5
S8	We look at what people who are working as scientists do.	1	2	3	4	5	1	2	3	4	5

Scale 6 - Uncertainty in science		**Actual**					**Preferred**				
	In my Science classes										
U1	I teach that science *cannot* provide perfect answers to problems.	1	2	3	4	5	1	2	3	4	5
U2	I teach that science has changed over time.	1	2	3	4	5	1	2	3	4	5
U3	I teach that people can have different theories to explain the same thing.	1	2	3	4	5	1	2	3	4	5
U4	I teach that science is influenced by people's values, opinion and beliefs.	1	2	3	4	5	1	2	3	4	5
U5	I teach that science is about coming up with ideas.	1	2	3	4	5	1	2	3	4	5
U6	Scientific knowledge is presented as being incomplete - there are things that are still not understood.	1	2	3	4	5	1	2	3	4	5
U7	I teach that scientific information can change.	1	2	3	4	5	1	2	3	4	5
U8	I question some scientific theories.	1	2	3	4	5	1	2	3	4	5

Thanks again for your help!