The Nature of Technology and its Effect on the
Introduction of Learning Technologies

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Submitted in fulfillment of the requirements for the degree of Master of Education in the
Faculty of Education at The University of Melbourne, 1998.
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Declaration Of Originality

This thesis contains no material which has been accepted for any other degree in any university. To the best of my knowledge and belief, this thesis contains no material previously published or written by any other author, except where due reference is given in the text.

Signed: [Signature]
Abbreviations and glossary

The present study uses the following abbreviations:

ANT - actor-network theory
BBC - British Broadcasting Corporation
CATS - Curriculum Assessment Tasks
CRDG - Curriculum Resources Development Group
CRO - Cathode Ray Oscilloscope
CSF - Curriculum Standards Framework
FOS - Field Of Study
IBM - International business Machines
ICT - information collecting technology
MBL - Micro Based Laboratories
PATT - Pupil Attitudes Towards Technology
PSSC - Physics Science Study Committee
STAV - Science Teachers' Association of Victoria
STS - Science-Technology- Society
TAS - technology as applied science
VBOS - Victorian Board of Studies
Acknowledgments

During the course of this study and preparation of the thesis, the assistance and support of a number of people has been invaluable.

Dr Susan Rodrigues, Department of Science and Mathematics Education at The University of Melbourne, for considered and relevant advice on all aspects of the present study.

The staff and students of the school in the case study for their time in interviews and follow up questions.

Very special thanks to Herbert Kemp for his encouragement and support throughout the duration of the present study.
Abstract

The development of adequate student conceptions of the nature of technology has followed in the footsteps of the work on the nature of science. Not only the students' but teacher's, education administrators' and curriculum writer's understanding of the nature of technology is of vast importance, given the unquestioning way technology is working its way into the educational culture. The purpose of this case study was to determine the technological literacy of the senior science students and teachers of a single sex secondary school. The study was conducted over a period of 18 months using a variety of qualitative instruments. The students and staff were surveyed to determine their beliefs about technology and its relationship with science. These results were preliminary to identifying the power structure needed to introduce information collecting technology (or learning technologies) into Senior Physics. The power structure was identified using Callon (1986, 1987) Actor Network Theory (ANT) and explained using Latour's (1987) theories on ANT. The study found that both staff and students had similar beliefs about technology and thought it was associated with computers, progress and making life easier. Both groups thought that technology was applied science. Whilst these beliefs were found to help the introduction of learning technologies the main power levers identified were the neo progressive Physics coordinator and Physics technician, combined with the linkage of learning technologies to assessment tasks. The case study also found that the staff and students' naive beliefs about technology meant that the opportunity to use learning technologies as instruments to explain the relationship between science and technology, was being lost.
Chapter 1

Introduction
1.1 Introduction

This thesis is entitled the Nature of Technology and its effect on the introduction of learning technologies. It arises from an interest in investigating the popular beliefs held by people at school regarding technology, where a school begins to introduce more and more technology.

It also grows out of two sociological histories. One is the study of the nature of science and the ramifications of this study to education. Secondly the interweaving of technology, society and knowledge (the societal effects of learning technology). Underlying this choice is a long-standing conviction that the social analysis of technology can make a contribution only if it is willing to tackle the shaping of technologies as well as their adoption, use and effects, and to grapple with the nature of specialized as well as lay knowledge (Mackenzie, 1990). However the social analysis is qualitative in nature in order to create greater richness in the study. This comes at the cost that any conclusions are not generalisable and only specific to the school context in which it is set.

At the very basic level, this perspective was formed in opposition to the idea that the development of technology is driven by an autonomous, non-social internal dynamic or technological determinism. It is due to the author's concern about the popular idea that technological change is unquestioned progress.
1.1.1 The Chapters

The chapters are numbered under major themes and are subnumbered to give structure to the thesis.

Chapter 1 starts by describing the situation at the secondary school, which lead to this case study. It also introduces the theoretical underpinnings of the arguments used in this thesis. It introduces social constructivism. It looks at the validity of a perspective called “actor network theory” developed by the French scholars Michel Callon and Bruno Latour. The central argument of actor network theory is that all successful technological motivation involves the construction of durable links tying together humans and non-human entities (“actors”). Actor network theory identifies the levers of power present within a school (specifically its Physics faculty) and focuses on the lever of assessment as persuasive in the definition of technology. Chapter 1 finishes by stating the questions, which will be answered by using the theoretical basis.

Chapter 2 introduces the methodology. It defines the sample, the qualitative and quantitative tools used to question the sample, the time frame the case study occurred. It explains why quantitative methods were preferred in this thesis and the problems associated with it.

Chapter 3 is the literature review, which covers seven areas:

1. The writings on the Nature of science duplicate many of the questions coming to light on the Nature of technology.

2. Literature on the Nature of technology shows what little research has been completed in this area.
3. Literature on the relationship between science and technology central to the question of Where does science end and technology begin?

4. Literature on research specific to students’ and teachers’ views on science and technology

5. Power structures cover the power of a specific technology in the school arena, the computer.

6. The area of ontology is long and involved. It covers technology as the instrument between reality and theory. It introduces constructivism as the link between reality and theory. It looks at social theory as explaining technology and the power levers in the school setting. It also introduces Bruno Latour and his writings on technology. His framework of theory will be one of the main tools used by the author to identify the nature of technology and its link to science via reference to the term "technoscience".

Chapter 4 presents the raw data and the analysis. Where the data is quantitative it is presented in tabulated form. Trends are mentioned and explained. The data is compared to the theory of the literature review. Qualitative data such as interviews with teachers is presented to give a rich picture as to what was going on during the time of the case study. The chapter starts with a reconstruction of the events that happened from interviews with the main participants. This is to help give the context under which the surveys were taken. These interviews will be used later to explain the power structure within the school. They are used to explain theory of Bruno Latour.

Chapter 5 answers the questions asked in chapter 1 revolving around the nature of technology in the context of school.
Chapter 6 looks at the implications of this study and finds three areas of interest in light of the literature review. These areas are curriculum, assessment and sociology of technology. It also looks into the areas of further study. A call is made to do more generalizable study to confirm findings on teachers' beliefs. Other areas, for example assessment, touched on by the tools of research need to be investigated by other means.

In general a call for more case studies is made as change due to introduction of technology is rapid, but little seems to be done to document these changes or explain them.

1.2 Milieu

The premise for this thesis can be garnered from the following scenario:

'School Charter 1994

Priority 2
To improve the use of technology in classroom teaching and student learning.

Intended Outcome
It is intended that computers and technology will become an integral part of the normal student learning process and that each faculty will devise, and introduce, ways in which computers and technology can be used to enhance learning, assist slower learners and excite general classroom interest.'

Three years later at the same school's speech night in 1997 the following statement came in the printed Principal's Report.
Technology has been advanced, with all subjects required to incorporate a technology based unit.

The Principal’s statement coincides with the adoption of computer data logging interfaces called Tain being used in physics classes. Tain is an integrated information collecting technology (ICT) that is connected to an IBM computer and to many measuring probes such as temperature and velocity. Tain was designed by Brian Taylor.

What seems like a fairly common set of linear cause and effect events leads to questions like:

Why the push for technology in 1994?
Why has it taken three years to complete the task (if it indeed has been completed)?
And most importantly: Why does ‘technology’ equate to ‘computers’ in the Physics department?

As Education academic Chris Bigum suggests:

‘Blind faith in technological progress has not served schools well.’ He believes schools should adopt a ‘heads up’ approach ‘...one that examines the social choices of whether and how to computerise an activity, and the relationships between computerised activity and other parts of our social world.’ Bigum (1997, p.2)

A useful starting point, common to the study of both science and technology, is the realisation that no knowledge possesses absolute warrant, whether from logic, experiment, or practice. There are always grounds for challenging any knowledge claim. But not all knowledge is challenged, nor is all challenge successful or even credible. Why some knowledge claims are challenged and some are not, and why
some challenges succeed and some fail, become interesting empirical questions.

Central to the answers are matters of the interests, goals, traditions, and experiences of the social groups involved; of the relative prestige and credibility of different links in the network of knowledge.

System builders do not respect knowledge categories or professional boundaries. In his notebooks Thomas Edison so thoroughly mixed matters commonly labelled economic, technical, and scientific that his thoughts composed a seamless web (Hughes, 1983).

This is an investigation into such a seamless web, the introduction of technology to high school physics. As a discourse it has three facets:

- The question of technological literacy
- The power structure which introduced this ‘technology’
- The actual Tain interface technology and how it is used.

These results carry implications for the introduction of new ideas. The second facet can be explored using Actor Network Theory (ANT) (Callon, 1986, 1987; Callon & Latour, 1992). The ANT has some advantages over traditional epistemological and ontological philosophies (Golinski, 1998).

An important note on definition is signalled in the title of the thesis and in these three facets. Technology can be used to represent many ideas (Gardner, 1994). The title of this thesis indicates that the definition of technology has in recent times meant learning technologies or ICT. In this thesis, the word technology is used to represent the same term as learning technology.

These results can be templated against a literature review, which looks at the nature of technology and its related topic, the nature of science. Related because many of
the questions asked by academics looking at the Nature of Science thirty years ago
have recently been asked about the Nature of Technology. The fact that it has been
thirty years and only recently that such questions have been asked about technology
is a thesis in itself. The reality is that a push for computers and other digital
technologies into all subjects of the curriculum has only become an organized
concern of recent times. It seems as if technology is being viewed as computer
technology.
While statements such as the development of an ‘adequate understanding of the
nature of science’ or an understanding of ‘science as a way of knowing’ continue to
be convincingly advocated as a desired outcome of science instruction (American
Association for Advancement of Science, 1989; Hazen & Trefil, 1991), but such an
occurrence seems to be far from fruition. The Nature of Technology should aim for a
similar model to that proposed for the Nature of Science. The model of Nature of
Technology proposed by philosopher-anthropologist Bruno Latour (1987) would
fulfil this need.

1.3 Theoretical Basis of the Study

1.3.1 Social Constructivist

This thesis is about the social constructivist approach to technology. This is an
attempt to apply recent work in the sociology of scientific knowledge to the case of
technology. Thus, in the sociology of science it has been argued that knowledge is a
social construction rather than a (more or less flawed) mirror held up to nature. It is
not given to scientists by nature whose phenomena are always susceptible to more than one interpretation. Rather, scientific knowledge is better seen as an irrefutable tool. Accordingly, scientific knowledge (and now it is argued, technologies and technological practices) is built in a process of social construction and negotiation, a process often driven by the social interests of participants. Roth (1998) refers to the sociology of scientific knowledge as science and technology studies because of its membership which now includes sociologists (e.g., Collins, 1982, Law, 1994), ethnomethodologists (e.g., Lynch, 1983), anthropologists (e.g., Traweek, 1988), feminist scholars (e.g., Haraway, 1989) linguists (e.g., Goodwin, 1995), philosopher-anthropologists (e.g., Latour, 1992).

Costa, Hughes and Pinch (1998) have said that educational constructivism and sociology of science have the same philosophical position on truth and knowledge. That constructivism is simply individual sociology of science. This idea will be applied to the sociology of technology.

This document reports on the issue of “closure” - a process by which conflicting groups reach (or impose) a specific outcome and so conclude the dispute. In this case the introduction of computer technology to the Physics department. Closure is multifaceted. It can revolve around the power struggle of interested groups (stakeholders) such as teachers in the Physics department. Or it can be about power struggle of a computer interface to mould phenomena into a data output of any recognizable form to the student. Laudan (1990) would argue that the former closure is an issue of epistemology, whereas the latter is an issue of ontology. Laudan (1990) would argue that the Tain computer interface is an instrument and thus defines a
student's individual notion of reality. These complexities are best addressed in an actor network theory.

1.3.2 Actor-Network theory

The actor-network theory (ANT) was first developed by French sociologist Callon (1986) and represents an attempt to find a neutral vocabulary to describe the actions of those who have since been called “heterogeneous engineers” (Law 1987). This allows us to analyse a situation and considers the stakeholders and the pathways that link them. The ANT is an extension of the underlying principles of the Sociology of Science Knowledge (SSK). Callon and Latour (1992) seek to capture the ways in which the ontological status of entities is itself an open question. They break down the distinction between human and non-human entities. In doing so they ignore as irrelevant the boundaries of ontology and epistemology. The situation described in the milieu is no longer a linear train of events but an intricate web with many heterogeneous engineers, both animate and inanimate.

What started as a question on the nature of technology and its meaning to different groups, became an investigation of a translation model (Latour, 1987) of educational change. To see whether curriculum and school policy reforms and specifically the rise of learning technologies changed the meaning of technology. Gaskell and Hepburn (1998) argue that a translation model is where the token in the actor-network simultaneously shapes and is shaped by other actors with which it comes in contact. So does the introduction of learning technologies have any influence on the
answers given on the nature of technology? Gaskell and Hepburn (1998) would argue ‘Yes’.

1.3.3 Levers of power

Rather than present a narrative with winners and losers in the stake of ‘What is technology?’ It is hoped that this situated cognition will indicate what levers cause real change. This is one of the main questions of the thesis. In reference to this question ‘What is technology?’ a number of issues are apparent:

- What levers cause real change?
- Will learning technologies be used to fulfil the self-interest of certain stakeholders?
- What dictates the use of learning technologies?
- Who defines learning technologies?
- Are computer interfaces an instrument of science or technology?

Self-interest is put forward as being the major motivation to change. Sociological reasons such as broad base non-rationalist technology will fail to have real meaning without changes to real politik i.e. the syllabus or technology literacy. This assumes that students will use the computer and understand the sociological change to their behaviour this is defined as transparency of meaning. If students recognise meaning with practice and accept it without question this is defined as opaque use. Constructivism can be used to show the transparency of meaning to the individual and the group.
Even more important are the teachers’ who are introducing the computers to the students understanding the signals they are sending to their students? The teachers are in collusion with the computer. Their status sends strong signals to their students. Just to achieve transparency would appear to need massive change in the status quo.

Von Glaserfield (1995) expressed this idea as follows:

‘The customary conception of truth as the correct representation of states or events of an external world is replaced by the notion of viability. To the biologist, a living organism is viable as long as it manages to survive its environment. To the constructivist, concepts, models, theories, and so on are viable if they prove adequate in the contexts in which they were created.’ (p. 7-8)


In accepting transparency the state education board or any other group of interested people, is giving up on its definition of technology because it means there is no one correct definition of technology. The state education board would accept that the definition is contextually based and want the students to recognise this. The state education board would be happy for students to recognise that levers of power can act on the individual or the social group. As a consequence different pedagogies will dictate different definitions of technology.

Constructivism helps to explain the border between science and technology as a power struggle between socially determined definitions. Tain data logging equipment
is an instrument. Latour (1983, 1986, 1987) would argue an instrument is important in defining this border.

1.3.4 Definition of Technology = assessment

Real politick requires being able to impose your viewpoint onto the masses both local and global. The viewpoint of the scenario at the beginning is that ‘technology equals computers’. Here the global is the school and the local is the Physics department. Local can be broken down further when looking at the forms of instrumentation which appear in the Physics class. Is the calibration or graphical form of the instrument a way of imposing a viewpoint on technology? Thus the local adds up to the global.

In the thesis this small global world does represent a weakness. While able to frame an answer to the question; Where did the push for technology come? The answer is clouded by the fact that students (and teachers) can have one set of beliefs for the real ‘world’ outside the school and another set of completely contradictory viewpoints for those in the classroom (Aikenhead, 1988). This makes identification of power levers difficult for this situation. Is it assessment? Is it the syllabus? Is it personnel? Or is it the equipment itself? Even when you look to the local department situation the question remains as to why this push only had this specific effect on Physics and not Chemistry? Is the difference due to the different assessment of Physics, which means that, technology can be introduced more readily than Chemistry. Assessment has been identified as a powerful change agent previously (Fullan, 1991). Maybe without the power of assessment, the definition of technology
is inconsequential. The definition of technology will remain, taken for granted, or worse ignored as students are not asked questions on it. They will not think about the definition. Their acceptance of the definition will mimic their acceptance of science practicals, which everyone agreed are good, but no one can prove their worth (Lederman, 1992). Until the definition of technology is tied to assessment only then will the definition move into power. However assessment is an unholy mess, driven by self-interest and conflict opinions. Thus connecting the definition of technology with assessment is difficult.

How can you obtain this change most effectively with the least amount of work? The power of assessment would seem the most effective change merchant/agent to influence technology. An example of this is the graphic calculator's voluntary introduction to Victorian mathematics examinations. The calculator's uptake was immediate and complete because it was tied to an assessment task. It is these observations which start to make the subject of learning technologies and their forms interesting. The secondary questions become:

- Is the introduction of learning technologies bound to fail without assessment being tied to it?
- Does assessment legitimise the viewpoint of technology held by the student?
- Would this viewpoint change if the assessment changed?

The last question cannot be answered in a strict sense as the thesis does not look at the before and after affect of the introduction of Tain in Physics. However a brief comparison can be made between two different subjects such as Physics and Chemistry. These have different assessment tasks that have different emphasis on technology.
1.4 Aim of thesis

There are three areas that are engaged with in this thesis to answer the questions posed earlier:

i) How is technology defined by those who influence or comprise a physics faculty

ii) What is the perceived relationship between science and technology

iii) What are the driving agents of change?
   a) student beliefs
   b) curriculum
   c) principal
   d) teacher
   e) assessment
   f) equipment

These aims need to be explained in greater detail:

i) The first question is addressed through an investigation into the definition of technology. The investigation looks at the belief system of a number of teachers in the Physics department and at key personnel of the school such as the Physics co-ordinator, Physics technician, Principal and Chemistry co-ordinator. These viewpoints are compared with students from both Year 11 and /Year 12 Physics and Chemistry classes and some Year 9 Science classes.

ii) Establishing an understanding of the relationship between science and technology is necessary for a number of reasons:
1. Previous studies on the Nature of Science will constitute a framework for studies on the Nature of Technology.

2. Many people define technology as applied science or even as science (Gardner, 1994). Arguably, Latour's (1987) technoscience provides the best definition of technology. Technoscience is a term for an inseparable merging of science and technology.

3. In looking at the introduction of Tain interface technology into Physics, questions of instrumentation become involved. Where does the science end and the technology begin? What is an object and is it out 'there' or is it a socially defined concept? These questions are rarely brought to the students' attention and may not be influencing the definition of technology. Much of the theoretical background will look at the unnecessary difference between the epistemology and ontology of science and technology. The theoretical background will be replaced with Latourian (1987) analysis of a blackbox (Tain), an encapsulation of reality and a social construction.

iii) What are the driving agents of change in adopting technology? The power structure in schools is often seen to drive these ideas. The central question to be answered here is: Why is school Physics fulfilling the technology component of the School charter by introducing only the Tain data logging device? (Tain is a simple grey box to which many probes can be attached to measure temperature, speed, current). Why is Physics fulfilling the school review? Yet Chemistry ignore the charter and Chemistry has not been penalised. Clearly agents of change exist in the Physics faculty and this thesis seeks to identify the role of these change agents. ANT will be used to show the levers of power. ANT's advantage over traditional ontological and epistemological philosophies, is described by Callon and Latour:
If engineers as well as scientists are crisscrossing the very boundaries that sociologists claim cannot be passed over, we prefer to abandon the sociologists and follow our informants (1992, p.361)
Chapter 2

Methodology
2.1 Introduction

The research employed an interpretive approach (Erickson, 1986) to investigate the three facets.

The thesis has into two distinct phases.

2.1.1 Literature review

A literature review encompassing the large field of information on the nature of science, and to a lesser extent the relationship between science and technology, followed by the nature of technology was conducted. This phase was on going over an 18-month period. The literature review provided a fast track method of determining some of the problems that might be encountered, such as a move in recent years away from quantitative methods to qualitative methods (Lederman & O'Malley, 1990). The literature review also provided two of the diagnostic tools, in the form of questionnaires, which were used to collect data (Rennie & Sillitto, 1988). The literature review provides the theoretical basis which the results will be discussed.

2.1.2 Investigation

The investigation consisted of the following tools (See appendices A,B,C,D & E):

1. A writing/drawing activity on technology
2. A Likert questionnaire on technology
3. A question sheet on Physics technology in practicals for 1996
4. A question sheet on Physics technology in practicals for Year 11, 1997
6. Semi structured interviews

The tools were used at various times over the 18-month period with different groups in the sample.

The analysis of the data produced by these tools aimed to:
1. document the range of secondary student's perceptions of technology,
2. identify secondary student's common explanations of technology,
3. distinguish any pattern in these explanations with respect of age,
4. distinguish any pattern in these explanations with respect to teacher or subject, and
5. draw implications for teaching technology and science.

2.2 The sample

2.2.1 Students

The author collected the data in November 1996 and April 1997 from one single sex government school. The population of these surveys concentrated on senior science students. The study did not cover the perceptions of humanities based students at a senior level. The survey group started off broad with science students from year 9, 11 and 12 contributing. Sampling was opportunistic and determined by the availability of the classes of students. As the 18 months moved on the surveying became more specific to year 11 and 12 Physics and Chemistry students, who had been used in Year 11 surveys in the previous year. As further depth of answer was looked for, the
sample size shrunk. When interviews with students were done, these came only from Physics students who had been surveyed. The impact on assessment and daily practices was noted for two specific departments, the Chemistry faculty and the Physics faculty. The move to concentrate on the Physics faculty and away from the Chemistry faculty was due to the introduction of Micro-Based Laboratories (MBLs), whereas there was no similar introduction of Tain computer interface learning technology to the Chemistry faculty. The full implementation of Micro-Based Laboratories (MBLs) to year 11 Physics and its influence on students became one specific issue which students of one class were questioned.

The first collection in November 1996 consisted of 4 classes of Year 9 science students (totalling 104 students) and 3 classes of Year 11 Physics students (totalling 66). They were given the writing/drawing instrument and the Likert instrument. This represented the largest possible cross section of students from Science or Physics/Chemistry background. The Physics classes were deemed the most important as this was the subject which was trying to instigate changes to its curriculum. Thus they were also given a question sheet on technology in Physics practicals. In April 1997 a class each of Year 11 and Year 12 Physics and Chemistry (totalling 98 students) were selected to give the writing/drawing activity and Likert questionnaire. 4 students had done the instruments the previous year so changes in their description were deemed important. One class of Year 11 Physics students (totalling 24 students) was given a question sheet on practical technology. One class of Year 12 Physics students (totalling 21) were also given a questionnaire on practical technology. These same 45 students were also given a semi-structured interview.
2.2.2 Others

Besides the students, data was collected from a number of adults deemed influential by the author. These adults included seven Physics teachers (including the Physics co-ordinator) and the Physics laboratory technician. To compare with Physics, the Chemistry co-ordinator and the Chemistry laboratory technician were selected. The Principal of the school was also included in the adult sample due to his policy influence.

In order to fulfil ethical considerations, coding of the Physics teachers was used to maintain anonymity. The following Physics teachers were interviewed: Karl, Shaun, Adrian, Paul, Justin, Ian and David (not their real names). Ian was also the Physics coordinator and so had a dual role. David was the coded name for the Physics laboratory technician. The Chemistry coordinator, Chemistry technician and Principal were also not named because of ethical considerations.

Student quotes were not attributed to individual names due to the large number interviewed and to maintain anonymity.

2.3 Research design

2.3.1 The Writing/Drawing Activity

The Writing/Drawing Activity used the essay topic from the PATT project (Raat and de Vries, 1986, See Appendix A). It was “Technology can mean different things to different people. When you read the word ‘technology’ what comes into your mind?” (Raat and de Vries, 1985). To this was added the instruction: ‘Please tell us
what technology means to you by writing about it, or by drawing a picture. You might like to do both.’ The responses to this activity were coded in terms of the identifiable ideas or elements of the drawing or writing using a descriptive framework developed by Rennie & Sillitto (1988).

The drawing aspect was designed specifically for primary school students and as such was not taken up by the students. Most students tended to give one-sentence answers. The students were given at least 15 minutes to complete the activity.

2.3.1.1 Quasi-Experimental method.

The above description of PATT places this procedure under the category of quasi-experimental method. This is important as it determines the type of data analysis and the conclusions allowed for the research problem. Burns (1994) gives the proof of this categorization. He asserts the four most important characteristics of scientific method are control, operational definition, replication and hypothesis testing. The control enables the scientist to identify why something happens. The procedure to be used on this research problem does not have a control. It will just identify patterns between groups. As far as operational definition is concerned the research project is trying to find what the operational definition on the nature of technology is. It will argue which group’s belief follow the thrust of recent research in the area. Hypothesis testing for this project is limited to ‘Is there any similarity between the groups in their perception of the nature of technology?’

Specific limitations of the statistical analysis of attitude tests
An argument about the appropriateness of attitude test revolves around whether the attitude survey from the PATT are parametric (i.e. data that can be treated as equal interval such as IQ score) or non-parametric [i.e. ordinal (ranked) or nominal (categorical)]. So that the correct statistical tests between groups can occur

2.3.1.2 Framework used to analysis Writing /Drawing activity

The purpose of analysing the data of the short essays is to find meaning in the data and this is done by systematically arranging and presenting the information. It has to be organized so that comparisons, contrasts and insights can be made and demonstrated. This is the difficulty for essay questions. Grouping is already possible from the participants themselves. The first groupings are administrator, teacher and student. Burns (1994) suggests content analysis as a means of grouping. Content analysis is used to identify themes, concepts and meaning. It is a form of classifying content. Burns (1994) points out that that content analysis needs a coding system that relates to the theoretical framework or research question.

Before the questions on the nature of technology could be answered, the raw data from the surveys (and later the interviews) had to be coded according to some models of the nature of technology. The author devised a method that used areas expressed by Rennie (1987) to code statements given. Like Palmquist and Finley (1997), a statement was defined as a paragraph, group of sentences, sentence, or phrase that contained a single unambiguous theme about the nature of technology. Some examples from teachers' transcripts include 'Technology is everything which is modern or cutting edge'. While reading this statement it was categorized into one
of the areas under product, process or social. A few categories that were not covered sufficiently in Rennie's categories lead to a small portion of new categories. Rennie (1987, 1988) stated most of the categories, so a trial of this analysis was not deemed necessary. However certain weaknesses are inherent in this methodology such as losing fine detail in order to achieve broad categorization.

The four broad categories were broken down to sub categories, as follows:

**Design and making**
- systems
- making models
- testing and developing ideas
- inventing

**Machinery**
- computers
- electrical
- transport
- general machinery

**Learning/Science**
- equate with science
- acquiring learning
Other

- structure
- secondary industry
- art
- textiles
- modern
- progress
- easier
- applied science
- technology and society
- negative viewpoint.

Other categories were entered if the template did not fit the response.

The four main categories looked at technology being process, an artefact and as instigating a feeling and came from a combination of Rennie’s 1987 paper and an English technology text (Solomon, 1993). However the sub categories were heavily dependent on Rennie’s 1987 paper. The separation of the categories: modern and progress, is arguable. But to combine them is to fall into a self-determined trap of equating modern with progress.

2.3.2 Attitude surveys

Changes on student perceptions were determined by a number of attitude surveys during the 18-month period. The first major survey was the Pupils’ Attitudes Towards Technology, PATT (Raat and de Vries, 1986). This survey was broken into
two parts. Part A. What is technology? And Part B. What do you think about technology? (See appendix B). It was a Likert questionnaire on technology. As such it was highly structured. This allowed for patterns in the answers to be analysed in terms of difference between year levels, class groups, subject groups and teacher and student. Any such analysis is only as good as the tool used. This PATT questionnaire had been used previously in West Australia (Rennie & Sillitto, 1988). Thus some results were available for comparison.

The other attitude surveys (See appendices C, D & E) were of the short answer type and were designed by the author. The questions were specific to the Tain technology being introduced into Physics. In the case of the Year 11 survey a comparison with older technology was asked. In 1996 the first attitude survey (appendix C) was given to three Year 11 Physics classes to determine their opinion on the introduction of Tain data logging equipment. The first survey also tested the attitudes of students to the introduction of Tain interface equipment when its use was parallel to traditional practical equipment. In 1997 the second attitude survey (appendix D) was given to one year 11 Physics class and a similar attitude survey (appendix E) to one Year 12. In the case of Year 12, as they did not do the same practicals with Tain, they were not required to answer questions on specific practicals. Questions on Tain to the Year 12 students were problematic, as Tain was used by students in Year 12 in different topics in 1997. However as Year 12 students had used Tain the previous year it was interesting to see what impression it had left on them and get some feedback from those students who had used them in their major project.
Also encompassed in both surveys was the students' response to the relationship between Science and Technology, using the categories of Gardner (1994) as a template.

These attitude surveys were used to provide questions for the Physics and Chemistry staff interviewed.

2.3.2.1 Internal validity of attitude surveys

Research into the weakness of attitude scale instruments is aided Lederman and O'Malley (1990, p.237) when they refer to language mismatches in objectively scored test items: 'Language is often used differently by students and researchers and this mismatch has almost certainly led to misinterpretation of students' perception of the past'.

Aikenhead et al. (1987) originally noted this concern with attitude scale instruments that have been used to assess 'The epistemology and sociology of science. These instruments have, by and large, been used with the erroneous assumptions that students perceive and interpret the test statement in the same way as researchers do.' (Ryan and Aikenhead, 1992, p.2). They refer to this as 'the doctrine of immaculate perception'.

2.3.2.2 Difficulties with attitude surveys

In 1997 Tain interface technology had replaced most of the older technology in the practicals so direct comparison was difficult. The Tain thermocouple was in use in
the Heat and Temperature topic in 1997 but not in 1996 so no comparison could be made over two years. There was concern that the gradual take over of old practical equipment by Tain computer equipment in 1997 implied a vote by the Physics faculty for Tain. The concern was this might bias the viewpoints of the students. The number of responses to each question in the surveys was less than 50% in some cases. Students would leave the question blank. This problem can lead to some problems about the validity of the conclusions made from these responses.

2.3.2.3 Framework used to analyse attitude surveys

In the case of the Likert questions, answers were simplified down to agree/disagree/neither and were tabulated as simple percentages as had occurred in both the Raat and de Vries (1986) and Rennie and Sillitto (1988) surveys. These were then compared question by question across each interest group. In the case of the other two attitude surveys, some simple yes/no questions were tabulated. For more open questions, the most common answers were found and used as categories for each question. Then responses were simply added up as a percentage under each category as had occurred in the comparison survey of Rennie and Sillitto (1988).

2.3.3 Interviews

Interviews were semi structured. The interviews revolved around the answers that the interviewee gave to written surveys as far as beliefs on technology were concerned. They then delved into wide ranging questions of power. Only one Year 11 Physics
class of 24 students and one Year 12 Physics class of 21 students were interviewed due to insider privileges. A smaller number (five) of Year 12 Chemistry students, who had been sampled previously as Year 11 students and were available, were also interviewed, however their results were not used. This was due to the small sample size. Each student interview lasted 7 minutes and was used to check the validity of their written responses to the questionnaire (See appendix F).

Seven Physics teachers were chosen because the number was large enough to yield a reasonably representative group of teachers whose diversity would reflect and seven was small enough to be a manageable size for a qualitative study. Two semi-structured, 45 minute interviews were conducted with each participant. The questions asked were essential the same as those in appendix E. The staff was also questioned as to how they thought learning technologies had been introduced to the school. Guided by the heuristic of teacher practical knowledge, teacher profiles were developed from the information recorded on the interview audio. Each participant was asked to review his completed profile and to make any changes that would increase its accuracy and anonymity. Interviews were conducted only on staff members as a means of verification. Those interviewed were seven Physics teachers including the Physics co-ordinator, the Physics technician, the Chemistry co-ordinator, the Chemistry technician and the Principal (See Appendix F for interview schedule).
2.3.4 Problems of interviews

A teacher conducted interviews, which may be problematic. Some researchers may question whether students really told what they thought or whether they told what they thought the teacher expected them to. This is the problem for classical research, which attempts to get students' beliefs, attitudes and epistemology thought to be properties of individuals. For discourse analysis, this is not a problem. First, discourse analysts recognise that talk is always situated action, employed to get things done. Ways of talking (language games) are always seen to be properties of collectives rather than individuals. Rather than just reporting on beliefs held by individuals, it has been documented what power structure situates these beliefs.

2.3.5 Overview of research sampling

<table>
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<tr>
<th>GENERAL</th>
<th>GENERAL &amp; SPECIFIC</th>
<th>SPECIFIC</th>
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<tr>
<td>1996 SCIENCE</td>
<td>1996 PHYSICS</td>
<td>1997 PHYSICS &amp; CHEMISTRY</td>
</tr>
<tr>
<td>YEAR 9 (4 CLASSES)</td>
<td>YEAR 11 &amp; TEACHERS (3 CLASSES)</td>
<td>YEAR11&amp;12, STAFF (1 CLASS OF EACH)</td>
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<tr>
<td>TECHNOLOGY ATTITUDE SURVEYS</td>
<td>TECHNOLOGY &amp; TAIN INTERFACE</td>
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Figure 1. Flow chart of overview of research sampling
During the 18-month period of classroom observations and interviews, data was generated and analysed from within an interpretive framework that was shaped by a constructivist perspective on the nature of knowledge. The plausibility of the interpretations was enhanced by triangulation of data generated from audiotapes and teacher interviews (Denzin, 1988) which were conducted over an extended period of time. Teachers and administrators were invited to respond to the initial interpretations of the author.

2.3.5.1 **Justification of methodology employed**

The case study used a variety of qualitative methods to increase the validity of the study. There was also a move from the general to the specific i.e. from a large sample size to more specific groups i.e. physics students.

A qualitative research method was chosen to enable the participants to express their own views and to use actual participant statements as data. Quantitative instruments such as Likert surveys force participants to choose between predetermined views. Lederman and O’Malley (1990) asserted that interviews are essential to assess views of the nature of science. Their research indicates a fallacy of the research methodology used by previous reports. Most students, given a questionnaire about the nature of science, indicated an absolutist viewpoint. However when the same students were interviewed on the same subject, the students indicated that scientific knowledge is tentative.
2.3.5.2 Validity and triangulation

Part of the research employed an interpretive approach (Erickson, 1986) to investigate the relationship between the teachers' beliefs about the nature of technology and their classroom roles. To see whether the teachers' beliefs transmitted to their students' beliefs. This might be indication of the power of the teachers. This took place in the form of a questionnaire and interview. Similarly the laboratory technician who became essential to the introduction of MBLs and the Principal were also polled for their views on technology to ascertain the power of their beliefs on their students. The plausibility of my interpretations was enhanced by triangulation of data generated from audiotapes, field notes of staff meetings and pamphlets from government bodies, and student-teacher questionnaires (Denzin, 1988; Mathison, 1988). To maintain the plausibility of the observations and interpretations, which were conducted over an extended period of time, teachers and students interviewed were invited to respond to the initial interpretations.

2.3.5.3 Advantages of PATT

The major advantage of using the instruments of the PATT is it eliminates the need for a pilot study. The PATT has two instruments that are from the qualitative method. Qualitative studies rely on more provisional questions, data collection sites, people to interview, and things to observe. They assume less in advance, including which variables are relevant, and are more open ended, sensitive to context, and likely to be focused on the intentions, explanations, and judgements of participants (Howe, 1985).
The advantage of the open-ended essay form over attitude scales is it places no restriction on the manner of the respondent's reply. The disadvantage is it might create information which is hard to compare or contrast.

A problem is that the researcher is open to the vagaries of the informant's interpretation and presentation of reality. This is a problem of validity, but if the informant genuinely perceives events in the way stated then their behaviour follows as a corollary (Howe, 1985).

2.3.5.4 Internal reliability

The research presented blends qualitative and quantitative measurement tools to make it more internally reliable. The findings from whichever methods come together in the content, which is presented as an argument, a narrative, or even as a story. Kidder and Fine (1987, p.67) contended that ‘...All research is a form of story telling, some more obvious than others are. Randomised experiments are the least obvious. Nonetheless, beneath the technical language is a story about how people behave under various conditions.’ They go on to argue that two methods are better than one. House (1991) argues that the investigation of complex social reality sometimes leads to the use of multiple research methods, of which the quantitative and qualitative constitute entire families.
2.3.5.5 Advantages of the case study

From the research presented what is left is a move towards multiple methods and approaches in a case study. Smith (Shapiro, 1987, p.46) describes the case study as a story: 'The case study tells a story about a bounded system. It has character, it has totality, and it has boundaries. It is not something we want to represent by a score or an array of scores. It has a complex, dynamic system. We want to understand complexity.'

The case study approach, which is particularly suited to inquiry in curriculum research, was chosen because it provides an integrated way of describing aspects of classroom learning, offering a synthesized view of classroom practice. Jane and Jobling (1995) point out that this research methodology is contextual, holistic and interpretive. A range of ethnographic research is employed. Hence this case study provides internal validity via triangulation, the process of cross validation (Burns, 1994), by using different data sources and different data collection methods.

2.3.5.6 Problems with case studies

As Burns (1994) explains case studies are held in disdain due to the role of human subjectivity when selecting evidence to support or refute, or when choosing a particular explanation for evidence found. This criticism can be labelled at any qualitative method of research. The second problem is the lack of evidence for scientific generalization. This is based on the assumption that generalizing theory is the only worthwhile goal.
2.3.5.7 Reliability of evidence in relation to children’s ideas

The stance of this study is that understanding what a child is thinking is not a simple matter of interview or survey. A constructivist position carries with it a natural limitation that must be recognised, and therefore treated as not proven. A supposition that children will have ideas is not a sufficient basis for according such a status to any response. (Johnson & Gott, 1996) There is always a ‘translation interface’ for communication between two individuals (Johnson & Gott, 1996). The child could be answering a different question to the one the researcher thinks he/she has asked. Teachers, in their own differently ordered minds, can often convict children of error. In fact, the children’s statements are right answers to questions different from those the teachers thought they had asked (Hawkins, 1983). Does this mean the enterprise of finding out what a child is thinking meets an inevitable impasse and so is doomed to failure? ‘Neutral ground’ is defined as that in which a largely (but never completely) undistorted communication takes place between child and researcher. The child understands what the researcher is asking in the meaning intended by the researcher, and the researcher understands the child’s response in the meaning intended by the child. Three basic methodological principles that allow neutral ground are: that the task be neutral; interpretation takes place on neutral ground; and that ‘triangulation’ be seen as a priority. Lythcott and Duschl (1990) define Neutral tasks where: Novel Verbiage used by an interviewee (verbiage that has not been introduced into the conversation by the interviewer) reflects a part of the cognitive system of that student, that is what he or she knows. Triangulation tries to avoid a student’s instant invention due to little reflective thought. Rather it represents a position in which they have some continuing stake (Johnson & Gott, 1996). Validity
is being questioned on the grounds of reliability. Does his/her’s stated views shape responses in related tasks? A particularly important form of triangulation would be to explore component aspects of an event. Triangulation addresses not only the issue of reliability but also increases our confidence in the validity of evidence (which reliability of itself is no guarantee). Confidence in the validity and reliability of evidence increases as the neutral ground is developed. This depends on the number of ‘measurements’ that are made, at different times and, ideally, with different instruments; and the range of contingent ideas that are examined. Lythcott and Duschl (1990) comment on the issue of ‘weighing’ the evidence. When verbiage of children, from interviews, is compared to segments of public domain science knowledge, goodness of fit can be assessed. Verbiage can then be argued as being consistent in meaning with public domain science knowledge can be said to arise from that child’s scientific conceptions.

2.3.6 Timeline

The time of 18 months turned out to be fortuitous as it coincided with the last 18 months of a 3-year technology plan of the school investigated. Thus it coincided with a mixture of the old system and the new and finished mainly with the new. Certainly at the time of completion both the school and the Physics department both claimed to have completed the charter agenda.

Effort was concentrated on the Physics department as change was noticeable and due to the insider privileges of the author. The author also had insider privileges to the
Chemistry department but as no change was discernible in Chemistry, the author concentrated on Physics department.
Chapter 3

Literature Review
3.1 Introduction to review

Lederman (1992) stated that the development of an "adequate understanding of the nature of science" or an understanding of "science as a way of knowing" continues to be convincingly advocated as a desired outcome of science instruction (American Association for the Advancement of Science, 1989). The literature review defines the nature of science then the nature of technology to understand the relationship between the two. The well-researched efforts on the nature of science can be used as a blueprint for the less researched area of nature of technology. Then the literature review investigates the philosophy of power to create change. It investigates the epistemological and ontological power of technology, specifically computer technology (Tain). Each section looks at an ideal position that might be suggested by the educational leaders of that subject. This ideal might not represent the reality occurring in schools. For ethical considerations any literature that could lead to the identification of the school of case study was not included in the references.

3.2 Nature of science

3.2.1 Nature of science: The ideal

Although the "nature of science" has been defined in numerous ways, it most commonly refers to the values and assumptions inherent to the development of scientific knowledge (Lederman & Zeidler, 1987). For example, an individual's
beliefs concerning whether or not scientific knowledge is amoral, tentative, empirically based, a product of human creativity, or parsimonious reflect that individual's conception of the nature of science. This viewpoint is further backed by Project 2061: Science for all Americans (Rutherford & Ahlgren, 1990). It promotes not only the development of intellectual honesty, curiosity, and openness to new ideas but also scepticism in evaluating claims and arguments. The nature of science also encompasses scientific literacy. The attainment of scientific literacy is important for social and personal reasons (Soren et al, 1994). A more scientifically literate citizenry can better participate in enlightened decision-making about science and technology policies. Issues of what literacy means and how it gets developed are but two features of its complexity. There are several possible explanations for the existence of confusion and conflict in defining these literacies. First there are different types and levels of literacy calling for skills and knowledge for ordinary citizenry and everyday life, to the expertise necessary for career scientist and technicians. Second, there are different settings in which people are exposed to representations of science, including the messages in the formal school curriculum, the media and personal acquaintances. Personal conceptions of science are developed from these messages, which are likely not consistent from context to context (Soren et al, 1994).

3.2.2 A philosophical position

The nature of scientific knowledge-its epistemological and social character- can be viewed from many perspectives: tacit and focal knowledge (Polanyi, 1958), public
and private science (Holton, 1978). Scientific knowledge can be viewed as bound to a paradigm, to a research program, or to neither (Kuhn, 1970). It can be appreciated as being socially constructed (Latour and Woolgar, 1986). Student views that converge with Holton (1978) and Kuhn (1970) are considered to represent a worldly perspective. They recognize knowledge is a social construction. Views that diverge from this contemporary literature are thought to be naïve (Ryan & Aikenhead, 1992). Naive views are often identified with logical positivism: One vestige of logical positivism is the belief that scientific knowledge connects directly with reality, unencumbered by the vulgarity of human imagination, dogma or judgements. This ontological view is often associated with the idea that science finds absolute truth, and does so independently of the investigator’s psychological and social milieu (Aikenhead, 1987). Nadeau and Desautels (1984) label this epistemic view “scienticism” and offer a five-category description of it:

1. Naive realism: Scientific knowledge is the reflection of things as they actually are.

2. Blissful empiricism: All scientific knowledge derives directly and exclusively from observation of phenomena.

3. Credulous experimentalism: Experimentation makes possible conclusive verification of hypotheses.

4. Blind idealism: The scientist is a completely disinterested, objective being.

5. Excessive rationalism: Science brings us gradually nearer the truth.

Mackenzie (1990) extends the viewpoint above by suggesting science has two types of knowledge, explicit and tacit knowledge. Explicit knowledge is information or instructions that can be formulated in words or symbols and therefore can be stored,
copied and transferred by impersonal means, such as written documents. Tacit knowledge is knowledge that has not been (and perhaps cannot be) formulated completely and therefore cannot be stored or transferred entirely by impersonal means. Motor skills such as riding a bike are an example of tacit knowledge. The focus on method in the traditional view of science downplayed the role of tacit knowledge, and the image of technology as "applied science" led to a similar de-emphasis there. When looking at the operation of scientific instruments such as learning technologies this tacit knowledge needs to be taken into account.

3.2.3 Science Education

Numerous authors (e.g., Abimdola, 1983; Duschl, 1990; Hodson, 1988) have claimed that science education has been and still is based on a logical empiricist view of science. In general, logical empiricists are concerned with the logical formulation of theories and laws from observations. To these people the main goal of a scientist is to discover the absolute, objective truth in nature (Bauer, 1992). The contemporary viewpoint used by Palmquist and Finley (1997) is based on the common ground found in the writings of philosophers Kuhn (1970), Lakatos (1977), Laudan (1990), and Toulman (1953). Within this postpositivistic view, theories are the end result of creative work within the scientific community. While scientists certainly use specific procedures in their work they do not follow a single scientific method. A content-orientated image of science is consistent with logical positivist approach (Naudeau & Desautels, 1984), while a social context image is consistent with an STS approach (Bybee, 1987).
3.2.3.1 Science teachers

Palmquist and Finley (1997) go on to exert that scientists’ methods or interpretations can depend on their prior knowledge (Bauer, 1992), the prevailing research paradigm under which they work (Kuhn 1970), or contextual values (Ziman, 1980). This ties in with research that science teachers mimic scientists in their teaching methodology. Instead of prevailing research paradigms teachers operate according to cultural myths (Britzman, 1991) of science teachers, whether this can be extended to their students was not investigated. Lederman’s (1992) research showed very weak, or non-existent, links between teachers’ views on the nature of science and the views expressed by their students.

Lederman’s 1992 review found that the majority of teachers’ conceptions tended to be the substantive content of science as fixed and unchangeable. This agrees with the logical positivism mentioned in the previous section. That teachers were too busy imparting factual information to their students to be interested and/or concerned about instruction on the nature of science (Anderson, 1950, Behnke, 1961). No similar study was done on teachers’ conceptions on technology.

Kimball (1968) showed the viewpoint on the nature of science was no different between scientists and qualified science teachers.

This would indicate the need for improvement of teachers’ conceptions. Some research shows that efforts to improve this situation had worked. Koulaidis and Ogborn (1989) indicated that most teachers’ beliefs could be viewed as contextualist, rationality had a weaker role. But Koulaidis and Ogborn (1989) did not define what types of contexts lead to what type of beliefs. King (1991) indicated that the lack of
science teachers' background in the history and philosophy of science clearly influences the teaching of science.

3.2.3.2 Science students - data

Lederman's (1992) review of many studies, for example Rubba (1977), Rubba & Andersen (1978) and Lederman (1986a, 1986b), showed that a large proportion of students had a simplistic and naive absolutist view of scientific hypothesis and theories and that scientific research reveals incontrovertible and necessary absolute truth. Aikenhead (1997) looked at student views on the influence of culture on science. His conclusions found that the minority of students embrace the traditional ideology of science held by so many science teachers. The mass media exerts a greater influence on student views than science classes exert, and their images varied in a way that reflects the stereotypes and caricatures of the mass media (Aikenhead, 1988). Students' everyday world is one full of socially determined practices and therefore the students may have applied their everyday world to the world of science. Ryan and Aikenhead (1992) found that axiomatic assumptions underlying science were beyond the comprehension of most 11th and 12th grade students i.e. a knowable universe, effects necessarily having causes. Only a minority of students (21%) sided with the scientific community by acknowledging that the uniformitarianism assumption is central to science. By far the largest group (46%) subscribed to the view consistent with a creationist posture and in direct conflict with the tenets of the epistemology of science (Ryan and Aikenhead, 1992). Larocheele and Desautels (1989) hypothesized that the success of a constructivist approach to learning science
may be contingent upon an adequate understanding of the epistemology of science. But the evidence given by Ryan and Aikenhead (1992) would indicate that this has not happen. Even though curriculum statements made in later sections will show that educationalists are trying to teach the epistemology of science, further will be given to show that it has not been successfully achieved at both the teacher and student level. Gil-Perez (1996) proposition on epistemology affirms that it is not possible to separate Hodson’s (1993) three elements: learning science (acquiring conceptual and theoretical knowledge), learning about science (developing an understanding of the nature and the methods of science and an awareness of the complex interactions between science and society) and doing science (engaging in and developing expertise in scientific inquiry and problem solving). However for Larochelle and Desautels (1991), the assumption in the epistemology of science raises the question: Does scientific knowledge tell us what is really out there in the universe (ontology) or is scientific knowledge “mind stuff” (epistemology)? A sizeable minority of students (34%) expressed a purely ontological view, only 17% held a purely epistemological view. The largest group were apparently influenced by a classic but erroneous notion of accidental discoveries, a notion heralded in the media and by popular writers. The results of Larochelle and Desautels (1991) demonstrate how important it is for science teaching to make assumptions explicit and hold them up for examination (Ryan and Aikenhead, 1992). Students tended to hold a vague preconception that the scientific method was “questioning, hypothesizing, collecting of data and concluding”. This amplifies the problems that science educators have identified concerning laboratory work (Hodson, 1988). Hodson’s 1988 study found less than half of the students in the sample were aware that consensus (or
uniformitarianism) is the basis of scientific knowledge. He also found that they believed their tentative knowledge in science changed, but their reasons differed:

1. Old facts change and become different facts.
2. Old facts become wrong facts.
3. Old facts do not change only their interpretation and application changes.
4. Old facts do not change; new facts are simply added to old facts. Student views were divided among three different perspectives: constructivists, falsificationist, and excessive rationalists.

3.2.4 Relevance of nature of science for the nature of technology

There are a number of themes from the nature of science that can be taken into consideration for comparison with the nature of technology. Arguments of epistemology and ontology, which initially were asked in the studies on the nature of science but which, may be used to investigate the nature of technology. Similarly there are many warnings which are signposted by the earlier studies on the nature of science. The ideal that nature of science should be taught as a social construction has never been successfully implemented. That despite years of research, students and teachers maintain simplistic and naïve absolutist view of scientific hypothesis and theories and that scientific research reveals incontrovertible and necessary absolute truth. The effect of the curriculum in causing change toward an ideal was mixed. Aikenhead (1979) and Palmquist & Finley (1997) said it had a positive effect, Tamir (1972) said it had no effect. Whilst Fensham (1994) noted curriculum was important,
Aikenhead (1984) pointed to student assessment as having a greater effect. Later studies pointed to teacher practices and found the teacher too busy imparting factual information to their students to be interested and/or concerned about instruction on the nature of science. However Aikenhead (1984) reported that teacher practices could approach an ideal. Discovery orientated classes created awareness of the nature of science whereas rote memory/recall did not. One of the major points was there was no singularly preferred or informed nature of science which ironically fitted with the viewpoint that science was tentative. In such absence the scientific method tended to fill the vacuum.

The point of the battle between ontology and epistemology also has its ramifications as far as technology and instruments are concerned. If students prefer ontology of science do they have the same viewpoint for technology?

### 3.3 Nature of Technology

#### 3.3.1 Introduction

Unlike the nature of science there are very few papers that express a view as to the nature of technology.

#### 3.3.2 Ideal of nature of technology

Technological literacy is thought to empower citizens to examine issues of importance in sociotechnology, and affect change (Fleming 1989, Aikenhead 1990, Soren et al 1994, p.136). However the views of the sociologists Mackenzie (1990)
and Bijker and Laws (1992) would like to move it in the same direction as the nature of science i.e. a socially determined knowledge area. Mackenzie (1990) has formed an opposition to the idea that the development of technology is driven by an autonomous, non-social, internal dynamic. He understands that such a viewpoint is not prevalent in academic circles but is in society at large. He suggests that the general public views technological change as just progress. Such ‘technological determinism’ is mimicking the naïve views of the nature of science and is also called logical positivism (Ryan & Aikenhead, 1992). Most of the definitions of technology are expressed in the curriculum of each country. Most of these definitions shown in the next section take into some account the social construction of technology and the concerns of Mackenzie (1990). Whether this equates to teachers and pupils accepting these viewpoints is up for debate. The intention for adoption is certainly there.

3.3.3 Technology education

In Australia the definition of technology varies from state to state. In Victoria it is defined in the Curriculum & Standards Framework (CSF) Technology (VBOS, 1995). The CSF recognizes Technology as a separate key learning area, the equivalent to Science and English. CSF Technology has three strands - Materials, Information and Systems. These strands have phases - Investigating, Designing, Producing, and Evaluating. The phases give some indication as to the Victorian Board Of Studies definition of technology. The definition of the nature of technology is given in the CSF is as follows:
Technology is a term that refers to the equipment and processes people use to enhance, maintain, manipulate and modify the environment and resources to support human endeavour. It involves the purposeful application of knowledge, skills, equipment, materials and information to create useful products. People come into daily contact with a wide variety of both simple and complex technologies - in the home and workplace, through health services, transport and communication, and in leisure activities. Technology is applied in areas such as food production and processing, transport, transport, manufacturing, management and entertainment.....technological developments can affect ...the way we learn. Technology education gives students the knowledge and skills to produce quality products that solve problems or meet needs. It involves students studying mechanical, electronic, electrical and other technological systems and also examining the effects the use of particular technologies or processes has on society and the environment...' (VBOS, 1995, p.9).

The CSF further defines educational goals in a very positivistic manner:

'Goals of technology education. Technology education aims to develop in students: a systematic and creative approach to generating technological solutions, the knowledge and skills to use a variety of equipment and resources an understanding of the principles for safely operating equipment. The ability to explore and assess the past and potential consequences of using technology, a sense of self-confidence and self - sufficiency in dealing with technology.' (VBOS, 1995, p.7)
The CSF defines technology as a process, similar to that of the English syllabus (Soloman, 1993):

'The technology process: The technology process sets out a path for solving a problem or meeting a need using a technological methodology. The process may be sequential, moving directly from investigating phase to designing, producing and evaluating, or students may need to return to phases to solve a problem. For example, continuing evaluation during each phase will often result in returning to a previous phase. The diagram shows both the sequential and non-sequential paths that could be followed when solving a problem using a technological methodology.' (VBOS, 1995, p.11)

This technology process seems to mimic the scientific process, however there is little research to prove that technology as a process is well recognized. The CSF Technology booklet states:

'In the middle secondary levels, it may be more appropriate to present technology courses based on each of the strands. This caters for students who want to increase their knowledge and skills in specialised areas in preparation for VCE studies. Depending on school priorities, students could concentrate on particular strands.' (VBOS, 1995, p.15)

However a Victorian student may never encounter this curriculum as he/she can elect to not do technology.

The 1990 Statutory Order for Technology in the National Curriculum of England and Wales requires knowledge of technology and society and experience of working with technologies. These ideas are inseparable from the acts of designing, making and
evaluating and the development of design and technological capability. The nature of technology is explored in its attainment target 4 in which students must:

- understand the social and economic effects of some artefacts.
- understand that artefacts, systems or environments from other times and cultures have identifiable characteristics and styles, and draw upon the knowledge in design and technological activities.
- evaluate the ways in which materials have been used.
- understand that artefacts, systems or environments reflect the circumstances and values of particular cultures and communities (Solomon & Aikenhead, 1994).

The last point about the effect of cultures on technology is not specifically covered by the Victorian syllabus. This point ties the nature of technology to epistemology, that consensus is the basis of technology.

A recent German technology curriculum (Ziefuss, 1987) locates technological development in a historical context by studying long-established technologies. In doing this the curriculum engages the idea of unilinear progress, an idea suggested by Mackenzie (1990). Fensham & Gardner (1994) put forward a set of ideas known as socio-scientific and sociotechnological concepts. These ideas revolve around socially negotiated connotations of objective concepts. For example what is ‘objectively’ the ‘best’ inertial guidance system to use is shown by Mackenzie (1990) to be socially determined. Of all the curriculum designs the one, which in the author’s viewpoint encompasses the ideal in technological literacy is the Systems strand of Victoria.
‘In technology, systems are combinations of human and technical elements that work together to achieve specified outcomes. Systems are used, applied and developed in all areas of human activity. Particularly important are environmental, engineering, energy, manufacturing, and information systems...All technological systems have particular inputs, processes and outputs controlled by people (for example, deciding on organisational arrangements, using mechanical and chemical means, devising electronic switches, or even relying on self-regulatory processes). ...Each system contains separate parts or elements connected in a specific way to make the system work.’ (VBOS, 1995, p.13)

Like the 1990 Statutory Order for Technology of England and Wales it draws in the human element involved in technology. It also mimics (possibly unintentionally) the ‘actor-network theory’ of the French scholars Michel Callon and Bruno Latour that will be developed later.

### 3.3.4 Students’ viewpoint

Rennie & Sillitto (1988) investigated the beliefs of Western Australian Year 8 students using essays and found that most students associated technology with computers, inventions, making life easier, machinery and progress. While not expressed by Rennie & Sillitto, these viewpoints coincide with a naïve absolutist view of technology being equated with modern objects. This naïve absolutists view dominates students’ thoughts on science (Lederman, 1992).
Rennie (1987) investigated the beliefs of Western Australian Year 8 students using a technology questionnaire. Rennie (1987) commented on the lack of awareness of the students of technology. This lack of awareness was more pronounced for girls in the sample. Students thought that technology was important, however they did not appreciate the historical aspects of technology. Many of the students failed to appreciate that technology existed more than 100 years ago. The majority of students thought that at school you did not hear much about technology and because of this Rennie (1987) suggested many pupils have no idea that technology includes the design and manufacture of the household appliances the students took for granted. Rennie (1987) suggested there was a gender bias, with girls being less informed than boys.

3.3.5 Teachers' viewpoint

Rennie (1987) asked 94 Western Australian Science teachers what their perception of technology were. The overwhelming theme advanced by three quarters of the teachers was that technology was an application of scientific knowledge. Technology was also linked to society by the majority of teacher. Rennie (1987) stated the problem with his view was that it suggested that new artefacts or processes cannot be produced without scientific knowledge.

Rennie and Jarvis (1995a) surveyed the perceptions of technology held by primary school teachers in England. Rennie and Jarvis (1995a) found that the perceptions of primary teachers ranged from technology as the application of science to designing and making of artefacts. Many of the teachers surveyed were confused about the
relationship between the National Curriculum view (Department for Education, 1995) and that held by general society.

3.4 Relationship between science and technology

3.4.1 Introduction

Technology can refer to artefacts or processes or entire social system or fields of work, or fields of study. Science, also a broad term, can mean organised knowledge about natural phenomena, or the thought processes which generate such knowledge, or as a rubric for a set of disciplines; it can also refer to social systems and fields of work and study. The terms are used differently by various authors, in various cultures, and in various historical times. For example in English, the word technology embraces connotations which in French are covered by two words, technique (organised knowledge and skill) and technologie (scientific technology). Gardner (1994) supports the view that the aim of the scientist is to produce tested knowledge. The aim of the engineer or technologists is to transform knowledge into techniques and artefacts for which there is a human demand. Scientists operates within the domain of knowledge, engineers and technologists operate within the domain of practice. Gardner (1994) does identify other positions as follows.
3.4.2 Science and technology as indistinguishable

If science and technology were indistinguishable, any discussion of science-technology relationships would lose most of its point. Gardner (1994) argues that people can think the terms science and technology represent the same concept. There is also a philosophical argument that science can be defined as any systemised positive knowledge (Multhauf, 1959) hence this definition covers technology as well. Franklin (1990) sees science and technology as ‘..one enterprise with a spectrum of interconnected activity rather than two fields of endeavour'(p.38).

3.4.3 Science and technology as distinguishable

This fits Gardner’s (1994) earlier engineer/scientist definition although he admits that the distinctions are not sharp. Given this difference, Gardner (1994) manages to summarise four possible relationships as:

(I) science precedes technology i.e. technology capability grows out of scientific knowledge; this position, often called the technology as applied science (TAS) view, is widely held and influential. It is sometimes presented as the definition of technology. It frequently finds expression in curriculum statements, instructional content and teachers opinions. For example, in New Zealand, Jones and Carr (1992) reported that the secondary science teachers in their small sample ‘..all saw technology education in terms of applications of science’(p.231).Similar findings were reported by Rennie (1987) and Rennie and Jarvis (1995a) The problems of this position manifest in a number of ways. It gives a limited view of how an artefact “works”. For example the
artefacts operation is explained in terms of one scientific principle, determined by the science topic that is to be illustrated. It gives a limited view of the goals of technology education, for example the art of design in creating a successful artefact is generally ignored by the TAS view.

(II) science and technology are independent, with differing goals, methods and outcomes (the demarcationist view).

(III) technology precedes science; this materialist view asserts that technology is historically and ontologically prior to science that experience with tools, instruments and other artefacts is necessary for conceptual development.

(IV) technology and science engage in two-way interaction; this interactionist view considers scientists and technologists as groups of people who learn from each other.

The author in his questionnaire uses these four viewpoints in order to determine which viewpoint dominates this case study. And then try to determine why this viewpoint dominates. Gardner (1994) would argue each position has implications for the content and sequencing of science and technology curricula.

The case study is built partly around the introduction of learning technologies to Physics, specifically computer data loggers (see section 1.1). The case study can be compared with the implications of each viewpoint and the results of the questionnaire on which viewpoint dominates.

Gardner (1994) argues the first tends to be the dominant view. Supporters of the TAS view point to artefacts and systems that have followed scientific discoveries. This view frequently finds expression in curriculum statements and teachers' opinions, for
example the work of Jones and Carr (1992). Gardner (1994) suggests this position leads to a number of problems:

- First is a limited view of how an artefacts "works". The artefact's operation is often 'explained' in terms of one scientific principle, determined by the science topic, which is the focus of the study.

- Second, it can lead to a limited view of the goals of technological education. Educators have been introducing technology education as a major new component of the school curriculum. It aims at the ability to conceive of a need, design a solution, and utilise resources to make and appraise an artefact (or system or procedure). The appraisal of the artefact is also be concerned with the broader effects of technological development on society and the environment. The consequence of the TAS view is that it leads to a neglect of these crucial design skills, which are not normally considered as scientific knowledge. The learning technologies used in Physics, the data logging devices are not appraised like might occur in technology education. They are accepted as irrefutable instruments, tools of science. They are used in analysis work to prove a law. Students are lead to a belief that technology is progress and it occurs in a sequential manner.

- Third, unsound history can occur as development of an artefact is attempted to be explained in a logical sequence with the development of scientific knowledge. This is not necessarily so. Eyeglasses were developed before the discovery of Snell's law.
• Fourth, curricula that treat technology as applied science frequently treat the process of application soporifically, as if the turning of a scientific idea into a technological outcome were a simple matter.

• Fifth, the TAS position is associated with an idealist rendering of the history of science, that is the contribution of scientific ideas is emphasised and the role played by the inventive people with craft skills is neglected. Nor does it pay heed to the relationship of instruments in scientific discovery. The problem with the TAS view is the unequal esteem between science and technology. The TAS view casts science in the role of gatekeeper to admission into technological careers, a view that one finds repeatedly expressed in government reports and university admissions policies in various countries.

Gardner’s (1994) second position (the demarcationist view) suggests science and technology are independent. The demarcationist view treats science and technology as distinct fields, pursing different goals, utilising different methods and carried out by different social groups. Science is analysis, concerned with the generation of knowledge; technology is synthetic, making things for utilitarian motives. An example of science ignoring technology in curricula is the American PSSC Physics course. This is of interest as the majority of Australian Physics teachers learnt the PSSC Physics course which dominated the 1960s and 1970s. More recent courses also borrowed heavily from the resources and practicals developed by PSSC.

Gardner’s (1994) views are fairly pragmatic in so far as the boundaries between each allow them to be put forward in a questionnaire. Also most other viewpoint on the subject of the relationship between science and technology can be grouped under one
of the four categories. Fleming's (1989) viewpoint moves into the area of epistemology. Fleming describes science and technology as distinct forms of cognition, autonomous spheres of knowledge. He believes that a dialectic between knowledge and production is the essential tension between science and technology. Technology is understood as a social process in the context of culture, in which knowledge created by science and the knowledge created by technology, are put at the disposal of people. Fleming refers to this as 'technology-practice' or 'sociotechnology'. To this point his ideas mimic the relativist argument developed later in this chapter by Latour and Callon. However Fleming goes on to suggest science deals with 'the exploration, study and characterisation of our world and the universe' and is the body of knowledge that 'predicts and explains natural phenomena'. Science is 'largely defined by logic'. Technology is seen as 'the fabric that created the infra structure of society' as 'the understanding', since it was 'the use of, or application of, and doing of science' in that it works with 'discoveries that have practical applications'. This is just Gardner's (1994) 'technology as applied science' under a different guise.

Others believed that technology 'harnesses the scientific knowledge into systems or products that are useful and valuable to society' (Soren et al, 1994, p.137), as such technology precedes science. This basic premise is historical, humans have been making artefacts, such as tools, ever since our emergence as a species. Likewise the technology of metal extraction preceded the development of the chemistry of metals by a millennium. This is just Gardner's (1994) 'technology precedes science' viewpoint. The strongest argument for this viewpoint is actually ontological: technology is held to be necessary for generating scientific ideas. Ihde (1991), a
powerful advocate of this view, regards artefacts and instruments as shapers of thought. This point is revisited in section 3.7 Ontology of computer technology. Star and Griesemer (1989) would argue against this ontological distinction. They would argue along sociological grounds that instruments are where boundary objects move from one social realm to another. This viewpoint is developed in the section 3.7.5 on Latour. However Ihde’s (1991) views are important to this case study as the computer data loggers introduced are just instruments. Measuring devices Ihde (1991) argues, do not merely permit improved vision and accuracy: they also induce new ways of conceiving the world. Instruments such as the Nuclear Magnetic Resonance create a whole body of scientific knowledge. Ihde (1991) acknowledges an intellectual debt to Martin Heidegger, a philosopher who championed the belief that usage gave meaning. Buchanan (1963) had argued that ancient Greek science had sprung from technology: by making an artefact, and reflecting on the processes used by the artist to make it, one might gain insight into parallel processes operating in nature. Gardner (1994) suggests there is very little support of this materialist position in curriculum expressions. He also suggests that the neglect of the materialist view is to de-emphasise the crucial role of instruments. This viewpoint becomes critical when examining the role of learning technologies in Physics. The learning technologies are computerised instruments. It stands to reason that technology used in a Science study would be down graded in comparison to say, scientific laws. If you look at the Victorian Curriculum and Assessment Board (1991) VCE Physics: study design, you will see scientific principles mentioned that must be covered by an examination. You
will not see such a prescriptive statement about the use of computer technology as practical instruments.

The final viewpoint of Gardner (1994) also has its supporters. The interactionist view proposes that technologists and scientists can learn from each other. This interaction has flourished during the past century. The American historian of technology, E. Layton (1977, p.21), stated that “Science and technology have become intermixed. Modern technology involves scientists who ‘do’ technology and technologists who function as scientists.” In fields such as electronics it is difficult to untangle the scientific and technological contributions. Layton (1977) also highlights the importance of social interactions between scientists and technologists for generating innovations. Pedretti’s (1995) review of the literature on science and technology literacy showed that science and technology are becoming increasingly difficult to distinguish. They share a symbiotic relationship, each depending on the other, although they are not synonymous. Gardner (1994) points out that there is little in the way of curriculum expressions of the interactionist view, because of the historical development of subjects into areas such as Chemistry, Physics and Biology. But this lack of ability to define the boundary between science and technology has become the beginning point for many of the sociologists of Science such as Latour (1987) and Shapin (Shapin & Schaffer, 1985).

### 3.4.4 Science and Technology curriculum

Gardner (1994) suggests that although views of science and technology influence curriculum designers, they do not necessarily determine the curriculum. Other
criteria such as student motivation and teacher confidence affect the outcome. Technology in the curriculum could be introduced to show how abstract ideas relate to concrete phenomena, for example in the use of instruments. Applications-led science courses introduce science theory on a need to know basis and are best exemplified by the UK, Salters' course in Chemistry, the Dutch PLON Physics course and its Australian related VCE course. But these courses do not teach technological design.

Curriculum based on technological capability is very limited. Gardner (1994) draws attention to technology being introduced to the senior secondary physics course (Victorian Curriculum and Assessment Board, 1991). The third semester unit of the four semester program includes topics on electric power and electronics systems; students are expected to demonstrate capability through completing work requirements chosen from a set of options e.g. design and construct a device, or investigate the operation of a device, or solve a scientific or technological problem. This does not indicate the importance of the work requirements as an assessment task. The work requirements are flexible enough for teacher interpretation. The work requirements can be overlooked in preference to more pressing assessment tasks such as the examination. This is a good example where the first hurdle of recognising technology education is overcome. Having technology education on the syllabus does not mean that it will be uniformly treated with the same importance as other parts of the syllabus. This will be further investigated in the section 3.7.3.6 on Assessment.
3.5 Science and technology education in schools

The way the relationship between Science and Technology has been introduced into schools has varied.

1. Science and/with technology

Courses have been structured in terms of scientific concepts and principles, with the technology being 'added on' to illustrate the application of the science in the situations likely to enhance students' interests in, and understanding of science. Science in Action is an English curriculum development which ties A level subjects such as Physics to contexts. Science in Action is representative of this genre.

2. Science of technology

The prime aim is to improve the learning of science such as applications-led or context-based approaches. The VBOS Physics course (1991) is supposedly context-driven. Although the science and technology were drawn into a close relationship, the partnership was to meet science outcomes.

3. Science for technology

The determination of the students' technological capability is the main aim and the science is treated as a resource, along with other forms of knowledge and skills. Pure science becomes servant to technology. There is no example of this type of course in the literature investigated.

4. Science-Technology-Society (STS)

Technology was not necessarily subservient to science; the focus was on societal issues and topics with a strong science and technological dimension. This lead to more interest in the nature of science and technology, and also to a diminishing of
personal involvement in technological activities intended to develop design and
technological capability (Weller, 1996).

Science-Technology-Society (STS) based curricula look at the impact of
technological artefacts on society. Gardner (1994) indicates that this often results in
the technology being treated as a 'blackbox' or real object. To treat technology as a
'blackbox' is to neglect consideration of human abilities and the social forces that
were needed to develop and shape the scientific ideas and innovative artefacts in the
first place. This definition of blackbox is the complete opposite to the definition
proclaimed by French philosopher Bruno Latour.

While the technology as applied science position dominates North American
textbooks (Ryan & Aikenhead, 1992), technology is not generally viewed that way in
Europe (Fleming, 1989). The instances of technology driven science far exceed the
instances of science -driven technology (Ziman, 1984). Thus there seems to be some
type of cultural determinism. In Australia the relationship varies in different States.
Queensland and Victoria have a very different view of the relationship between
science and technology. The Queensland syllabus (Butler et al. 1996) conceptualised
the interaction between science and technology as one where the abstract science is
followed up by reference to technological outcomes, that is 'a motivational' use.
Whereas the Victorian syllabus (Butler et al. 1996) specifies that the lessons be
designed so that the technology initiates the lessons, and then be elucidated by the
science.
3.5.1 Students’ views about science and technology in schools.

Students confuse science with technology. Such confusion is sown and nurtured by a North American myth that states: ‘technology is applied science’ (Collingridge, 1989; Fleming, 1987, 1989; Snow 1987). Ryan and Aikenhead (1992) found one third of the Canadian students defined technology as the application of science. Rennie and Jarvis (1995a) also found that children from both England and Australia confused technology with science. The literature shows students supporting Gardiner’s (1994) Applied Science viewpoint in the main or at least were confused about the border between science and technology. This would tend to signpost Gardiner’s (1994) fourth viewpoint of science and technology being interactionary.

3.5.2 Teachers’ views

Research on teachers’ beliefs on the relationship between science and technology was very limited. Rennie and Jarvis (1995a) in their study on primary teachers’ perceptions of technology stated that very few of these teachers linked technology to science. Only the science co-ordinators made reference to science in their descriptions of technology. All of these science co-ordinators referred to technology being applied science. All the teachers in this study were English. Questions like what influence the teacher’s beliefs have on students have yet to be documented. This is one area which is investigated by the case study.
3.5.3 Beliefs on power

Research studies into the students’ or teachers’ beliefs on computerised instruments or their power appears to be non-existent. However there is much written on the philosophy of what causes change (Fullan, 1991), and the sociological power of instruments (Latour, 1986).

3.6 Power structures

3.6.1 Introduction

Up to now the literature review looked at the views of students and teachers on technology. The context of the thesis is the introduction of computer interfaces into Physics to fulfil a technology requirement. The purpose of this part of the literature review is to move away from the general question of What is technology? and go to the literature about one aspect of technology specific for this case study; computer interfaces or computer data loggers. These instruments are specific for Physics related practicals. However because they are connected to a computer they take on the power associated with the formidable piece of technology; the computer.

Power structures can also be ontology based. The computer interface is an instrument that acts as a border between science and technology (Latour, 1987). Computer interfaces indirectly define what technology is. Computer interfaces define technology for the individual via constructivism (Golinski, 1998) and for the group via sociology of technology (Costa, Hughes & Pinch, 1998). Power structures can be
phenomena based, for example part of the border between science and technology is where objects become facts (Latour, 1987). The computer interface helps students define facts in Physics.

The remainder of the literature review looks at:

- Why computer interfaces are used in science?
- Why computer interfaces as technology are so powerful?

3.6.2 Theory on computer interfaces

For more than two decades many science educators have hoped that computer technology would substantially help teachers provide students with efficient and effective opportunities to learn both science's products - facts, principles, laws, and theories - and its processes - manipulative and cognitive methods employed in the collection, analysis, synthesis, and evaluation of evidence (Weller, 1996, p.461.)

Many science educators hope that working with Micro Based Laboratories (MBLs) will enable the learner to connect graphical symbols to mental constructs presenting the products and processes of science, employ these constructs to interpret observed phenomena, and form quantitative and qualitative mental relationships between constructs (Weller, 1996,p.472)

Weller (1996) identified four factors that contribute to the power of learning using MBLs:

1. MBLs reinforce many learning modalities.
2. MBLs link, in real time, concrete experiences with their symbolic representations.
3. MBLs provide genuine scientific experiences, gathering and analysing real data.

Any of these points could be put forward by a Physics department to introduce MBLs.

Cooper (1993) suggested a relationship exists between instructional theory and its dependent technologies, bounded by three factors: instructional design methodology; the physical technology with which the instruction is implemented or mediated, and the programming mechanisms used to develop instructional software conveying the subject content. So Cooper would argue that Tain data logging interfaces are reliant on the context of the software being used.

An argument against the costly introduction of MBLs was Beichner (Weller, 1996), who found that MBL 'simulation' exercises in projectile motion were no more effective than convention laboratory. The researcher surmised that kinesthetic feedback might be the most important part of the MBL learning experience. Most of the research on MBLs involves graphing, not on whether students understand the relationship between theory and reality as presented by an MBL.

Adams and Srum, as reported by Weller (1996), found with 10th-grade general biology students that MBLs were a less effective supplement than conventional laboratory exercises in helping learning graph construction. They found no significant difference in interpreting graphs for students who used MBLs or students who used conventional laboratory exercises.

Stuessy and Rowland, as reported by Weller (1996) found that 10th-grade biology students who used laboratory thermometers and graphed the results by hand showed superior learning on a content test as compared to students who used a digital thermometer or computer probe. Other studies (Weller, 1996) indicate that students
who used a computer temperature probe and real time computer graphing had higher gain scores on a graphing skills test than others.

Settlage (Weller, 1996), an educationalist, made the following findings concerning learning via MBLs.

1. The MBLs contributed to the students' science learning, especially in the form of increased facility with scientific inquiry.

2. Many students developed an increasingly sophisticated understanding of graphs and how they related to light, with their theories being grounded in the data that the MBLs helped them to collect.

3. Many students increased their graphing repertoire (especially, adding line graphs to their options for representing data) and sophistication of interpreting graphical representations. So there appears an advantage in one processing skill due to MBLs.

Nakhleh and Krajicik (Weller, 1996) compared three different technologies in titrations: MBLs, pH meters and chemical indicators. The students who used the MBLs exhibited larger positive changes in their concept scores, indicating a greater differentiation and integration of their knowledge of acids and bases. However, the MBL students also had more inappropriate connections in their concept maps than the pH meters or chemical indicator students. The researchers speculated that this was because of the high level of involvement of the MBL students with the technology. Computers may cloud the issues. Nakhleh and Krajicik also found that the students using any technology built their understandings predominantly on a macroscopic level and did not relate them well to microscopic and symbolic system representations. Finally, Nakhleh and Krajicik note that students using any technology linked their inappropriate understandings to a few major ideas, where no 70
clustering existed (Weller, 1996). Sometimes the mistake in graphing is more deep-seated than the use of the computer.

A most frequent graphing misconception held by students is the tendency to see a graph as a picture rather than as a symbolic representation of information (Brasell, 1987). This misconception though lessened in MBL still lead to 40% of students making the same errors as non-MBL (Linn, 1987).

One of the features pushed by proponents (Weller, 1996, Morkos, 1986) of Tain and other data logging manufacturers is the real time graphing ability. There is a suggestion that this linking in time of a physical event with simultaneous graphic representation may facilitate an equivalent linking in memory. Morkos (1986) discussed the possibility that, to the extent that this linking occurs, the real time graphing may operate as a bridge to formal reasoning and development. Real time graphing allows learners to process information about the event and the graph simultaneously rather than sequentially. Real time graphing may also motivate students. It may interact with cognition by influencing (a) the direction and intensity of attention; (b) the depth of involvement; (c) the level of arousal; and the representation of abstract problems by providing or prompting effective means (Brassell, 1987). It also could alter the perception of amount of mental effort invested in the task.

Specifically in the field of Physics on which the case study is built around. Brasell (1987) found errors involving the conventions of graphing and measurement were reduced by MBL. Real-time graphing made the graphs appear more responsive, more manipulable, and more concrete. Barton (1990) said MBL overcomes the problems of delayed analysis, making it difficult for the pupil to link the experiment with
numerical description. This problem becomes particularly acute when measurements of acceleration are made. It is doubtful that pupils gain much understanding about the measurement of acceleration by struggling with ticker tape.

Pupils can be encouraged to make predictions, then carry out the measurement and be confronted by the results all within a short time. Barton (1990) suggests that forcing students to confront their misconceptions and then allowing them to retest is a powerful method of concept building.

In using data logging for electricity Barton (1990) suggested the following advantages are:

- No difficult circuits
- No problems in reading the scales
- No time consuming graph plotting.
- Removing these barriers makes work more accessible to younger and less able students.

The pupil is put in the position of an interpreter, analyser and predictor of experimental results.

So there is quite some positive evidence to the adoption of MBLs in Physics practicals. However there are a few arguments against the MBLs and rather than arguing against specific skills been developed they argue the point of whether technological literacy benefits.

Papert (1986) was highly critical of those who attempted to measure the outcomes of the constructionist environment and felt that culturally and historically we are trapped in a technocentric stage where we tend to give centrality to a technical object. He believed that until we moved beyond this stage we would not be able to
clearly evaluate the strengths and weaknesses of what we were doing with computers and how we were doing it.

Hodson (1993) concurs and argues that not all-scientific inquiry is experimental. The search for correlation and theory building can be done by computerised data management systems. By displaying data in a variety of ways, plotting graphs, performing calculations, analysing data, collecting data, and even monitoring and controlling experiments, computers can eliminate much of the 'noise' associated with complex apparatus, the boredom of long wait times and the 'mathematical noise' of lengthy calculations. This is the epistemology of technology which seems not to be questioned by those adopting MBLs. However Hodson (1993) does not care about technological literacy, he is more of a pragmatist. Hodson (1993) draws to attention to differences of authentic and inauthentic labour. The former is an integral part of the learning and makes a valuable and direct contribution to it. The latter is necessary simply in order to proceed with the learning task, it is additional to the learning and has no particular value in itself. Hodson (1993) argues that the needs and interests of the student should be uppermost. Hodson (1993) argues the computer acts as a technician leaving more time for reflection of results. So he is not as concerned by the means, more so by the ends. Galbraith et al (1997) who predicted that computer technology will be used increasingly for the observation and recording of data, and in measuring and instrumentation, thus reducing more mundane aspects of science-related occupations supports him.
3.6.3 Problems of computers in the classroom

When discussing problems about computers, the argument is not specifically about computer interfaces used in practicals but more generally about anything associated with computers. These are legitimate concerns as in the power struggle to introduce computer-based technology and they are socially based.

Alfred Bork (1995) identified several reasons for failure of computers to deliver their promise in education:

1. Hardware emphasis
The tremendous emphasis on how many computers are in the school, the types and other hardware information. More recently this has shifted to the number and type of networks and multimedia systems.

2. Little focus on learning
There is a vague belief in the magic of technology by parents, administrators, and teachers, and not on the role it will play.

3. Little Focus on Students
The students become the last things to be considered after the hardware is purchased.

4. Software-Based Failure
There are a variety of problems with software. Some software may work with very good students, or with extremely skilled teachers. The difficulties of setting up the equipment are often considerable. Furthermore, after the student does an experiment and obtains graphs on the screen, the question is; Are these graphs reasonable? Were there errors involved in the measurement process? Then there is the critical question
of whether the student understands the results, even if the results are reasonable. Can they draw any conclusions? What is learned? (Bork, 1995)

Hennessey et al (1995) reported that computer tasks were atypical in being more prescriptive than normal science activities, requiring less responsiveness and adaptation from the teacher.

Bork (1995) talks about the idea of the moment being pursued like true believers following a cult. Often these "cults" go on afterwards with strong believers, even when the evidence is negative. There is usually little positive evidence for the beliefs of the cult, but as with religious cults, that does not discourage the believers. Bork argues that so little is known, on the basis of current careful experimentation, leaving a vacuum where proponents of different points of view continue to argue with each other, gathering their own "empirical" evidence.

### 3.7 Ontology of computer technology

#### 3.7.1 Introduction

Ontology of computer interface technology can be important to explain the relationship between science and technology, an important focus of this study. Ontology of instruments can be important to explain the relationship between theory and reality, another area of technological literacy. Constructivism can also be linked to ontology. Constructivism can be defined in many ways. Social constructivism is more of a methodology than a philosophy (Golinski, 1998) and will be covered in a later section. Social constructivism is not an ontological theory. Individual
constructivism (O’Loughlin, 1992) is concerned with the individual’s construction of reality and is ontologically based. This constructivism can be used to explain how the individual constructs their viewpoint on what technology is. Instruments like Tain help construct this reality. Sociology of science or technology can be used to explain the group belief of what technology is. The central similarity between sociological and educational constructivist standpoints rests in each one’s philosophical position on truth and knowledge (Costa, Hughes & Pinch, 1998).

3.7.2 One viewpoint of constructivism of science and technology

Constructivism refers to that process of constructing, in effect, creating a concept, which serves as a guideline against which objects or people can be gauged. During the course of interactions with objects, people, or events the individual constructs a reality of them. This mental construction then guides subsequent actions with the objects or events (O’Loughlin 1992). Thus the use of computer interfaces helps construct views on the nature of technology.

Costa, Hughes and Pinch (1998) recognized a similarity between constructivism and the sociology of science:

‘In sum, the central similarity between sociological and educational constructivist standpoints rests in each one’s philosophical position on truth and knowledge. Like the sociology of scientific knowledge (SSK), educational constructivism dismisses as meaningless traditional notions of
objectivity in scientific knowledge, emphasising instead the human construction of knowledge. (p.12)

Since this research is concerned about the introduction of learning technologies in the classroom, it is concerned about how computer interfaces might lead to different viewpoints on technology. Both the teachers and students may construct their physics concepts in a different way. Costa, Hughes and Pinch (1998) suggest:

‘However, an important difference between SSK and radical constructivism is that the former studies knowledge as constructed by groups while the latter regards knowledge as fundamentally constructed by individuals.’ (p.12)

To understand how computer interfaces were introduced into the classroom it is necessary to study it through a SSK perspective. To understand an individual's viewpoint on technology Costa, Hughes and Pinch (1998) would suggest it is important to understand constructivism.

3.7.2.1 Instrumentalism

This section deals with the relationship between theory and reality. However it concentrates on a more specific area of this relationship, specifically instruments. This is important as the data logging Tain interface is an example of such an instrument. Does the complexity of Tain help to expose or conceal these concerns? Instruments are the centre of Latour’s black box and the argument over the boundary between technology and science.

This could be retitled “construction of knowledge” vs. “constructed nature of reality” because there is a big distinction to be made between epistemology and ontology. In
the battle between 'realist' and 'constructivist' there are many shades of grey which fall into epistemological or ontological realms. Many realists might agree that knowledge is constructed but the reality on which they are constructed is a given. A pragmatist might not be so precious about this concrete reality but more concerned with agreed meaning or reality and the outcomes of this meaning. Someone who believes in positivism lies in between, agreeing that objects have constructed labels but are still real objects (Laudan, 1990).

According to Segal (1997), a realist ontology incorporates the following views:

1. Knowledge is a social and historical product, facts are theory-laden, and the task of science is to invent theories to explain the real world and to test these theories by rational criteria developed within particular disciplines.

2. The real world is complex and stratified so that one is always discovering more complex layers of reality to explain other levels.

3. [In this ] conception of causation, entities act as a function of their basic structure. The task of science is to determine this structure so that one can understand how the entity acts, which must always be in terms of tendencies and probabilities (Maicas & Secord, 1983, as cited in House, 1991, p.2)

3.7.2.2 Pragmatism

It was mentioned in the section on problem of computers that some educationalist are not concerned about technological literacy, but more so in teaching the syllabus. Such viewpoints are considered to be pragmatic. This viewpoint needs to be considered when looking at the power structure to introduce Tain.
Peirce (1905) as cited in Segal (1997) stressed the importance of 'clarifying meanings of intellectual concepts' by tracing out 'their conceivable practical consequences' (p.13). Cherryholmes (1992) explains that pragmatists also accept the scientific realist position that facts are theory laden, but argues that pragmatists recognise that actions are also value-laden.

Selby (1993) states that pragmatists recognise and emphasis the central importance of values already held by scientists in determining their future actions. She argues that school science could make clearer this understanding of scientific knowledge by:

1. Discussing the links between the values of scientists, the motives of those who fund their research and the development of scientific knowledge.
2. From discussing links between the values, feelings and emotions of scientists and the scientific processes in which they engage.
3. From discussing what is, and what is not valued in our culture, and reasons for differences.

Richard Rorty (1989), one of the leading pragmatist philosophers stated:

"In our culture, the notions of 'science', 'rationality', 'objectivity' and 'truth' are bound up with one other. Science is thought of as offering 'hard', objective'. Truth is thought of as correspondence to reality, the only sort of truth worthy of the name. Worries about 'cognitive status' and 'objectivity' are characteristic of a secularised culture in which the scientist replaces the priest. The scientist is now seen as the person who keeps humanity in touch with something beyond itself." (p.14)

Rorty (1989) would like to substitute the idea of 'unforced agreement' for that of objectivity. To put all culture on an epistemological level. He would like to see
'objective truth' replaced by agreed intersubjective agreement. Because of this Rorty is accused of being a relativist, when he would call such definitions as ethnocentrism. This would also destroy the traditional distinctions between knowledge and opinion. Thus he mimics House in his beliefs and indicates his pragmatic nature.

Paul Feyerabend (Rorty, 1989) suggests that the metaphor of enquiry as converging rather than proliferating should be discarded. On the contrary, we should relish that the thought that the sciences as well as the arts will always provide a spectacle of fierce competition between alternative theories, movements and schools.

Anti Kuhnians tend to unite in support of the claim that 'merely psychological or sociological reasons' will not explain why natural science is so good at predicting. Rorty (1989), is not interested in the success of Western science as he is not of Western politics.

Progress is the sense we are less ethnocentric than our ancestors are. Teachers and students need this enlightenment. In Rorty's terms (Rorty, 1989), the understanding that objectivity equals universality gives the teachers and students' power. Knowing is viewed as a process of examining current reality and of other possible realities so that one may become empowered to envisage and enact social transformation (O'Loughlin, 1992).

### 3.7.2.3 Realism

Realism is another viewpoint that students or teachers of the case study might possess to explain the difference between theory and reality. An approach that is
scientific, that incorporates the perspectives of participants, and that leads to social justice is scientific realism, put forward by the philosopher House (1991).

Realists believe there are actually entities electrons (House, 1991).

Scientific realism does not stop at the surface events, like naive realism, but examines the underlying patterns and tendencies.

Incorrectly, according to House (1991), reality came to be defined as equivalent to the empirical that is what is experienced. Anything beyond this was discredited as metaphysics.

House talks of the Central Notion of Causation. This implies we are determined by custom alone. The powers by which bodies operate are entirely unknown. We have no knowledge of anything but phenomena and our knowledge of phenomena is relative and not absolute. If such objects can be verified, it must be solely through their relation to sense data hence all knowledge is based on fallible experience; hence all knowledge is mere supposition (House, 1991). There are degrees of reality. House would view objects as real but phenomena as supposition. Philosopher Larry Laudan would argue that this would be the standpoint of the pragmatist. Laudan would argue that a relativist would go one step further and dispute the reality of the object.

Realists would view the instrument as a physical tool that measures factual entities such as electrons. The realist would be correct in his belief that Tain is more accurate than the old equipment. Laudan would argue that this is a pragmatist view. It can be seen that not only is there a lack of commonality in belief systems, but some lack of agreement of the actual categorization of these belief systems between living and non-living objects. House’s Central Notion of Causation could easily be used in reference to the data logging of Tain but previously presented research tends to
suggest teachers and students fall into the naïve realism category. To them the computer interface presents reality.

3.7.2.4 Critique of a viewpoint of constructivism

If constructivism is a legitimate way for teachers and students to build up the belief systems on technology, then it is important to understand the problems associated with this theory. Problematic features underlying social constructivism emerge once the focus shifts to examining constructivist practice in school settings. These problems involve the untheorized nature of the communication processes involved in active learning, and the unexamined nature of the power relations between teacher and students (O’Loughlin, 1992).

The author, O’Loughlin, was surprised at the degree to which learning outcomes were controlled and directed by apparently well-intentioned teachers who wanted to engage students in specific activities in order that they might derive certain predetermined conclusions (O’Loughlin, 1992). Computer technology with its menu driven practices is perfect for this.

However there is a problem with this as many of the students seemed to have gained a very limited grasp of the underlying principles that the activities were intended to establish. Instead, many of the students treated the activities as rituals to be followed in order to please the teacher and play the game of school (O’Loughlin, 1992).

The conclusion is constructivist teaching does not problematize the voice of authority inherent in classroom pedagogy and texts, students will learn that their voices and cultures are not valued, and that school is not a place in which genuine
construction and construction of meaning is valid. They will also learn that the voice of authority, whether teacher or text, is privileged and authoritative (O'Loughlin, 1992).

Bakhtin (O'Loughlin, 1992), an educationalist, indicates that different speech genres (jargon of professional groups) contain not only different sociocultural perspective on meaning, they also vary in the degree of authority they bear. In a given situation one form of discourse may be regarded as inferior or inappropriate. The discourse of schooling provides a case in point.

Depit (O'Loughlin, 1992) agrees with the authority of different speech genres and argues that working-class children and children of colour have to abandon their speech genres to succeed.

The key question to be asked about schooling as Wertsch, another philosopher, is ‘Who is doing the talking’. Wertsch argues that in schools the ‘speech genre of formal instruction’ takes precedence. Wertsch argues that when teachers ask instructional questions rarely is it their intention to seek information or to provoke dialogue, more likely the question is ‘a directive designed to get the student to participate in formulating the problem in the ‘right way’(O'Loughlin, 1992). Wersch would argue that the meaning of technology could come to the students from the teacher.

Finally, Wertsch makes the point that even when students dialogue among themselves as equals, the possibility of privileging still exists. Those students who have access to and make use of sophisticated technical rational vocabularies and scientific-sounding explanations implicitly carry with them the authority of the speech genres they invoke (O'Loughlin, 1992).
Science teachers, therefore, face the simultaneous challenges of validating their students' personal ways of knowing, introducing them to the powerful speech genres of conventional science, and equipping them with an understanding of the fundamentally socioculturally constituted ways of knowing that underlie science or technology. So that the process of doing science is demystified and they do not feel compelled to defer to the intrinsically authoritative power of the received view (O'Loughlin, 1992).

At this point it is necessary to point out the similarities between constructivism and realism/relativism. One is a theory developed by educationalists and found in their journals, the latter developed by philosophers of science and found in their journals. It is arguable that these terms mean the same but are recognized by different cultures (Costa, Hughes and Pinch, 1998).

3.7.3 Sociology of science and technology

3.7.3.1 Implementing social change through technology

While there was a small amount of research on the impact of data logging, there was plenty of the topic of computers in class. Given that Tain is essentially a digitalised instrument, these papers are relevant to this thesis. Not so relevant were any research papers on simulation or information technology.
The American educator Todd Oppenheimer states:

‘There is no good evidence that most uses of computers significantly improve teaching and learning, yet school districts are cutting programs—music, art, physical education—that enrich children’s lives to make room for this dubious nostrum, and the Clinton Administration has embraced the goal of “computers in every classroom” with credulous and costly enthusiasm.’ (Oppenheimer, 1997, p. 45)

Cuban (1989) in his work on teacher use of machine technologies places the computer as one of a number of technological innovations aimed at making teaching and learning more productive. He found that each of the innovations went through a similar cycle consisting of four phases: expectations, rhetoric, policies and limited use. Often the initial introduction was accompanied by extravagant claims as to the power of the machine to transform teaching and learning. After a period of time use of the machine was formalised in the nature of policy. Then came a backlash where, upon the failure of many of the claims to be met, criticism and negativity accompanied discussion.

Cuban (1993), identifies a number of key impulses in the advocacy of a particular program for using electronic technologies. Each impulse was a different weapon of change, appealing to different actors in the education bureaucracy. The first impulse is the desire to keep schools up-to-date with the work place ensuring students are prepared to compete in a changing job market. The second impulse is the push from the neo-progressives who wish schools to be places where students are active learners busily constructing knowledge that makes sense to them. The third impulse
is the quest for a more efficient education using the power of electronics to teach more quickly and efficiently.

Cuban (1993) predicted that the most common pattern of use would be timetabling students into classrooms containing a large number of desktop machines and that use would seldom exceed 5 percent of the instructional week. He concluded by predicting that the computer, like its predecessors, would be tailored to fit the teacher's perspective and the tight contours of school and classroom settings. Research by Gusky (1986) indicates often the change teachers face come from external sources such as an entrepreneurial school administration. The ideas embodied in these changes may not complement the existing practices or ideology of the classroom teachers yet teachers are expected to be able to take on board the beliefs and practices inherent in the changes and make them their own. Gusky (1986) suggests that teachers change classroom practices before they change their beliefs and attitudes. It is only after they observe positive changes in student learning outcomes that teachers develop a commitment to the change and are then more likely to retain it.

These ideas are also incorporated into a notion of situated pedagogies. Situated pedagogies imply that those involved in educating must directly address social and cultural influences that frame what and who is deemed as important, as having access to the means of communication, and as worthy of our concerted attention (Miller, 1996).
3.7.3.2 Curriculum/syllabus

Fensham (1994) states the following: '...reform of Science education starts with the conceptions of curriculum that science educators have of science and of science teaching and learning, and develops as these conceptions change as a result of the new experiences and challenges that the key persons encounter from inside and outside the school system' (Fensham 1994, p.303). This could be extended to the goal of technology education.

According to Hord and Huling-Austin (1987), educational change is a long and tedious process that does not end with the adoption of a new curriculum or a new approach to teaching. They found that it takes three or more years for teachers to make a substantial change in their teaching. Cronin-Jones (1991) identified several categories of beliefs which appeared to influence curriculum implementation: beliefs about how students learn and their ability level, the teacher's role in the classroom, the relative importance of content topics, and the attitude towards curriculum packages. Assimilation of a new curriculum, particularly if it involves new technologies, should therefore be fostered by in-service teacher training.

Tobin and McRobbie (1994) saw the curriculum shaped by cultural myths such as time being a scarce commodity, with a high priority goal being to cover prescribed content. Add to this a need to prepare students for the next educational level and to succeed in examinations. Also was the problem of specification of the syllabus as the prerogative of the external agencies. They believed the teacher's goals were congruent with those of the students and that building understanding was less of a concern in this system of goals than covering content and preparing for success on examinations Tobin and McRobbie (1994) argue that adherence to these cultural
myths made the teacher disempowered in regard to enacting changes. In doing so they fail to recognize the powers of these myths (nor itemize them) given the context of senior chemistry class. They do recognize the power of the teachers' beliefs as being moulded by their own experience as a foundation of learning. They however place too much importance on the congruence of goals, beliefs and constructions between the teacher and the class. They recognize in framing of goals and context, the micro culture of a classroom interacts with macro culture that includes the actions of others such as administrators at school, district, and state levels, professional organisations of science teachers and chemists, fellow teachers within the department, and school, parents, and members of the community at large. Tobin and McRobbie (1994) will not be drawn as to what are the most important restraints in this culture.

3.7.3.2.1 Innovative curriculum

Research on the development, use, and assessment of curricula designed to improve student conceptions of the nature of science has shown opposite results. Klopfer (Klopfer & Cooley, 1961) and Jones (1965) used a curriculum called 'History of Science Cases for High Schools' (HOSC) and measured its effect with the Test on Understanding Science (TOUS) and found a positive effect. More recently, Aikenhead (1979) tested a curriculum via the Science Process Inventory (Haukoos & Resnick, 1983) and found it to make positive gains. However Troxel (1968) and Tamir (1972) comparing different chemistry curricula noted no difference.
The assumption made by the research above, was for the most part, that the teacher as a variable was ignored.

A review of 27 state curriculum guidelines (Bybee et al. 1991) indicated that slightly less than half of the guides called for the study of the history of science and technology. Examination of state and local social studies curriculum guides show little emphasis on the history of science and technology.

Rennie (1987) argued that changes in the science curriculum were needed to minimise the large uncertainty in the student population as to what technology was.

Rennie and Jarvis (1995a) wanted changes to the teacher-training curriculum to reconcile confusion between the National Curriculum (Department for Education, 1995) definition of technology and the perception held by general society.

3.7.3.2.2 Textbooks as curriculum

Gallagher (1991) reported that given the dominant role played by textbooks, very few mentioned the history and development of scientific ideas, none talk of technology as a process. Bybee et al (1991) examined four areas for evidence of History and Nature of Science and Technology: student and teacher understanding of the subject, curriculum guidelines, studies of actual classroom practice, and current instructional materials. They found very little evidence.

In the new History-Social Science Framework for California Public Schools (1988), which, according to Bybee (Bybee et al, 1991), many thought to be to have a significant impact on social studies nationwide, science and technology are listed as two aspects of culture to be studied in historical perspective. The course descriptions
provided in this document give little specific attention to the history of science and technology, however.

Bybee et al (1991) state that a full program on either the history or philosophy of science and technology has no home in current school science or social studies programs. However, a conceptual framework with recommendations for supplementing and enhancing current programs is an achievable innovation. In addition, teacher preparation programs can incorporate the conceptual framework into their efforts to improve the quality of future science and social studies teachers.

3.7.3.2.3 State involvement in curriculum

Fullan (1991) points out that the biggest development on the educational science has been the increased presence and activity of the state in educational reform.

As Jarvis and Rennie (1996) indicate, the use of unfamiliar words in teaching and learning is a problem in education, created when teachers use specialist words that also have different familiar meanings for example the definitions of technology or learning technology. The problem for children's understanding of definitions arises from a mismatch between a word with both general meanings and specific scientific use. It was shown in the section on the nature of technology, that the state definition of technology varied slightly from country to country. The students of at least one state, Western Australia (Rennie & Sillitto, 1988) had a different viewpoint to the syllabus. This is true when the teachers' concepts of the term are also variable and evolving. This variation is also institutionalised (Rennie & Jarvis, 1995b). Both these concentrate on the process skills associated with technology, of investigation,
research, and identification of need, planning and making. Whereas more common meanings for technology may include computers and high technology objects.

Atkins (1993) in his evaluation of the use of interactive technologies observed that much research in this area fails to provide a curriculum context. He felt that 'research tradition in educational technology has become locked into a restricted means/ends view which holds learning to be unproblematic and value free'.

Rennie and Jarvis (1995a) points at other definitions embracing all human activities, whereas others see technology as a problem solving activity. These are but two of the different prior knowledge backgrounds from which to build a definition of technology. Hence it is important to become more informed about what students understand about the meaning of 'technology' to see how effective changes in the curriculum have been. Also to see whether students have multiple meanings and which ones are more powerful or ingrained. This can also lead to determination as to the effect of teachers and school cultures understanding as to its effect on the students' belief system. Examining the factors that influence student's understanding of this term may also explain how the concept develops. However are all the different voices of authority, VBOS curriculum, the assessment or the textbook viewed to have the same power? This is an unanswered question by the literature.
3.7.3.3 Principal/school

Fullan (1991) describe six distinct platforms surrounding the implementation decisions. They are:

- new approaches to teaching and learning
- the innovating personality
- the visionary principal
- the entrepreneurial school administration
- the resource allocation approach
- social justice initiatives

A seventh pathway may be that of improved efficiency in achieving educational outcomes.

Fullan (1991) explains that principals are being asked to change their role and become active in curricular leadership in the school. The role change is a far more important innovation to the principal than any specific program innovation. Fullan (1991) goes on to indicate that Initiator principals worked more with staff to clarify and support the use of innovation (consultation and reinforcement, with 40% of their interventions in this category compared with 20% for responders and managers. How principals work with other change facilitators (a vice-principal, lead teacher) was noteworthy. Initiator principals worked in collaborative ways with other change facilitators. These collaboratively led schools experienced more interventions (notes to staff, small meetings, conversations about progress) and more multiple target interventions (actions taken with a group or more than one person), more actions...
taken to consult with teachers, more direction by the principal, more action taken by the teachers, and more focus on students and learning.

Hall (1991) concludes that:

'Principals do not lead change efforts single-handedly. Rather, principals work with other change facilitators, who, in most cases, are making a large number of interventions also. It was discovered in earlier studies that the key is not merely having other change facilitators active at the school site; the important difference seems to be related to how well the principal and these other change facilitators work together as a change facilitating team. It is this team of facilitators, under the lead of the principal, which makes successful change happen in schools.' (p. 49)

Hall (1991) proved that the principal is essential for success. The role of the principal is not in implementing innovations or even in instructional leadership for specific classrooms. The larger goal is in transforming the culture of the school.

Fullan (1991) points out that the principal is constantly being admonished to ensure or support implementation of this or that new policy or project. In Canada, revised provincial curriculum guidelines are always on the doorstep as the cyclical revision process continues ad infinitum. The USA has strong indirect presence in local innovation.

3.7.3.4 Teacher

According to Smith (1987), there appears to be a difference in attitudes towards computers between students and their teachers; students are more confident than
teachers in using computers are. This lack of confidence may have an affect on
instructional method. For example, teachers with a weak background in science rely
on lecture and student memorisation (Anderson and Roth, 1989).

However, programs of study in themselves cannot bring about a change. The most
influential factor in educational change is the teacher (Fullan, 1991 as cited in Duffee
and Aikenhead, 1992).

Teachers adapt a curriculum in ways they think are most appropriate for each
specific teaching situation (White, 1988).

In the context of curriculum implementation, Lantz and Kass (1987) discovered that
teacher practical knowledge is heavily dependent upon a teacher’s past experience,
and the current teaching situation.

3.7.3.4.1 Teacher's Visions

Teachers respond to teaching situations by drawing from their past experiences upon
which they formulate decisions for action in an attempt to change the current
situation into one which is better to their own beliefs, values, and vision of what the
teaching situation should be. Visions orient the teacher’s overall conduct by
providing frames that enable the teacher to conceptualise his or her actions (Nespor,
1984)

Visions are formed intuitively from a teacher’s feelings, values, needs, belief,
experiences, theoretical knowledge, and school folklore. Visions provide a mental
picture (an image) of how the teaching situation should be (Feiman-Nemser et al,
1994).
However these visions might be limited. Via interviews with teachers, Gallagher (1991) found their pre service teacher education to lack any history, philosophy, or sociology of science.

Before a teacher actually reaches a decision for action, the teaching situation and all pertinent solutions are reconsidered in terms of the teacher's vision of what teaching should be like. Such images guide and inspire classroom action, in response to a specific teaching situation (Duffee & Aikenhead, 1992). This image provides the teacher with a framework with which to make the adjustments that align (1) the rules and principles of practice and the teacher's beliefs and values, with (2) the demands of the current situation (Duffee & Aikenhead, 1992).

The heuristic is used as a 'clue structure' (Duffe & Aikenhead, 1992).

There is the existence amongst teachers of an entrenched belief in the infallibility and permanence of scientific knowledge (Milne & Taylor, 1995) which makes constructivist reform in science and technology education difficult. When recruiting new teachers consider their background. The science teacher who can most easily adapt to an STS type of course will not be the teacher who has a narrow orientation toward pure science (Duffee and Aikenhead, 1992).

Roth and Lucas (1997) say '..for the teacher, it was not an issue of indoctrinating students to a different kind of truth but presenting knowing as a personal dimension rather than an abstract truth.' (p.148) But what tainted personal dimension is the student creating and whom does it serve?

Palquist and Finley (1997) state that science teachers need to recognize the nature of scientific endeavour and how it relates to science teaching if they are to help students completely understand the content and underlying philosophy of science. They were
concerned how the teacher presented a particular view of the nature of science. Choosing to teach not only the principles and laws but also the history of the accompanying scientific arguments by the critical studies of actual cases may present the more contemporary view that scientists create scientific theories.

Research (Fullan, 1991) shows that teachers find change difficult and confronting. Often the changes teachers face come from external sources such as the Directorate of School education or from an entrepreneurial school administration. The ideas embodied in these changes may not complement the existing practices or ideology of the classroom teachers yet teachers are expected to be able to take on board the beliefs and practices inherent in the changes and make them their own. Research by Gusky (1986) indicates that teachers change classroom practices before they change their beliefs and attitudes.

Cuban (1989) predicted that the computer would be tailored to fit the teacher’s perspective and the tight contours of school and classroom settings. McRobbie and Tobin (1995) argue that the beliefs of a teacher affect their classroom practice, but that this is also constrained by environmental/cultural influences. They define an action as a holistic concept that can be thought of as a set of dialectic interactions involving an individual’s goals, the belief that a set of behaviours is viable in a given context, the individual’s construction of the context in which the action is embedded, and the behaviour of the individual.

Lederman (1992) reviewed later research into the effect of the teacher’s conceptions on student outcomes. He found the initial research on the nature of science (which was supported by more recent investigations) may be summarised as follows:
(a) science teachers do not possess adequate conceptions of the nature of science, irrespective of the instrument used to assess understandings;

(b) techniques to improve teachers’ conceptions have met with some success when they have included either historical aspects of scientific knowledge or direct attention to the nature of science; and

(c) academic background variables are not significantly related to teachers’ conceptions of the nature of science.

The two underlying assumptions to come out of this early research were:

(i) A teacher’s understanding of the nature of science affects his/her students’ conceptions. This was disproved by later research (Rothman, 1969; Durkee, 1974).

(ii) If it is assumed that teachers’ conceptions of science affect students’ conceptions, some method of influence must exist; naturally the influence must be mediated by teacher behaviours and classroom ecology. This lead to the focus on classroom practice. There was some evidence to support teachers’ conceptions affecting classroom practice (Brickhouse, 1989, 1990) as well as the position that there is no influence (Duschl & Wright, 1989; Lederman & Zeidler, 1987). However these papers come to a general agreement about the strong influence of curriculum constraints, administrative policies, and teaching context on the translation of teachers’ conceptions into classroom practice. Because teachers cannot be expected to purposefully teach what they do not understand, many researchers focused their attention on the development and assessment of techniques designed to improve teachers’ conceptions. Unfortunately, the results of such attempts were equivocal and the specific variables contributing to improved conceptions of the nature of science remained unknown.
Toward the end of the 1980s, research on preconceptions has begun to pay attention to teachers' own conceptions about the nature of science and about science teaching and learning, and their influences on the teaching/learning process (Gil-Perez, 1996; Hewson and Hewson, 1988). But no similar research was done on technology.

### 3.7.3.4.2 Teachers and evaluation

Duffe and Aikenhead (1992) looked at the affect of teachers on evaluation. They did this by introducing a new curriculum. Three new areas were included in this new curriculum: the nature of science, STS interrelationships, and the values that underlie science.

They found that teachers select evaluation practices based almost exclusively on their practical knowledge.

All teachers suggested that their evaluation practices had evolved as a result of much trial and error. They all expressed the view that they had little academic training that specifically equipped them to evaluate student work. All stated they were influenced greatly by their own personal experiences of being evaluated as a student (Duffe & Aikenhead, 1992). Once again teachers fall back on old patterns and they are rewarded by a curriculum assessment which is a product of that environment.
3.7.3.5 Students

Driver and Easley commented as follows:

'It would seem that more valuable information could be gained by both curriculum developers and the practising teacher through interviewing pupils in order to understand their ideas and ways of thinking about a topic in question, rather than as a device for classifying pupils and prescribing programmes for them.' (Johnson and Gott, 1996, p.562)

Pupils' explanations for their answers to the questions were highly dependent on the context of the questions. In the case of the scientific context question, pupils tended to misinterpret the instructions in the question about what they were supposed to do. As a result, they gave answers and explanations that were irrelevant, but based on scientific knowledge which appeared to them to be relevant (Song & Black, 1992).

Pupils again tended to concentrate on applying their everyday experience or common sense rather than controlling the variables (Song & Black, 1992).

Rather than being told what developmental psychologists have found, they would become psychologists themselves. Rather than being told how to teach they would construct their own pedagogy (O'Loughlin, 1992). Once again the study was on science not technology.
3.7.3.6 Assessment

It is widely agreed that assessment procedures, and external examinations in particular, exert a significant influence on the curriculum and can promote or hinder the adoption of particular classroom activities (Butler et. al 1996). When teachers contemplate the adaptation of a new curriculum, they give high priority to the issue of student evaluation (Aikenhead, 1984). In this case study all the assessment involving Tain was in practical work.

The work of Tobin (1987) into high school science commented on a number of assertions.

Assertion 1: The assessment system was used to motivate students and had a focussing effect on the implemented curriculum.

At all Year levels, and in all classes, teachers constantly motivate students by referring to tests and exams. Work identified as likely to be tested had higher status than work not so identified. So any learning technology would have to be tied to real and important assessment for both the students and teachers. Otherwise it would not be adopted. Assertion 2: Teacher expectations for student performance and achievement affected the implemented curriculum.

Assertion 3: Teachers endeavoured to cover the curriculum in the prescribed time whether or not learning occurred.

The focus of the implemented curriculum tended to be covering planned content rather than ensuring that students developed depth of understanding.

Assertion 4: Laboratory activities are not an integral part of the science program.
The purpose of laboratory work seemed to be an appendage to the program, but did not contribute to the knowledge to be learned.

Of further relevance were Tobin’s assertions 7 and 8.

Assertion 7: Algorithms and procedures were used to reduce the cognitive demands of the work.

Doyle (1983) defined procedural tasks as those that involved the use of standard routines to generate correct answers. Procedural tasks were differentiated from tasks that require an understanding of why the algorithm works or when it should be used. As a consequence students were able to obtain the correct answer without necessarily understanding the science involved in the problem.

Assertion 8: The cognitive demands of the practical works were low.

Actions of the teacher and the students often reduced the cognitive demands of the academic work for most students in the class. Teachers would set up high cognitive questions and then proceed to answer them by reducing them to a yes no question, at which time they were turned over to the students. Laboratory activities tended to be of a cookbook type with a strong emphasis on following procedures in order to collect data. There was little emphasis on planning an investigation or interpreting results.

3.7.4 Another viewpoint on constructivism of science and technology

According to Milne and Taylor (1995), science education researchers have been directing increasing attention towards constructivism. This educational
constructivism is more in line with social constructivism. It is methodology not ontology (Golinski, 1998). According to constructivist science educators such as Tobin (1990, 1993) and Driver (1988), we develop our knowledge of the natural world by reflecting on the viability of new ideas that spring from our attempts to make sense of new and problematic experiences. Knowledge is not to be found in books; it does not exist out there, separate from us as claimed by objectivists. Instead, from a constructivist perspective, knowledge - the current state of our knowing - resides inside our minds.

Gil Perez and Carrascosa (1994) suggest the metaphor which guides their teaching strategies, conceives pupils as novice researchers and teachers as experts who can orientate the pupils' work. Driver and Oldham (1986) have pointed out, from a constructivist point of view 'the curriculum is seen not as a body of knowledge or skills but the programme of activities from which such knowledge or skills can possibly be acquired or constructed.' Resnick (1994) summarised the characteristics of this approach in three statements:

- Learners construct understanding. They do not simply mirror what they are told or what they read. To understand something is to know relationships.
- Bits of isolated information are forgotten or become inaccessible to memory.
- All learning depends on prior knowledge.

Prior knowledge includes beliefs about digital technology and electronic instrumentation. Gil-Perez (1996) suggests the view of science learning as conceptual change in three basic steps:
• An elicitation phase of pupils' ideas, making them conscious of the plausibility and productivity of those ideas

• A restructuring phase, creating cognitive conflict, generating pupils' dissatisfaction with their current ideas and preparing them for the introduction of scientific concepts.

• An application phase which gives opportunities for using the new conceptions in different contexts and consolidating them.

No research has been done on pupil's ideas on technology but the above three steps could be applied to understand the individual's viewpoint on technology.

Milne and Taylor (1995) argue there are two major principles to the constructivist perspective. The first of which is that learning involves mental construction of knowledge by individuals, rather than absorption from external sources (von Glaserfeld, 1984, 1989). This principle implies learning by interpreting new experiences in relation to our extant knowledge, a process that leads to changes in knowledge including additions, replacements and alterations (Cobern, 1992).

The second principle requires the replacement of the concept of absolute truth with the concept of viability (Mahoney, 1989; von Glaserfeld 1984). This entails the idea, that it is not reasonable to claim that our experiences of the world mirror exactly the reality of the world. As a result, it is generally accepted that there is no justification for claiming that scientific knowledge has absolutely authoritative foundations.

Similarly technological knowledge falls in the same category. The viability criterion entails a tentative view of the nature of scientific knowledge (and for that matter technological knowledge) and an ethical position for teachers of not presenting
current constructions of the world as the only acceptable ones, for example progress as a euphemism for technology.

Research on constructivism indicates certain sociological barriers to changing the nature of science or the nature of technology. For example research by Milne and Taylor (1995) in Australian high schools indicates that the development and implementation of constructivism pedagogies is difficult when the prevailing pedagogy is based on an objectivist theory of knowledge.

Traditionally, the objectivist teacher constructed a learning environment in which his/her expert perspective was dominant. Teaching was regarded as synonymous with the explication of the teacher’s expert perspective, and learning was synonymous with studious absorption and reproduction. One of the hallmarks of objectivist teachers is a belief that their role is to enable students to absorb and understand (what they believe to be) universally correct scientific truths whose certainty is beyond doubt. So there is a link of constructivism with teacher belief influencing the student perception of knowledge. Work by Driver & Bell (1986) and Gardner (1984) showed students often ignore their newly constructed knowledge if it fails to conform to their prior understandings, or they modify their new knowledge so that it does conform to their prior understandings. It can be very difficult to modify students’ preconceptions even if they can be demonstrated logically to be scientifically incorrect. For many students, their intuitive preconceptions provide commonsense explanations of the world, whereas scientific explanations often are experienced as counter intuitive (Larochelle & Desautels, 1991).

For a constructivist teacher the goal is to set up activities that generate cognitive conflict (Milne & Taylor, 1995). This may be problematic in the case of technology,
for two reasons. One, their prior knowledge might not be known and secondly, is it of benefit for the students to change their preconceptions.

This metaphor of a novice researcher is associated with three basic elements of what we can call a ‘radical social-constructivist orientation’ for science learning: open problematic situations, scientific work in cooperative groups and interactions within the groups and the ‘scientific community’, represented by other pupils, the teacher and the textbooks (Gil-Perez, 1996).

Bell and Pearson (1992) have pointed out, that it is not possible to change what teachers and pupils do in the classroom without transforming their epistemology, their conceptions about how knowledge is constructed and their views on about science.

3.7.5 Latour

Latour’s perspective mimics social constructivism. He does not see a difference between epistemology and ontology. Latour’s perspective belongs to radical sociology (Golinski, 1998). In Latour’s view, facts and machines are transmitted in the same manner, passed down the chains of linked persons and things he calls “networks”. Networks are fundamental to the motion from local knowledge in laboratories to worldwide technoscience. The networks comprise Latour’s solution to the problem of construction.

Latour’s networks are heterogeneous linkages of people and things—human and non-human entities he calls “actants”. Latour and his collaborator Callon explain that they are interested in mapping the construction of these heterogeneous networks of
humans and non-human actants because it offers a way of following (though not explaining) the passage from controversial to accepted knowledge (Callon & Latour, 1992).

Before looking at the validity of Latour's claims, his meaning of 'technoscience' needs to be defined. It is arguable that the combining of scientific facts and technical artefacts under the term technoscience is correct. Instruments are a link between science and technology. This confirmed by the Eric Layton (1977), an historian of technology. He states:

'The division between science and technology are not between the abstract functions of knowing and doing. Rather they are social. We recognise science and technology to be on a par with each other. Both sets of practitioners creatively extend and develop their existing culture; but both also take up and exploit some of the culture of the other... They are in fact enmeshed in a symbiotic relationship' (p.166).

Latour's arguments centre on social networks of power. Latour's description of science as power (or what the author argues is technology as power) by process via this blueprint:

'1. Move one : capturing others' interests
2. Move two: moving the leverage point from a weak to a strong position

But the major interest is in the relative power of each different lever Latour mentions. This is something Latour does not investigate and is a perceived weakness of his analysis.
Latour’s view on literature is that it is a lever of power. Latour is talking about scientific literature such as refereed journals. His point, however, is true as far as educational literature is concerned. Text, in any form, as a form of power should be included.

Latour talks about bringing friends in, thus appealing to higher and more numerous allies as an argument from authority (Latour, 1987, p.31.)

Latour’s second rule of method (Latour, 1987, p.59) is that the fate of facts and machines is in the hands of the later users.

### 3.7.5.1 The instrument as a laboratory

Latour (1987) states, in the beginning of his chapter on laboratories:

‘You doubt what I wrote? Let me show you! The very rare and obstinate dissenter who has not been convinced by the scientific text is led from the text into the place where the text is said to come from. I will call this place the laboratory.’ (Ibid. p.64.)

The machine /instrument is the portable laboratory, the text maker. This is the potent but unidentified power level. Inscriptions are created by the machine thus are hard to dispute.

### 3.7.5.2 Instruments and reality/objectivity

Latour talks about appealing to nature. He talks about the two faces of Janus being:
On the left side scientists are realists, that is they believe that the presentations are sorted out by what is really outside, by the only independent referee there is, Nature. On the right side, the same scientists are relativists. They believe representations to be sorted out among themselves and the actants they represent, without independent and impartial referees lending their weight to any one of them (Ibid., 1987, p.252.).

These viewpoints might be defined as technological determinism. In the words of sociologist Bruce Bimber, technological determinism would be defined as believing in the nomological account of technology, which rests on the laws of nature rather than on social norms. Bimber goes on to compare Nomological determinism with Thomas P. Hughes term ‘technological momentum’ which describes the increasing capacity of technological systems to influence societies as those societies grow in size (Latour, 1987, p.89). This idea of momentum does fit the beliefs of the students and teachers. They believed that computers were progress thus they believed that Tain was progress.

3.7.5.3 Machine as an instrument

Latour is correct in making the statement ‘A machine, as its name implies, is first of all, a machination, a stratagem, a kind of cunning, where borrowed forces keep one another in check so that none can fly apart from the group.’ (Ibid., p.127.) This machine automatically brings into line the behaviour of the operator. The operator must obey the instruction booklet if the machine is to function. Any independent or aberrant behaviour by the operator will stop the machine functioning. The machine
cannot easily be reopened, it was designed to be operated by students and as such the operators would not necessarily know how they work. Latour states that if the blackbox is successful it gains its own impetus and inner strength in what he calls the model of diffusion (Ibid., p.132.).

### 3.7.5 4 Social influence of instruments

Latour's chapter on machines comes closest to explaining the success of instruments. It is the fact that the interfaces are machines that make them a powerful lever. Latour's comment: 'The total movement of an artefact, will depend to some extent on your action but to a much greater extent on that crowd over which you have little control' (Ibid., p.104.) can explain the success of instruments. This success was highly dependent on the outside social forces. Latour believes that you need '.. to enrol others so that they participate in the construction of the fact.' (Ibid., p.108)

Latour mentions that it is just not good enough to enrol allies but you must keep them in control. He further mentions that: 'A chain is only as strong as its weakest link' (Ibid., p.121.).

Latour warns that the whole process of enrolment is wasted if others gain credit for it (Ibid., p.118).

Latour was not happy with what he called the diffusion model stating that the blackbox is translated, by each owner, into something different. A powerful example of the translation model is tied up with the users of machines and their different behaviour.
There is criticism of Latour that he doesn’t look at the consequences of this
construction.

Fujiimura, a sociologist, has written:

‘..I want to examine the practices, activities, concerns and trajectories of all
the different participants - including non-humans. In contrast to Latour, I am
still sociologically interested in understanding why and how some human
perspectives win over others in the construction of technologies and truth,
why and how some human actors will go along with the will of other actors,
and why and how some human actors resist being enrolled.. I want to take
sides, to take stands.’(Star, 1991, p.29.)

She is commenting on the fact that Latour is well known for not taking sides.
Up to now the analysis has identified power levers responsible for changes but have
not really attributed which were the most powerful, for example the social or the
instrumental? (Latour would not make a distinction between human and non-human)
This is one flaw with Latourian analysis. Another flaw is Latour cannot explain the
power of the belief in “progress” (Pickering, 1995) which is attributed to technology.

3.7.6 Summary

Lederman’s (1992) conclusion was that the most important variables that influence
students’ beliefs about the nature of science are those specific instructional
behaviours, activities, and decisions implemented within the context of a lesson. It
appears that continued stress on higher-level thinking skills, problem solving,
inquiry-oriented instruction, and frequent higher-level questioning within supportive
risk free environment are at least related to desired changes in students' conceptions.

Debate still surrounds the issue of whether a teacher's understanding of the nature of science is directly related to the development and/or performance of any of the aforementioned variables or other aspects of classroom practice.

As Lederman (1992) points out, while the nature of science is agreed to be an important subject there is no singularly preferred or informed nature of science and that the nature of science is as tentative, if not more so, than scientific knowledge itself. Lederman (1992) warns not to impose a set view on the nature of science but communicate both the changing nature of science, as well as its various forms. If this is a problem with science it is even more of a problem with technology.

Lederman (1992) points to some consensus that the influence of teachers' conceptions on classroom practice is mediated by a complex set of factors (such as curriculum constraints, administrative policies, teachers' attitudes about students and learning, etc.) This complexity marks the answers obtained by research on the conceptions of the nature of science.
Chapter 4

Data
4.1 Introduction

In this chapter, tables of findings are each presented for the four questionnaires. Two questionnaires investigated perceptions of the nature of technology and technology. The third questionnaire is the 1996 questionnaire on Tain practicals and the fourth questionnaire is the 1997 on Tain practicals. The second section of this chapter includes transcripts of interviews arranged to present the background of the introduction of computer interfaces. The material is qualitative and detailed analysis is provided in Chapter 5.
4.2 Students’ interpretation of technology

4.2.1 Data for Year 9 Science students’ view of technology

Table 1 provides data with respect to Student response from four classes of Year 9 Science 1996. All figures are given as percentages of total replies.

<table>
<thead>
<tr>
<th>Category</th>
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<tbody>
<tr>
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<td>Making models</td>
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<td>Inventing</td>
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<td>Transport</td>
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<td>Modern</td>
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<tr>
<td>Easier</td>
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<tr>
<td>Science applied</td>
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<tr>
<td>Technology and society</td>
<td>10 5 4</td>
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<tr>
<td>Negative</td>
<td>3 3 3</td>
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</table>

Table 1 Questionnaire: What is technology? Figures in brackets are comparative percentages with Rennie and Sillitto (1988)
4.2.2 Data for Year 11 Physics students’ perception of technology

Table 2 shows student responses from three Year 11 Physics classes 1996 that have been categorised. All figures are given as percentages of total replies.

<table>
<thead>
<tr>
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Table 2: What is technology?
4.2.3 Data for Years 11 and 12 Chemistry and Physics

students’ perception of technology

Table 3 shows student responses from a Year 11 and Year 12 Chemistry and Physics 1997 that have been categorised. All figures are given as percentages of total replies.

<table>
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<td>Technology and society</td>
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<td>Negative</td>
<td>2</td>
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</table>

Table 3: What is technology?
4.2.4 Data for teachers’ perception of technology

Table 4 shows the teacher responses 1997 that have been categorized. All figures are given as percentages of total replies.

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<thead>
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<tr>
<td>Test and develop ideas</td>
<td></td>
</tr>
<tr>
<td>Inventing</td>
<td>8</td>
</tr>
<tr>
<td><strong>Machinery</strong></td>
<td></td>
</tr>
<tr>
<td>Computers</td>
<td>23</td>
</tr>
<tr>
<td>Electrical</td>
<td>8</td>
</tr>
<tr>
<td>Transport</td>
<td></td>
</tr>
<tr>
<td>General machinery</td>
<td>23</td>
</tr>
<tr>
<td><strong>Learning/Science</strong></td>
<td></td>
</tr>
<tr>
<td>Equate with science</td>
<td></td>
</tr>
<tr>
<td>Acquiring learning</td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Secondary industry</td>
<td></td>
</tr>
<tr>
<td>Art</td>
<td></td>
</tr>
<tr>
<td>Textile</td>
<td></td>
</tr>
<tr>
<td>Modern</td>
<td>8</td>
</tr>
<tr>
<td>Progress</td>
<td>15</td>
</tr>
<tr>
<td>Easier</td>
<td>15</td>
</tr>
<tr>
<td><strong>Science applied</strong></td>
<td></td>
</tr>
<tr>
<td>Technology and society</td>
<td></td>
</tr>
<tr>
<td><strong>Negative</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: What is technology?
4.3 Technology questionnaire

4.3.1 Response to technology questionnaire for Year 9

Science and Year 11 Physics students

Table 5 shows the responses of Year 9 Science and Year 11 Physics 1996

<table>
<thead>
<tr>
<th>The categories are: A = agree D = disagree U = undecided</th>
<th>Science9A</th>
<th>Science9B</th>
<th>Science9C</th>
<th>Science9D</th>
<th>Physics11A</th>
<th>Physics11B</th>
<th>Physics11C</th>
</tr>
</thead>
</table>

gram: What is technology?

1. Technology mainly concerns computers and similar equipment. | A | U | U | A | A | A | U |
2. Making models and testing them is part of technology. | A | A | A | A | A | A | A |
3. Technological appliances can only be used by qualified people. | D | D | D | D | D | D | D |
4. Working with materials is an important part of technology. | A | A | A | A | A | A | A |
5. Without electricity, there would be no technology. | U | D | D | D | D | D | D |
6. Technology involves designing solutions to problems. | A | A | A | A | A | A | A |
7. Most people have little to do with technology in their everyday lives. | D | D | D | D | D | D | D |
8. In technology there are opportunities to design new products. | A | A | A | A | A | A | A |
9. Two hundred years ago there was no technology. | D | U | D | D | D | D | D |
10. Technology means inventing new ways of doing things. | A | A | A | A | A | A | A |

Part B: What do you think about technology?

1. I am interested in technology. | A | A | A | A | A | A | A |
2. Technology makes the world a better place to live in. | A | A | A | A | A | A | A |
3. I would like to learn more about technology. | A | A | A | A | A | A | A |
4. Technology has brought more good things than bad things. | U | U | U | A | A | A | A |
5. I would like a career in technology later on. | U | A | U | A | A | A | A |
6. It is worth spending money on technology. | A | A | U | A | A | A | A |
7. I like to read books and magazines about technology. | U | A | A | A | A | A | A |
8. Inventions in technology are doing more good than harm. | U | U | A | U | A | A | A |
9. I would like to join a hobby club about technology. | U | U | U | D | D | D | U |
10. Technology is needed by everybody. | A | U | A | A | U | U | A |

Table 5: Technology questionnaire
4.3.2 Response to technology questionnaire for Physics teachers

Table 6 shows the responses of the Physics teachers in 1996 to the technology questionnaire.

The code for the responses are: A = agree D = disagree U = undecided

<table>
<thead>
<tr>
<th>Part A: What is technology?</th>
<th>Justin</th>
<th>David</th>
<th>Karl</th>
<th>Geoff</th>
<th>Shaun</th>
<th>Adrian</th>
<th>Paul</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Technology mainly concerns computers and similar equipment.</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>2. Making models and testing them is part of technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>3. Technological appliances can only be used by qualified people.</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>4. Working with materials is an important part of technology.</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>U</td>
<td>A</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>5. Without electricity, there would be no technology.</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>6. Technology involves designing solutions to problems.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>7. Most people have little to do with technology in their everyday lives.</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>8. In technology there are opportunities to design new products.</td>
<td>U</td>
<td>A</td>
<td>A</td>
<td>U</td>
<td>A</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>9. Two hundred years ago there was no technology.</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>10. Technology means inventing new ways of doing things.</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part B: What do you think about technology?</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am interested in technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>2. Technology makes the world a better place to live in.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>U</td>
<td>A</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>3. I would like to learn more about technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>4. Technology has brought more good things than bad things.</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>5. I would like a career in technology later on.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>U</td>
<td>D</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>6. It is worth spending money on technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>U</td>
<td>A</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>7. I like to read books and magazines about technology.</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>U</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>8. Inventions in technology are doing more good than harm.</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>9. I would like to join a hobby club about technology.</td>
<td>D</td>
<td>D</td>
<td>U</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>10. Technology is needed by everybody.</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Technology questionnaire
### 4.3.3 Response to technology questionnaire for subject coordinators, technicians and Principal

Table 7 shows the responses of Subject coordinators, technicians and Principal in 1996 to the technology questionnaire.

The following are responses to the technology questionnaire. A = agree D = disagree U = undecided

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Technology mainly concerns computers and similar equipment.</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>2. Making models and testing them is part of technology.</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>3. Technological appliances can only be used by qualified people.</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>4. Working with materials is an important part of technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>5. Without electricity, there would be no technology.</td>
<td>A</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>6. Technology involves designing solutions to problems.</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>7. Most people have little to do with technology in their everyday lives.</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>8. In technology there are opportunities to design new products.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>9. Two hundred years ago there was no technology.</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>10. Technology means inventing new ways of doing things.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part B: What do you think about technology?</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am interested in technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>2. Technology makes the world a better place to live in.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>3. I would like to learn more about technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>4. Technology has brought more good things than bad things.</td>
<td>A</td>
<td>A</td>
<td>U</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>5. I would like a career in technology later on.</td>
<td>A</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>6. It is worth spending money on technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>7. I like to read books and magazines about technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>8. Inventions in technology are doing more good than harm.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>9. I would like to join a hobby club about technology.</td>
<td>A</td>
<td>U</td>
<td>A</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>10. Technology is needed by everybody.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

Table 7: Technology questionnaire
### 4.3.4 Response to technology questionnaire for Year 11

**Physics teachers and their students**

Table 8 shows the teacher responses compared with their students’ response in 1996.

The following are responses to the technology questionnaire. A = agree, D = disagree, U = undecided. The code for each column: S = overall student response, T = teacher response.

<table>
<thead>
<tr>
<th>Part A: What is technology?</th>
<th>Justin’s Class 11A</th>
<th>Shaun’s Class 11B</th>
<th>David’s Class 11C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Technology mainly concerns computers and similar equipment.</td>
<td>A</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>2. Making models and testing them is part of technology.</td>
<td>A</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>3. Technological appliances can only be used by qualified people.</td>
<td>D</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>4. Working with materials is an important part of technology.</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>5. Without electricity, there would be no technology.</td>
<td>D</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>6. Technology involves designing solutions to problems.</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>7. Most people have little to do with technology in their everyday lives.</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>8. In technology there are opportunities to design new products.</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>9. Two hundred years ago there was no technology.</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>10. Technology means inventing new ways of doing things.</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

**Part B: What do you think about technology?**

| 1. I am interested in technology. | A | A | A | A | A |
| 2. Technology makes the world a better place to live in. | A | A | A | A | A |
| 3. I would like to learn more about technology. | A | A | A | A | A |
| 4. Technology has brought more good things than bad things. | A | A | A | A | A |
| 5. I would like a career in technology later on. | A | A | A | A | A |
| 6. It is worth spending money on technology. | A | A | A | A | A |
| 7. I like to read books and magazines about technology. | A | A | D | A | A |
| 8. Inventions in technology are doing more good than harm. | U | A | A | A | A |
| 9. I would like to join a hobby club about technology. | D | A | D | U | D |
| 10. Technology is needed by everybody. | U | D | U | D | A |

Table 8: Technology questionnaire
4.4 Practical Questionnaire

4.4.1 Analysis of Practical Questionnaire for Year 11, 1996

Q1. Which practical did you enjoy most? The one with the carts or the one with the Tain interface? “n” equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>Shaun n=13</th>
<th>Justin n=12</th>
<th>David n=9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tain</td>
<td>46</td>
<td>75</td>
<td>66</td>
</tr>
<tr>
<td>Cart</td>
<td>46</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Same</td>
<td>8</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 9 Responses of Year 11 students to question 1, 1996

Year 11 was also asked to justify their responses.

Shaun’s class gave 12 responses, 25% said Tain was easier, 17% said Tain was accurate, 8% said Tain allowed more time on analysis, 17% said the cart was more tangible, 8% said the cart was easily understood, 8% said the cart required more thought, 8% said the cart required group action.

Justin’s class gave 10 responses, 35% said Tain was more accurate, 18% said Tain was easier, 12% said Tain uses computer, 6% said Tain does the graph, 6% said Tain was faster, 6% said Tain was less boring, 12% said the cart requires thinking.

David’s class gave 9 responses, 20% said Tain was new, 20% said Tain was faster, 10% said Tain was easier, 10% said Tain processes information, 40% said the cart can see the practical operate.
Q2. Which practical explains the Physics concepts better to you? “n” equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>Shaun n=13</th>
<th>Justin n=9</th>
<th>David n=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tain</td>
<td>15</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>Cart</td>
<td>15</td>
<td>50</td>
<td>44</td>
</tr>
<tr>
<td>Same</td>
<td>70</td>
<td>10</td>
<td>23</td>
</tr>
</tbody>
</table>

Table 10 Responses of Year 11 students to question 2, 1996

When year 11 students were asked to justify their responses, 8% of Shaun’s class said Tain was more accurate and 8% said Tain helped to plot graphs better. 60% of Shaun’s class responses thought the cart allowed you to see the results better, 8% said the cart was not just a computer and 8% said the cart practical was not just instructions.

35% of Justin’s class responses said Tain was more accurate and 18% said Tain was easier. 12% of Justin’s class response thought the cart required thinking.

57% of David’s class responses said that Tain allowed you to see the data, whilst 43% of his class responses said you could see the cart working.

Q3. Which practical is easier to do? Why? “n” equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>Shaun n=13</th>
<th>Justin n=10</th>
<th>David n=9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tain</td>
<td>77</td>
<td>82</td>
<td>67</td>
</tr>
<tr>
<td>Cart</td>
<td>16</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>Same</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 11 Responses of Year 11 students to question 3, 1996
When year 11 students were asked to justify their responses, 45% of Shaun’s class responses said Tain involved less work, 18% said Tain was more accurate and 9% said Tain was a data gatherer. 9% of Shaun’s class responses thought the cart shows you how the practical operates and 9% said the cart was more enjoyable.

33% of Justin’s class responses said Tain was easier, 11% said Tain was accurate. While 22% of Justin’s class responses thought the cart was simpler.

75% of David’s class responses thought Tain required less equipment, 12.5% thought Tain was time saving and 12.5% liked the data processing of Tain. There was no response in David’s class in favour of the cart.

Q4 What is the advantage of using the Tain interface? “n” equals number of responses; all figures are percentages.

| Shaun n=13 | faster 50%, accurate 50% |
| Justin n=17 | accurate 35%, easier 24% |
| David n=18 | accurate 44%, graphing ability 17%, faster 17% |

Table 12 Responses of Year 11 students to question 4, 1996

Q5 What is the disadvantage of using Tain interface? “n” equals number of responses; all figures are percentages.

| Shaun n=13 | hard to understand software 23%, not understand how it works 15% |
| Justin n=10 | not understand how it works 22%, technical difficulty 22%, computer knowledge required 22% |
| David n=12 | fragile 33%, slow to set up 25% |

Table 13 Responses of Year 11 students to question 5, 1996
Q 6. Is the Tain better to use for electronics pracs or force/motion pracs? “n” equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>Shaun n=13</th>
<th>Justin n=10</th>
<th>David n=9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>electronics</td>
<td>64%</td>
<td>50%</td>
<td>44%</td>
</tr>
<tr>
<td>force/motion</td>
<td>7%</td>
<td>30%</td>
<td>44%</td>
</tr>
<tr>
<td>same</td>
<td>29%</td>
<td>20%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Table 14 Responses of Year 11 students to question 6, 1996

When students were asked to justify their responses, the most common responses in Shaun’s class were for electronics: accurate, nature of data, less reliance on human interaction. While in Shaun’s class the most common responses for force/motion practicals were that other equipment was better suited.

In Justin’s class, responses for electronics were: 44% said Tain was accurate and 11% said Tain was better as multimeter. In Justin’s class responses for force/motion practicals, 11% said Tain was too complex for electronics.

The most common responses in David’s class were: for electronics 40% thought Tain was better as multimeter. While for force and motion in David’s class, responses thought Tain confusing as multimeter.

Q 7. Explain how the ticker tape machine can determine velocity. “n” equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>Shaun n=13</th>
<th>Justin n=10</th>
<th>David n=9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct</td>
<td>83%</td>
<td>80%</td>
<td>80%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>17%</td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Table 15 Responses of Year 11 students to question 7, 1996
Q8. Explain how the pulley of the Tain interface can determine velocity. “n” equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>Shaun n=13</th>
<th>Justin n=10</th>
<th>David n=9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct</td>
<td>23%</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>77%</td>
<td>40%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Table 16 Responses of Year 11 students to question 8, 1996

4.4.2 Responses to the practical questionnaire for Year 11, 1997

Q1. Heating and temperature. “n” equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>advantages</th>
<th>disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>thermometer n=6</td>
<td>simpler 33%, ease of use</td>
<td>unable to record</td>
</tr>
<tr>
<td></td>
<td>33%, ease of set up 33%</td>
<td>continuous data 50%, not</td>
</tr>
<tr>
<td></td>
<td></td>
<td>accurate 50%</td>
</tr>
<tr>
<td>thermocouple (Tain) n=7</td>
<td>graphing 37%, accuracy</td>
<td>hard to set up 33%, time</td>
</tr>
<tr>
<td></td>
<td>37%</td>
<td>consuming 33%</td>
</tr>
</tbody>
</table>

Table 17 Responses of Year 11 students to question 1, 1997
Q2. Mechanics. "n" equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>advantages</th>
<th>disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamics cart n=10</td>
<td>simplistic 30%, know how it works 20%, fun 20%</td>
<td>slow 38%, never works 15%, less accurate 15%</td>
</tr>
<tr>
<td>Tain interface n=10</td>
<td>graphing 30%, produces results other equipment cannot 30%</td>
<td>time to set up 50%, difficult to understand 25%</td>
</tr>
</tbody>
</table>

Table 18 Responses of Year 11 students to question 2, 1997

Q3. Electricity. "n" equals number of responses; all figures are percentages.

<table>
<thead>
<tr>
<th></th>
<th>advantages</th>
<th>disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>meters n=16</td>
<td>easy to see results 50%, quicker 20%</td>
<td>too complicated 43%, less reliable 29%</td>
</tr>
<tr>
<td>Tain interface n=7</td>
<td>accurate 57%, user friendly 29%</td>
<td>time to set up 43%, didn't understand 43%</td>
</tr>
</tbody>
</table>

Table 19 Responses of Year 11 students to question 3, 1997

4.4.2.1 Response to section B of practical questionnaire for Year 11, 1997

Students were asked what technology they used in Year 11. Of the ten responses, five students said computers, two said Tain, one said videos, one said projector and one said thermometer.
The same students were also asked about the effectiveness of computers. The ten responses said the advantages were: accurate results (4 students), spread-sheeting (2 students), word processing (1 student), increased effectiveness (1 student). Only 2 students mentioned the disadvantages of wasting time setting up.

Students were asked whether Tain interface teach physics concepts better than the practicals it replaced. Of the ten responses, six said it was better, three said it was worse and one was undecided.

Students were also asked what topic areas (heat, mechanics, temperature) better suited Tain interface. Of the ten responses, four students said mechanics, four students electricity and two students said heat/temperature.

Students surveyed said that technology was computers, machinery and progress, and six students said they derived this perception from media, two students from advertising and two students from school.

Eighteen students responded with their viewpoint of technology and its relationship to science as follows:

| A. science and technology are the same | 0% |
| B.(i) science precedes technology | 50% |
| B.(ii) science and technology are independent | 0% |
| B.(iii) technology precedes science | 10% |
| B.(iv) technology and science engage in two-way interaction | 40% |

Table 20 Responses of Year 11 students to section B, 1997
4.4.3 Responses to Year 12 Questionnaire on nature of technology, 1997

Nineteen students responded with their viewpoint of technology and its relationship to science as follows:

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. science and technology are the same</td>
<td>5%</td>
</tr>
<tr>
<td>B.(i) science precedes technology</td>
<td>37%</td>
</tr>
<tr>
<td>B.(ii) science and technology are independent</td>
<td>5%</td>
</tr>
<tr>
<td>B.(iii) technology precedes science</td>
<td>16%</td>
</tr>
<tr>
<td>B.(iv) technology and science engage in two-way interaction</td>
<td>37%</td>
</tr>
</tbody>
</table>

Table 21 Responses of Year 12 students to question 6, 1997

Students were asked about the technology they used in year 11 Physics. Of the responses, 13 mentioned Tain, 9 mentioned ticker tape, 5 mentioned multimeter, 3 mentioned dynamics cart, 2 mentioned the lightbox, 2 mentioned video, 2 mentioned computers, 1 mentioned software, 1 mentioned weights and 1 mentioned lights.

Students were asked about the technology they used in year 12 Physics. Of the responses, 9 mentioned the multimeter, 9 mentioned electronic components, 7 mentioned the Cathode Ray Oscilloscope, 4 mentioned computers, 4 mentioned signal generators, 3 mentioned Tain, 2 mentions were made each of power packs, video, bread boards, soldering iron and 1 mention was made each of camera and integrated circuits.

Students were asked whether use of computers in Physics has been effective. Of the advantages mentioned by the students, seven said greater accuracy, five said Tain
was easier to read, three said Tain processed real time data, two said Tain easier to use and one student mentioned the multi-use capability of Tain. Of the disadvantages mentioned by the students, five said the software, four said Tain was hard to set up, three said Tain gave no idea of physics concepts, two said Tain was time consuming to set up 9%, whilst another two mentioned the lack of speed of the computer and one student each mentioned learning how to use it, expensive to replace, calibration difficult, simplistic representation, lack of accuracy and not user friendly.

4.4.4 Responses to practical questionnaire from Physics teachers’ interviews, 1997

Seven teachers were asked what technology did they use in Year 12 Physics.
Ten mentions were made of Tain, five mentions were made of electronics, two mentions were made of computers, two mentions were made of software and one mention was made of the overhead projector.

Seven teachers were asked what technology did they use in Year 11 Physics.
Four teachers said Tain, two said computers, one teacher each mentioned electronics, ticker-timer, pulleys and audio-visual equipment.

Seven teachers were asked how effective had been the use of computers in Physics.
The advantages mentioned included two teachers indicating student interest, two teachers indicating accuracy; two teachers indicating instant feedback and two teachers indicated computers helped to prove concepts.
The disadvantages mentioned included one teacher indicating too much taken as read, one teacher indicating computers made it easy to copy work, one teacher indicated lack of computer resources and one teacher stated that computers did not allow the concepts to be understood.

Of the seven teachers were asked whether Tain was better than traditional practicals, four said yes, three said no and one said there was no difference.

Three teachers said Tain lends itself to topic of electricity, three teachers said Tain lends itself to mechanics and one teacher said Tain lends itself to heat/temperature.

Seven teachers were asked about the factors influencing the adoption of computers over the last two years. Of the responses, three mentioned the Physics co-ordinator, two mentioned the Physics technician, two mentioned the Physics teachers’ conference, one mention was made each of the Principal, assessment and cheap computers.

When the seven teachers were asked as to where their students obtained their definition of technology, six teachers said the media and one teacher said an Information technology assignment.
Seven teachers categorized their viewpoint of technology and its relationship to science as follows:

<table>
<thead>
<tr>
<th>Viewpoint</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. science and technology are the same</td>
<td>0%</td>
</tr>
<tr>
<td>B.(i) science precedes technology</td>
<td>4%</td>
</tr>
<tr>
<td>B.(ii) science and technology are independent</td>
<td>0%</td>
</tr>
<tr>
<td>B.(iii) technology precedes science</td>
<td>0%</td>
</tr>
<tr>
<td>B.(iv) technology and science engage in two-way interaction</td>
<td>3%</td>
</tr>
</tbody>
</table>

Table 21 Responses of teachers to question 6, 1997

4.5 Teacher interviews on technology in Physics

The following account is determined from interviews with the staff. It is meant to give the reader the context of the events that occurred and the background under which the questionnaires were surveyed. The analysis of these comments will occur in Chapter 5.
4.5.1 Learning technology in Physics prior to 1996

Physics teacher Paul said:

'I used simulations for many years using BBC computers. I asked the previous Physics coordinator to get the television adapted for the BBC monitor... so he could display the simulations to the rest of the class. This was the extent of learning technologies in the form of computers in Physics. Five years ago I talked to Ian, the present Physics Coordinator about buying one Tain interface and trialing it. That is to have a Tain demonstration to wheel into a room. Later that year it was demonstrated at the Monash Physics Conference. I coerced Ian to seeing technology demonstrations as the conference had a technology bent.'

However according to Ian he was already thinking about going down this path. He said:

'It goes back to when I taught at Dandenong High over 10 years ago. I saw electronics courses going down this track.'

The Physic coordinator saw the interface technology as subject specific. He said:

'I first hit on doing something at Springvale High in 1979-80. I noticed the stuff used at tertiary level. The prices came down. At the Physics conference of 1991 I noticed that Tain was the vehicle to do this'
The Physics-co-ordinator was already pursuing a path which had not appeared in the School Charter or Ministry guidelines. Paul said:

'I started on the Curriculum Resources Group. I drafted a letter to parents for three computers, two printers and put a notice into the school paper asking for donations. A submission to Parents and Friends asked for $10,000 for interfaces. The idea was to put in a new submission once we set up the Physics laboratory. Also on the Curriculum Resources group was the Technology coordinator who saw a necessity to network the whole school infrastructure then faculties could develop their own networks.'

Ian supports part of this story. Ian stated:

'The first thing I did as coordinator was buy one of the Tain interfaces, but we were limited by time to implement. In 1993-94 I advertised in the school newsletter for old computers. The ones we obtained became redundant as we got 286 computers as old stock from the Information Technology faculty. At this time we were sceptical about Tain as it was just a little box. Meanwhile in the background the School Charter justified what I had already done.'

The importance of a lab technician with specialist skills in this area became apparent. Up to this time there had been a lab technician who was also shared with Chemistry and Biology and Science. As Paul says:

'Teachers are not technocrats. They are there to do the job they are paid for; quality teaching. I had argued with the previous Principal that teachers should not do the physical tasks. Ian showed me a draft of the criteria to select David. Technical support is number one. Maintenance support is number two. Clerical support was a bonus'
Ian concurred, stating:

'In 1995 we had Wei as a lab technician but the first classroom refurbishment of Physics stopped development for a while, then he left after a year. A lab technician who has the time is tantamount (sic) as this is forefront stuff. Wei never got the opportunity.'

4.5.2 Learning technology in Physics during 1996

David was appointed Lab technician in March 1996. He said:

'I was appointed to bring in Tain interface into Physics. Already in place were only 286 computers at year 11 with more in cupboards. First thing I designed was the PIAT (temperature) stuff. Late in the year I got 286s into Year 12. Not a full set, just eight.'

As to the Year 11 Physics practicals in 1996, David said:

'I didn't introduce the probes into the cork box/temperature practicals. I pushed but it didn't happen. Some classes did it but majority had thermometers.'

As far as Movement practicals as Year 11 David mentioned:

'Movement was seen through the pulley interface via the F= ma practical. It was a real pain because the worry that the theory was beyond (the students). We did the energy practical with Tain and this saved using the ticker timers.'

The F=ma practical was typical of the development needed to bring Tain into use. As David explained:
...based F=ma on a writer who had done a lot of practicals for Tain. However it needed some deepening. The big hassle, the time consuming aspect of the practical is the writing it up because you have to make sure every instruction works. That it is foolproof. It takes draft after draft and there are always hiccups when the kids do them'.

David said the big push came at the end of that year for a Power monitor:

'Some year 12 guys had done Capacitor theory for CAT 2 and asked me to design a probe to measure. I had a half-hearted attempt at a voltage divider in June or July 1996. Ian (the Physics coordinator) put the hard word on me to do it for Unit 2 Electricity. Tain had a power monitor but it couldn’t measure milliamps so had to work out current shunts to do it.'

Ian added more specific detail to the picture. Ian said:

'The power monitor operated on 5-10 amps. I phoned Stephen from Tain and said we could use a 100mA range. He said it was not available but that he would send a circuit diagram. We saw that it could be modified so I phoned back with these suggestions. He then spoke to his technical people and said it could be modified for 100mA. He has made them available to other schools'.
There were a number of year 11 electricity practicals done in 1996. Ian said:

`Starting current of a lamp was one that was offered for the first time. It allowed capture of measurements in milliseconds. Something that could not be done by the students before. It showcases the accuracy of the technology and was designed to indicate the possibilities of this equipment should the students want to use it in their Year 12 CAT next year. It was not part of the actual syllabus. Similarly, how to measure AC using Tain was of the same vain.'

Laboratory work in the Year 12 Physics classes did not use Tain. However there were a number of demonstrations for the teachers; one of sound wave capture, another of the ultrasonic sensor set up for circular motion. A large number of year 12 students did use Tain for their CAT project. David pointed out:

`Stacks were using the power monitor for electronics projects like: amplifier, rectification, Flip-flop, capacitors. No one did sound. Tain was mildly successful. This year (1997) it is just fine-tuning.'

4.5.3 Learning technology in Physics in 1997

In 1997 the work of the Curriculum Resource Development Group (CRDG) had an impact on the Physics faculty. The networking of the school in 1994 solved a technical problem encountered with the introduction of second hand 386 computers. David explained:
‘The hard drives were so crummy we could put them on a server. It is also not incredibly important for them to print off Excel and Word as the thing is so slow...In 1997 we want to refine the process. Fix up the errors. Add more rigidity, making sure the teachers do the practicals’.

David elaborated on how Tain was increasingly used for year 12 CATS:

‘They haven’t used them instead of dual trace CRO’s. Instead students who wouldn’t have done electronics CATS have done them now. Still a lot are using them for things that need long time recording, which is tedious or repetitious. The Capacitor practical they previously did with a stopwatch and voltmeter. Now the capacitor practicals are right on top. At least two dozen. The other push is for more practicals. The strain gauge was set up but it didn’t happen. I looked at the structure and materials testing. The main trick was it would demand a lot of time from me to attach a flexible sample and weigh it down. It would take a lot of time researching.’

He indicated that Tain was being used increasingly in topic areas not linked to learning technology equipment.

To the question of ‘What does the future holds?’ a variety of goals are put forward. In 1997 the push came from the administration for a presentation station in each room with the capability for computer overhead presentations. The Physics technician had already spent a month chasing up material on it already. As he explained:

‘Ian has always pushed to get technology in the department. When the AV (audio visual) stuff came up he wanted to get a big screen in 1996 but the money was used up on a 386 computer, so he was a year ahead’.
David further explained:

‘Get all the handouts on the servers. Ultimately on the Internet. The sampler stuff.....Since Tain costs so much money, we don’t want to buy anything out of date. We need to solder. We need to update. We are locked into for 2 years to use Tain that is all we can afford. Hopefully the kids will make samplers as they cost $30, and it does pretty much what Tain does. Maybe if I make 10 and sell them. But there is the issue of time and payment. Most of it is modular and multipurpose. The thing that drives most of this is cost.’

Ian agreed with David. He said:

‘Ultimately what I would like to do with Tain is teach the kids to make their own probes, but first we need to get up to speed ourselves. Adaptation is on the part of the teacher. The equipment is always there. Hundreds of kids have used the CROs, but only 4 dual trace CROs are available at any one time.’

David added:

‘Technology is great to have but costs. Kids get data and not what’s going on. They take the easy way out. Do it like a monkey. Four CATS were dynamite not A+ but like MOSFET first year university. Like bouncing balls with different pressures. Real world physics. Mechanics stuff they could do but examples of CATs shown do not have many motion practicals then again we only have one ultrasound unit for motion CATs.’
4.5.4 Other perceptions of learning technology in Physics

The scenario of the introduction of technology to Physics as presented by three of the main players is not necessarily the perception of the other teachers in faculty. Seven other Physics teachers were asked how did computers develop over the last two years and who/what influenced the changes? Most teachers mentioned the Laboratory technician. One mentioned the Physics coordinator. Two mentioned the Principal. The opinion varied from Geoff, who thought the 1994 Charter directive put the money in and the Lab technician introduced Tain. Karl thought it was due to cheaper technology being available but recognised the contribution of the teacher’s conference and the technician. Adrian, a Year 11 teacher was brave enough to say he had no idea where the push came from. David thought the coordinator was reacting to the Principal who was reacting to his 10% performance bonus, and the end of the buck-passing was the lab technician. However, the Principal was quite adamant that the push for technology was not coming from him. He suggested that a pay could be improved by implementation of any of a number of areas such as student leadership. The Principal was quite adamant that the school was not going down the laptop or multimedia track as there had been no perceived advantage to the students. That technology might be useful in some curriculum areas for enhancement. The introduction of technology in subject areas was also reflected in what was needed out in the real world. So for example Commerce was using a large number of computers. The Principal thought the Physics coordinator was pushing technology into the subject and that as part of the Principal’s role he had to give encouragement. Beyond this he had no knowledge as to how technology implementation had occurred.
Chapter 5

Discussion
5.1 Viewpoints of students/teachers and school administrators on science and technology

The following is a discussion of key findings from the tables and interviews presented in chapter 4. Each section will identify the data being analysed from the previous chapter. In the first section of this chapter concurrent statements are provided and analysed.

5.1.1 Nature of Technology

The following section uses information from chapter 4 to respond to the question ‘What is technology?’ The data used was presented in section 4.2

5.1.1.1 Discussion of Year 9 Science students’ responses

The two major categories of technology indicated by Year 9 Science students were computers and progress. The categories electrical machinery and general machinery were the next most popular. There are only minor differences between the classes. Though Class A mentions in greater numbers the category: testing and development of ideas. Testing and development of ideas is more aligned to a view of technology as a process. However, the majority of Year 9 Science students picked terms which aligned to technology categories of artefacts and positive progress. A previous study by Rennie and Sillitto (1988) on Year 8 students showed the students rated in their study the same categories as most important. The only difference between studies was the percentages were smaller for each category chosen by the Year 8. This trend
indicates that the Year 8 students were not quite as convinced that technology was computers and progress. The study by Rennie (1987) stated that students at Year 8, students were unaware as to what technology was.

These responses are interesting because Year 9 science is compulsory for all students and it therefore includes students who will not specialise in science subjects.

The reason for computers dominating the answers is open for speculation and is investigated within section 5.3.2. The Board of Studies definition of technology given in section 3.3.3 stated that technology refers to the equipment and processes people use to enhance and support human endeavour, it is easy to see computers and progress fall within this definition. The concern is that one piece of equipment represents technology so graphically and that no real mention is made of processes. It seems the students have learnt technology (theoretical knowledge) but not learnt about technology (developing an understanding of the nature and methods of technology). This argument of technology as ontology or technology as epistemology becomes important when introducing instruments such as Tain learning technologies to class (see sections 5.3.7.2 & 5.3.8). The other point to reflect on is one suggested by Gardner (1994) who indicates students are lead to believe technology is progress if their teachers support the TAS (technology as applied science) position. Perhaps the cohort of students in Year 9 coming from a predominately Asian background, or the fact that they are all boys, or even the fact they are a year older than the Rennie and Sillitto (1988) sample has meant that they have a more concrete and positive view of technology. This means these students view technology as equipment. No study has looked into the effect of cultural background on views of technology. No studies have shown a link to age of student
and technological beliefs (though this study does partly address that issue). Many studies have shown that boys feel more comfortable with technology than girls (Mackenzie & Wajcman, 1985).

Technology and progress is one of the themes mentioned by Donald Mackenzie (1998) as a form of ‘technological determinism’. This is the idea that certain technologies triumph simply because they are the best or the most efficient, especially where high technology. Students believe that the development of technology is driven by an autonomous, non-social, internal dynamic think that technology can only lead to greater efficiencies. Mackenzie (1998) thinks that history might indicate that technology that succeeds usually does look like a natural trajectory. However the reality is more complex. The underpinnings must be progress for whom? Different people may view technology in different ways. The results section 4.2.1 and 4.2.2 gives some of the richness of differing opinions. However it indicates that a viewpoint on technology and progress has already been ingrained. There is little mention of a link between science and technology. To the students they appear as separate stand-alone entities. This also is reviewed in section 5.1.2 on science and technology.

5.1.1.2 Discussion of Year 11 Physics students’ responses

The most prevalent responses at year 11 revolved around objects and positive progress. Computers, electronics and general machinery were the artefacts. Progress and making life easy were the dominant feelings. The two most popular responses in Year 11 are the same as those in Year 9. Slight differences, such as the higher
percentage of students in 11B nominating computers as an alternative as well as the smaller variety of responses of 11B are hard to explain. Is the narrower definition of technology in 11B attributed to the influence of the teacher or the class composition? Calculations to prove whether these differences were statistically relevant were not attempted due to the small sample size.

The data in section 4.2.2 also support the evidence in the Rennie & Sillitto (1988) study.

The students sampled were those who freely chose to do Physics unlike those students who had to do science in Year 9. It is interesting to note that the choices of these two sample groups were not different. It would suggest that the views of technology are ingrained before Year 9 and they are taken up by all students not just those who will go on to technological careers.

Fleming (1989) understood technology to be a social process in context of culture. The culture of this school indicates technology to equal progress. Fleming (1989) also stated that technology harnesses the scientific knowledge into systems or products that are useful and valuable to society. While the students see technology as useful, they are not making the link between science and technology.

5.1.1.3 Discussion of staff responses

The number of different Physics teachers determined if what the teachers taught besides Physics, tended to also have an influence on their answer. Adrian also taught Information Technology. His answer revolved around computers and their use with spreadsheets and the Internet. Whereas Karl, who also taught Information
Technology, thought technology was 'a tool to perform a task'. The youngest teacher Justin thought technology was 'Something new and innovative, a different, faster way'. The Physics coordinator's and Physics technician's responses also revolved around computers and their ability to do make life easier. The Chemistry coordinator and Chemistry technician answered along the lines of 'tools to make life easier'. Most of the teachers' responses were identical to the students. The most frequent responses revolved around 'computers', 'tools', 'progress' and 'making life easier'. The Principal's answer followed a more educational bent:

'Technology is the use of equipment especially electronic or audio-visual, to improve the processes presently used in business, commerce, teaching etc. It can be used to enhance existing methods or it can be used to replace existing methods. It should be used appropriately to enhance the learning process for the group and/or the individual. Its strength should be its ability to motivate or allow differential teaching/learning. It needs to be fully integrated into a teacher's methodology and not an add on.'

This skepticism by the principal that it can improve life but only if used appropriately was not mirrored by other teachers. However some skepticism becomes more apparent in the teachers' and students' responses to the PATT questionnaire.

As mentioned in the literature section, no reports into the belief system of Principals on the nature of technology could be found. Rennie (1987) found that science teachers focused on artefacts as technology. Whereas Rennie and Jarvis (1995a) indicated confusion by primary teachers in England as to whether technology was about designing artefacts or the actual artefacts themselves. The results expressed
above to a great degree are the same as the students shown in section 4.2 and the results of Rennie & Sillitto (1988). The teachers mentioned computers and modern technology rather than older equipment.

5.1.1.4 Summary of PATT questionnaire responses.

Overall the statements of PATT questionnaire might be trying to determine what are the intuitive views on technology. Larochelle and Desautels (1991) argue that for many students, their intuitive preconceptions provide commonsense explanations of the world whereas scientific explanations often are experienced as counter intuitive. While this argument might be fine discussing a student’s view on Science theories like Newton’s Third Law, it is difficult to translate such an argument to technology. What are the intuitive viewpoints on technology? We can question students on their belief of what technology is? But is this the same as questioning them as to how technology operates? Do students really need to know how a computer works in order to operate it? Most people do not have a clue how their car operates but use them. Do you want to challenge a student as to how an instrument operates? Or what is the meaning of accuracy? Unlike scientific knowledge that builds up on different concepts of knowledge (Newton’s Physics replaced by Einstein’s physics), technology tends just to be a measuring tool in Science.

By viewing the PATT question by question across the board agreement with a statement could be viewed as a definite viewpoint on technology.
'Technology mainly concerns computers and similar equipment' could be linked to the answers of the earlier open question. ‘What technology means to me?’ The answer to this question was overwhelmingly computers. The answer to question one was in agreement with most of the Physics teachers, the Physics coordinator, the Physics technician, and the Principal and Year 11 Physics students. Year 9 Science students showed greater variation in their answers. This may be because they include humanities students, who will not pursue Physics. The Writing/Drawing activity provides more detail to what else besides computers they might think technology is. The Chemistry coordinator and his technician disagreed with the first statement of the PATT questionnaire. The Chemistry co-ordinator and technician had a broader definition of technology. They used this broader definition to explain what technology had been introduced to chemistry, for example glassware was defined as technology.

'Making models and testing them is a part of technology' was agreed by all parties to be true with the exception of the Physics coordinator and Physics technician. There may be confusion with respect to the term ‘model’. A model could be viewed as a scale model or as an algorithm. For the Physics teachers this might be interpreted as an ideal or process, not something tangible. This is the viewpoint of the British technology policy not of the Victorian Physics study. The physics teachers have proven themselves to be the most deterministic group of the study. According to Mackenzie (1990) this could be because they are products of the culture they are now passing on.

The overwhelming support of technology as a process by most groups contradicts their stance in the open ended question. The explanation of this might lie at
difference of research tools. It is obvious from the open-ended question that technology as process was not at the front of their thinking.

'Without electricity, there would be no technology' was answered in the affirmative by the majority of Physics teachers and the subject coordinator, suggesting a subject link between Physics and electronics. Surprisingly all students of Physics also rejected the link of electricity and technology. This suggests the link between Physics and electronics might be generational, that these teachers had done at least two years of a Science degree involving Physics practicals and electronics. However it is difficult to understand why Year 12 students, who study electronics as their first subject would not make this link. All the parties not linked to Physics rejected the link between electricity and technology. The question might have also been misconstrued. Electricity can be linked to computers as it is needed to drive the electronic circuits, someone studying Physics may make that link via the topic of Electronics, others may link electricity to electrical devices such as drills and motors, considerably lower technology in comparison to computers.

'Technology involves designing solutions to problems' was agreed by everyone with the exception of the Chemistry coordinator. The Chemistry co-ordinator through his open-ended technology question linked technology with gadgets or concrete tools, not as a process. This indicates his belief in technology is more deterministic than the Physics teachers. The Chemistry co-ordinator only sees technology as objects regardless of the testing tool.

'In technology there are opportunities to design new products' was universally agreed upon, shown the positive viewpoint of all people interviewed towards technology and its link to future prosperity. This quoted statement and the previous
one concur with Laudan’s (1990) argument that to scientists and laymen the one striking feature of the diachronic development of science is the progress that it exhibits. Likewise technology equates to progress for the majority of the sample group. This link between progress and technology is supported by Laudan (1990). ‘Two hundred years ago there was no technology’ was universally disagreed with. Technology was understood to exist before electricity and modern science according to the sample. This answer would contradict an earlier response by teachers that technology needs electricity. No reason can be suggested for this contradiction. The recognition that ancient technology does exist was also confirmed by the reference to mechanical tools in the interviews with students. However the open essay question showed that computers were more likely to be the first choice of the school population as an example of technology, than even moderately old technology. The answers to nearly all the questions regarding thoughts about technology indicate the positive attitude towards technology and a general interest in the subject. Only the Principal and the Year 9 Science students showed a great deal of scepticism or uncertainty towards the benefits of technology, Even though many of their answers in the Writing/Drawing activity linked technology to progress. Similarly when intentions about careers in technology were asked or interest as a hobby, anyone not connected to Physics directly (these include Year 9 Science students) answered with uncertainty or in the negative. Asking the sample to identify with ‘Technology is needed by everybody’ highlighted differences between the samples. Most of the Physics teachers voted negative whereas nearly everyone else agreed with the statement to the affirmative. This could be viewed as scepticism on behalf of the
Physics teachers, or the same teachers being pedantic in their interpretation of the meaning of the word ‘everybody’.

A comment about, first the sample groups and secondly the two different year groups. As a generalisation the year 9 groups were more likely to choose the uncertain category than any of the other sample groups, except the principal. This is reasonable given many of the Year 9 students will not go on to science base subject. The principal is humanities based in his own teaching background may not have the same exposure to technology that the Physics teachers and students have. There were differences between students and teachers responses to the question as to whether technology was needed by everyone. Most students supported the view but half the teachers disagreed with it. Similarly most teachers did not like technology as a hobby, whereas their students were undecided on this. The result also contradicts the strong support given by teachers earlier in the questionnaire.

When a comparison between physics classes of the same year is made there was little variation.

When a comparison is made of the 1996 group of physics students and their respective teachers, the differences between class and teacher were small. For each class only one fifth of the answers of the teacher and their respective classes were different. These results tend to suggest that the viewpoints on technology are strongly ingrained and widely held within the school culture. This contradicts the evidence of Lederman (1992) showing no links between teacher beliefs and student beliefs on the related area, the nature of science. The difference is the tools used to measure this link. The PATT being such a rigid structure of questioning would afford less opportunity to voice variation than the open-ended questions. It really only
shows that teachers and their students live in the same culture and share similar viewpoints, however whether one influences the other or whether they are both influenced by a third party such as the media (Aikenhead, 1988) can not be determined here.

Age difference between teacher and students could be used to explain the results obtained.

Rothman (1969) and Durkee (1974) proved that a teacher's understanding of the nature of science affects his/her students' conceptions. This research would suggest a relationship between teacher's understanding of the nature of technology and his/her students' perception. Work on the nature of science (Brickhouse, 1989, 1990) suggested there was some evidence to support teachers' conceptions affecting classroom practice and that classroom practice affected some measure of influence.

This is true for the Physics coordinator whose belief in computer technology leads to changing the classroom practice of his entire faculty, in the adoption of learning technologies.

The teacher interviews show that some teachers are unsure of new learning technologies and the computers that drive them. Yet, ironically the teachers see technology linked strongly to computers. Cuban (1993) identifies an impulse for teachers to keep schools up-to-date with the work place ensuring students are prepared to compete in a changing job market. Perhaps the teachers see computers as important for work, thus important for students. Unfortunately this question was not asked in the interviews with teachers. Since the outside community sees technology as computers (No research could be found) so to do the teachers.
Comparisons between the Chemistry co-ordinator and technician with the Physics co-ordinator and technician show the physics cartel to be more supportive of technology. No research has been done on different science backgrounds influence on uptake of technology. The enthusiasm of the leader of physics will be looked at in a later section.

5.1.1.5 Further evidence in support of nature of technology

Further support could be found for teachers and students' view of technology as primarily computers. Both year 11 and year 12 when asked to identify what technology they had used at year 11 identified Tain interface technology. Similarly the teachers interviewed also identified Tain. Only the year 12 students of 1997 were caught in the context of their time. As Tain had not been introduced into year 12 at the time of the interview, students tended to pick electronic instruments and components to represent technology. Instruments such as the multi-meter were more often identified by students. Perhaps this example shows the dominance of computers in students' minds that once they are introduced into the class other technology is pushed to the back of their minds. In general the year 12 students would reflect on the fact that they did very little practical work at year 12 thus it was difficult to name technology used at year 12. This link of practical work and technology appears important in the minds of the students. The artefacts they use in practicals become their definition of technology. It is interesting to speculate whether this is context based. If Chemistry students had been asked the same question, would they only mention their practical equipment?
No literature supporting this link of practicals and the nature of technology could be found to support or negate it.

5.1.2 Relationship of science and technology

The 1997 Year 11 Physics, year 12 Physics students and all staff members were asked the question: ‘Which statement best describes the relationship between science and technology?’ They were then given a piece of paper with the five categories of relationship described in Gardner (1994). Some commonality can be seen in their responses. Firstly very few people saw science and technology as representing the same concept. In their minds there was no confusion between the two entities. To a certain degree this belief is supported by answers to the previous section What is technology? Technology was defined as computers, an answer that does not align with any of the definitions of what is the nature of science given in section 5.1. Also few students saw technology as preceding science. Ihde (1983, 1991) argues that artefacts and instruments are the shapers of scientific thought. The argument is ontological: technology is necessary for generating scientific ideas. The irony of the poor showing of this category is due to the timing of the question. One of the reasons the thesis was generated was due to concerns of the unquestioning take up of computer practical equipment and the effect that might have on learning. The students and staff questioned did not identify that connection. This idea that the instrument affects the theory was fully covered in instrumentalism section 3.7.2.1 The students and staff also rejected the idea that there was no relationship between science and technology. Gardner’s (1994) demarcationist view explains science and
technology as separate entities, pursuing different goals carried out by different social groups.

The two alternatives which most of the sample chose were science precedes technology and technology and science engage in two-way interaction. The former, also known as the 'technology as applied science', was slightly more popular. Gardner (1994) argues that this is the most prevalent view of the relationship between science and technology. Gardner (1994) argues that the consequence of this view is that it leads to neglect of technology as a process, that it aims at the ability to conceive of a need, design a solution, utilise resources to make and appraise an artefact (or system). This aspect of technology as a process was spelt out in the VBOS study design for systems technology (1995). A student who does not study systems technology would miss these skills. Evidence to support this occurring is minimal and contradictory. In tables 1, 2 and 3 very few students identified technology as a process, yet in the PATT questionnaire the students considered technology as a process. Gardner (1994) suggests that the TAS viewpoint would lead to treat the process of application of science soporifically, as if the turning of a scientific idea into a technology outcome were a simple matter. There is little direct evidence to support this observation from the thesis. Teachers supported this viewpoint, as did year 11 students. Whether this is due to the culture of senior science or that this viewpoint is more widely held was not determined.

The second most popular viewpoint on the relationship between science and technology was that they were engaged in a two-way interaction. This interactionalist view states that scientists and technologists can learn from each other. This response is partly attributed to the difficulty to untangle the scientific and technological
contributions in such areas as electronics. This dispute is fully exploited in Latour’s (1987) term technoscience. For him the problem is where the scientific theory ends and the technological application begins. This why instruments are central to Latour’s argument on technoscience. Latour (1987) uses instruments to blur the distinction between science and technology. Latour (1987) is taking the ideas of Ihde (1991), that instruments are shapers of thought, one step further down the relativist’s path. Finding further evidence of this viewpoint is difficult. Data regarding the practicals showed that students had some concern about the Tain interface equipment because they could not see what was going on to produce the results recorded. But there were just as many students who were not worried about the means, but more interested in the ends in terms of diagnosable data. The majority of the teachers interviewed did not express such a concern about Tain.

5.1.3 Technoscience as an ideal relationship between science and technology

The science-technology or technoscience relationship can be illustrated with two examples from this case study. The first looks at the links between scientists and the technologists. In these two instruments you have the person who discovered the scientific theory also being the person who turned it into a scientific instrument. The second looks more at the social factor of the relationship. The adoption of the Tain black box over the previous non computerised, more open practicals, supports the concept of Latour’s (1987) that machines are more powerful than scientific ideas, that their ability to have a phenomenon built in is one of their strongest ways to
stabilise the phenomenon (in this case a Physics practical). Latour (1987) says that only by viewing science in the making can you unpack the blackbox and this would suggest that the Tain interface takes away that opportunity for the student.

Decisions are the realm of people and organisations. Latour (1987) points out that many scientists stake their careers on the decisions they take and so too does the science educator in the case study. In this case the science educator staked his success to the introduction of Tain interfaces.

Decisions about routine choices that could easily go one way or the other, are decided by people in the picture (Latour, 1987, p.3). Who made the decision to introduce the Tain interface? Was it the Physics co-ordinator? Did the Physics staff have a vote in it, or was their silence a signal of acquiescence? It seems that the Tain interface was built on a bedrock of ‘facts’ rather than a questioning of them. The phenomenon of movement was known in the time of Galileo. The Tain equipment takes an old Physics ticker timer practical, prior technology, digitalises it and presents the phenomenon as a readout. Latour (1987) would argue that the movement from the old to the new, or the analogue to the digital comes with further layering of complexity. Latour (1987) supports this interpretation with his talk about the use of previous facts either straight from a textbook or from other machines (Latour, 1987, p.8). The students in the case study viewed this as progress. This acceptance of the accuracy of the instrument is what the students like.

But why must digital take over analogue practicals? Latour (1987) talks about the dichotomy of ‘Just get the most efficient machine’ and the alternative ‘decide on what efficiency should be’ (Latour, 1987, p.9). The first statement was the modus operandi of most of the students. They wanted to use the most ‘accurate’ machine.
The author believes that the efficiency is just one parameter of a successful stable blackbox. The fact that it is reliable is another parameter. An analogy to this is that some teachers expressed nervousness about things going wrong with the technical equipment, which would stop the practical going on. For the first year the reliability was not 100% as instructions were not fool proof. Nor were errors predicted or fallback contingencies worked out, as was the case with the old practicals. To the students the fact that it was easier to use because you always got results and the instrument did the monitoring over a period of time meant it was successful. The fact that it was connected to a computer meant that it adopted the other attributes of the computer i.e. progress, accuracy. It was like a 'Halo effect'. No questions were asked by the staff or the students as to whether they needed results to the 5th decimal place in order to get a better assessment mark. And why is the 5th decimal place so accurate? This accuracy could lead to students doubting the validity of their results. Noise in the background of some of the dynamics practicals, for example slippage of the string on the dynamics wheel, lead to students doubting indicated trends. Other students failed to see these results as faulty because if the computer produced them they must be accurate. Latour (1987) mimics this situation with his answer to what makes a good machine? The fact that it works in the interests of other people, or that people will eventually debug and make it work? This is really another way of saying successful technoscience is over determined. And pretrialled, preprogrammed datalogging is the best way to over determine. Graphic images almost did all the work for the students. A problem with the practicals was that the graphs could not be downloaded onto disks. This was due to dated software.
The problem with Tain was the software that drove it. It was too complex and students got lost and wasted valuable practical time. To overcome this, the laboratory technician wrote instruction sheets which navigated students through the maze to the results in as short a time period as possible. Latour (1987) encapsulates this with the statement ‘The left side considers that the facts and machines are well determined enough: The right side considers the facts and machine in the making are always under-determined.’ (Latour, 1987, p.13.) According to Latour (1987) the black box can never be closed, in this case, the Tain might be replaced by datalogging machines, which the students make themselves.

5.2 Viewpoints on interface computer technology

In this section an analysis of the data regarding students and teacher’s viewpoints of interface technology will be presented. Initially in covering these areas, the case study was moving away from the general beliefs of the students on technology to specifics of technology they were actually using in their practicals. Thus consistencies in their beliefs could be ascertained.

5.2.1 Introduction

The referendum on practicals was meant to:

- Detect if there was any difference between three Year 11 Physics classes as to their perception to the introduction of Tain interface (data logging) equipment.
- Test attitudes of students to the introduction of Tain interface when its use was parallel to traditional practical equipment.
• Detect any difference between the three Year 11 classes of 1996 and one Year 11 class of 1997

• Determine the attitude of one year 12 Physics class in 1997 and seven Physics teachers towards Tain interface.

• Link the students’ views on the nature of technology with their comments on practical technology

The procedure was pseudo-experimental as explain in the Method section.

The referendum was carried out over two years 1996 and 1997 with slight changes in the questions (See Appendices C, D & E). In 1997 the similar referendum/questionnaire was conducted about the new technology, with only one Year 11 Physics class. The questions asked in 1996 were essentially the same as in 1997. Only the order was changed to reflect changes in the practicals and the syllabus. Due to the smaller sample in 1997, all students in the Year 11 Physics class were interviewed to see whether their written answers were consistent with their spoken interviews. Tain interface technology had replaced older technology in the practicals so direct comparison was difficult. The Tain thermocouple was in use in the Heat and Temperature topic in 1997 but not in 1996.

A further modified version of this referendum was given to one Year 12 class (see appendix E). Seven Physics teachers in 1997 were given this modified version of the referendum in the form of an interview.
5.2.2 1996 Year 11 Student findings with respect to laboratory work and technology

Most students enjoyed the Tain more than the old practical equipment. Tain was liked because of its accuracy (all three classes) and it was perceived to be easier. This reference to accuracy appears in many answers. The greatest advantage for older equipment was perceived to be that it was tangible. This question of accuracy and computers is interesting. The students are not told computers are more accurate yet they perceive them to be more accurate. More importantly there is no requirement to have extremely accurate equipment to obtain useable data for the practical. It does not affect their mark. Students want ‘the right answer’ and think that only by having the most accurate equipment will they obtain it. This puts the students clearly in a realist’s, positivistic framework. One class, taught by Shaun was divided in their views. Half liked the Tain and half liked the other older practical method.

Tain is a datalogging device and thus a computer used in the context of Physics practical. It is a modern scientific instrument and, as such is a part of a ‘heterogeneous network’ (Bijker & Law, 1992) that includes technologies, institutions and social networks. The students are equating the attributes of the computer to those of the Tain interface. There is a good argument for not using the computer interface but substituting Latour’s expression of ‘blackbox’ for its meaning.

Students thought the older style practicals explained concepts better even though their preference was for using the Tain. Overall the students supported the older style practicals, however there was a significant difference between class responses.
Teacher David's Physics class indicated a slight preference for Tain, whilst Shaun's class showed a marked preference for the old practicals. This could be attributed to the attitudes of the teachers toward the Tain equipment. As teacher and Physics co-ordinator Ian was the main instigator of the Tain interface and teacher Shaun had the greatest skepticism about its worth. Shaun and David's interviews indicate both were of the opinion that Tain did not teach the concepts as well. David remained unconfident about the way to operate Tain. He felt the students knew more about it than him. While Shaun's students were allowed to use both pieces of equipment for one practical, the choice was not always made available to Ian's and David's classes due to time constraints. The reasons given for the student's preferences were the rather ambiguous. For example 'You can see the results' wrote a student. The student was referring to the operation of the ticker timer producing marked tape that had to be cut up then used to calculate the results. According to the student this process allowed you to understand the concepts. From a response to a later question it became apparent that some of them knew how Tain computer equipment calculated velocity.

There was the students' perception that if a computer did the work rather than the student, the student missed out. This is where Tain exhibits the form of a blackbox. This is where the term blackbox has acquired an expanded meaning beyond that of well-established fact or unproblematic object. For Bruno Latour (1987) the essence of a blackbox is that in it many potentially disparate elements are made to act as one.
Latour (1987) stresses each:

'...time a fact starts to be undisputed it is fed back to the other laboratories as fast as possible. But the only way for new undisputed facts to be fed back, the only way for a whole stable field of science to be mobilized in other fields, is for it to be turned into an automaton, a machine, one more piece of equipment in the laboratory, another blackbox' (Latour, 1987, p.131).

He also stresses that activity is continually needed to keep the blackbox closed. It is this concept of Latour's which will be discussed further in the section on Power.

Latour (1987) states:

'Until it can be made into an automaton the elements that the fact-builder wants to spread in time and space is not a black box. It does not act as one. It can be disassociated, dismantled, renegotiated, reappropriated' (Ibid.p.131.)

Some of the students recognised this facet of Tain.

Latour's (1987) perspective revolves around a series of Janus-faces. They strongly distinguish between science prior to the settling of a dispute, and science sedimented, after the settling of a dispute. It could be argued that at this point of time the students could compare the blackbox of Tain with the open black box of the old practicals.

The advantage of Tain was mentioned to be the real time date display, which gave better or more immediate understanding of the concepts, this is supported by research disseminated by Weller (1996) and Morkos (1986).

The conflicting answers suggest a lack of familiarity with the Tain equipment, both by the students and the teachers.

Without training there are inevitably unforeseen problems that make Tain complicated. After this year the comparison was not available across one practical.
The choice would be taken away from the students without any feedback as to what they thought of the changes.

Most answers, for either Tain or traditional method, were simplistic in that neither method seems to make apparent the theory relationship with observations. Either method was prone to instrumentalism (a belief that the measurement device presents absolute reality).

Students voted unanimously for Tain being the easier system to do practicals.

Despite the complexity of the menu driven software, students perceived it to be less work or simpler because of the fewer pieces of equipment. Hodson (1993) argues that the needs and interests of the student should be uppermost. Hodson (1993) argues the computer acts as a technician leaving more time for reflection of results. So he is not as concerned by the means, more so by the ends. Remember these results revolved around the ticker timer versus the Tain rather than thermocouple versus thermometer. In 1996 the comparison was only between one piece of equipment in one topic area.

Students identified the advantages of Tain computer equipment as accuracy was cited. Another advantage was speed. There was no variation between classes in this response.

Prerequisite computer knowledge was a problem with Tain. Students said Tain was not user friendly and required training to understand what was going on. The menu had a large number of terms that were instrument specific and not known to the students. The menu driven software did not approximate the Windows world of most students and was therefore problematic. The fact that they had to learn this system now would negate further training for year 12 Physics, which according to the
Physics co-ordinator was one of the reasons for its introduction at year 11. This training problem on Tain computer equipment could be eliminated by two different means. Either Tain computer equipment could be introduced to Year 10 Science (costly) or Tain could operate in a Windows environment (costly, as computer equipment would need to be upgraded).

The Tain interface being able to do so many different measurements, from dynamics to temperature, compounded this training problem. A large number of menus were needed to set variables such as x and y-axis for graphing. Despite this, some students enjoyed the challenge of mastery required and became self-taught experts on the system. Nothing in the literature review mentions the problem of software familiarity. The second disadvantage was perceived to be not knowing how the results were achieved. This harks back to the question on which method explained the concepts better. Interestingly there was variation between Shaun’s class, who strongly criticised Tain, and the other classes who suggested the concept difficulty or the closed blackbox.

In 1996 Tain was only used in motion practicals and electricity practicals. Overall the students thought it better in the Electricity topic, although David’s class was evenly divided with respect to the two topics. The accuracy of Tain as defacto multimeter was a reason for Tain’s acceptability for Electricity. The Tain power monitor was like a computerised multimeter, but it could only measure current and voltage. The students equated the computer on the multimeter with making it better. No reasons were given as to why Tain computer interfaces and motion practicals were any good. So it is difficult to ascertain whether the students were rating Tain
interfaces or the practicals the Tain interface were performing. Many students did not respond to the question.

One question investigated whether the students knew the Physics concepts behind the older technology, specifically the ticker tape machine used to measure velocity. The vast majority of students in all three classes provided a correct explanation. In terms of Latour’s black box this piece of technology appears to be partly open. It could be due to the concrete nature of the ticker timer that allows the students to see the distance being measured. The ticker timer provides only the raw data from which the students calculate velocity. When interviewed the students mentioned they could visually see the components of the formula for velocity, namely distance and time. As the students needed to calculate the velocity the ticker tape could be criticized for not giving direct feedback. Students never query the electromagnetic device which produce dots on a piece of ticker tape every one fiftieth of a second. This could be due to familiarity with the equipment as ticker timers are used in Year 10 Science. One question was designed to see whether students actually knew how the Tain interface operated in order to give graphs on velocity. The response from students was poor with the majority of students giving incorrect or incomplete answers like ‘The computer does it’ or ‘the pulley spins’ without explaining how this converted into velocity readings on the computer screen. This would support the answers given in the previous question that Tain is a closed black box.

According to Latour (1987), instruments are a link between science and technology. His version of ‘technoscience’. The adoption of the Tain black box over the previous non computerised, more open practicals, supports the concept of Latour’s that machines are more powerful than scientific ideas, that their ability to have a
phenomenon built in is one of their strongest ways to stabilise the phenomenon (in this case a Physics practical). Latour (1987) says that only by viewing science in the making can you unpack the blackbox and the findings from the case study would suggest that the Tain interface takes away that opportunity for the student. Individual interviews with students proved that their written responses were not reliable indicators that Tain did not teach the concepts. Interviews demonstrated most students had simply misinterpreted the question and given the simplest answer. When interviewed, the majority provided a theory to understand Tain computer equipment.

Due to the fact that the internal operations are not visible to the student Tain computer interfaces need their operation explained by the teacher. It is easier and saves time for the teacher to demonstrate how to use the equipment rather than how it works. Tain had the advantage of providing immediate feedback in the form of a graph of velocity or a real time numerical readout. However because of technical limitations in the computer software, the students could not print off the graph. They had to download the raw data of distance and time onto a computer spread sheet and reproduce their own graph. Some students were very adept at this. Many were not. Thus extra class time had to be devoted to demonstrating this procedure.

5.2.3 1997 Year 11 Student findings with respect to laboratory work and technology

The referendum on laboratory works and technology first asked very specific questions revolving around Tain computer interface equipment and its use in class
practicals. These questionnaires were followed up with interviews with the students, asking the same questions. In the main there was little difference between the written reply and the interview.

Students were asked for advantages and disadvantages of three pairs of practical equipment.

The first pair of practical equipment was thermometers and Tain thermocouple.

The advantages listed by the students for thermometer revolved around its simplicity and ease to use. The disadvantages listed by the students revolved around the lack of ability to read continuous values. The other disadvantage stated was the lack of accuracy.

The thermocouple was considered to be better because it did the tedious work. It drew graphs and the computer was perceived as more accurate. Students thought the graphs could not be saved from the computer due to hardware incompatibility. In reality the students forgot that they saved the results and used them in a package such as Excel to print off the graph. However such manipulation might still be time saving in comparison to pencils and a page of graph paper. The only disadvantage perceived by the students was the time required setting the computer interface up.

The second pair of practical equipment provided for comparison was the ticker timer and the Tain pulley interface.

These two pieces of equipment are used in the topic mechanics. According to the students the ticker timer had the advantage that it was simple, the disadvantage was it was slow. The advantage perceived by the students for the Tain was once again its ability to do graphs. Its disadvantage was the time taken to set up.
The third pair of practical equipment provided for the comparison was the multimeter and Tain power meter. This practical equipment is used in the topic electricity.

According to the students the advantage of the multi meter was it was easier to see results, the disadvantage was the dial settings were too complicated. The students perceived the advantage of the Tain power monitor was that it was accurate whereas the disadvantage was it was hard to set up.

A question compared old technology with the new computer technology, topic by topic. In all three topics, heat, electricity and motion, the advantages mentioned by the students of the Tain computer equipment were its ability to do the tedious continuous graphing and its accuracy. The continuous graph capability ties in with the assessment tasks, thus saves the students’ time. These were consistent with replies given in 1996. However learning to use and interpret graphs in ways specific to a scientific discipline is central to becoming a scientist (Bowen & Roth, 1998). More time can be spent interpreting graphs using the Tain interface rather than drawing a graph. The students interviewed did not mention this time to interpret graphs as an advantage. Students confirmed their belief in technology equaling progress by mentioning the high accuracy of the computer interfaces. No students mentioned ‘fitness for purpose’ in use of practical technology as an advantage. The students would say that the thermometer is simple to use but they would still vote for the Tain thermocouple because of its accuracy. For the experiment on heat transfer the thermometer would have all the accuracy need to correctly interpret the practical.

The answers to the general technology questions supported answers given in 1996 and answers given to the technology questionnaire.
The referendum on the laboratory work and technology also asked a number of
general questions involving technology. Some of these questions and their responses
have been addressed in earlier sections, see for example section 5.1.
The major technological tool used by the students in year 11 was the computer. The
students' most favoured example of technology was the computer. The students did
not mention more mundane artifacts such as rulers or stopwatches. Their answers
supported earlier findings that 'Technology mainly consists of computers and similar
equipment'.
The effect of computers in class once again drew student comment of more accurate
results. The Year 12s were asked what was the advantage of Tain and they came up
with the same answer, greater accuracy followed closely by its ability to record a
large amount of results over a period of time. When asked to mention a disadvantage
of Tain they mentioned the software.
Tain interface was considered very accurate. None of the students questioned
whether accuracy is necessary. This viewpoint was found at year 11 and year 12, and
also across 1996 and 1997. The accuracy belief is heavily entrenched.
The disadvantage of Tain was the software. Tobin (1987) asserted that algorithms
and procedures were used to reduce the cognitive demands of work. Menu driven
software like that used for Tain qualifies as an algorithm or procedure.
The students were evenly divided between mechanics, electricity and heat as most
suitable for Tain.
Tain interface equipment was also considered multifunctional. No one topic in
Physics, mechanics, heat or electricity was considered to be better served by Tain.
The media was named as the main influence on students' perception of technologies. Few students mentioned school. That seems reasonable considering the lack of devotion to the topic in either Science or Physics. It also indicates that according to the students, the school and its curriculum have little effect on the students in the students' opinion.

Most students in Year 11 Physics and Chemistry favored a view of technology as applied science.

5.2.4 1997 Year 12 Physics students results

The most significant advantage of Tain mentioned by Year 12 students, was its greater accuracy followed by it being easier to record a large number of results. This links directly to the advantages that the Year 11 students and teachers gave for Tain. It also links to the answers given to the nature of technology section 1.2 in its express of technology as progress, but here the progress is more specific. Similarly the disadvantages are problems that stop Tain allowing full progress, specifically the out of date software and the difficulty setting Tain up. In the literature review of further relevance was Tobin's (1987) assertion that algorithms and procedures were used by teachers to reduce the cognitive demands of the work. This assertion of Tobin’s (1987) fits the complaints of the students. However most of the complaints about Tain have nothing to do with ontological arguments, more procedural tasks. Doyle (1983) defined procedural tasks as those that involved the use of standard routines to generate correct answers. Procedural tasks were differentiated from tasks that require an understanding of why the algorithm works or when it should be used. Students
were able to obtain the correct answer without necessarily understanding the science involved in the problem. The results of this questionnaire suggest that the students are not worried about understanding.

5.2.5 Discussion of Physics teachers’ findings with respect to laboratory work and technology

The questions asked of the teachers were modified from those given to the students in 1997.

Teachers did not distinguish between year 11 and year 12 use of technology in Physics. The teacher’s responses concentrated on Tain interfaces and computers, they also mentioned ticker timers, circuit and other old practical pieces of equipment.

Most teachers were enthusiastic to praise the introduction of Tain. Like the students they mentioned Tain as being more accurate and easier to analyse via spreadsheeting. There was a feeling of natural progression, that this was the next step to take. A number of teachers mentioned that they made the practicals more interesting for the students and that old technology was boring for the students. When questioned as to how they came up with this conclusion it was from anecdotal evidence, not through their own polling.

One teacher Adrian mentioned that Tain taught the Physics concepts better. The other teachers identified the main disadvantage being more time was spent looking at the results rather than how they were obtained. Operating a software package like Excel spreadsheet distracted students from the physics concepts. Karl (who was an
The majority of the teachers were of the opinion that the Tain was not more suited to one topic than another. However Geoff pointed out that its use in Mechanics meant that you actually got the correct results to prove Newton’s Second Law, rather than the old practical which, in his opinion, never worked. This is an indication of the positivistic viewpoint by Geoff. The teachers were wary to state that Tain taught the Physics concepts better than the old practicals, they were more willing to say that it taught more effectively, timewise or allowed greater depth of exploration. Only one teacher Karl stated: ‘It was just different testing’.

Teachers don’t see themselves as influencing the students’ viewpoint on technology. This could be recognition that they only get to the students after Year 9, too late in their education to make a difference. Karl thought it might be teachers at primary school. Adrian had no idea what might influence them. But the rest of the teachers named the media. It is interesting to speculate, given the teachers’ answers to this question were similar to the students, what influenced the teachers’ viewpoint. Is it the same culprit? The media? Or something more complex?

Teachers viewed the relationship between science and technology in a very similar way to that of the students. Teachers’ viewpoints can be classified under two belief groups; those that viewed technology as applied science; those that viewed science and technology as interdependent. The majority supported the first viewpoint.
5.2.6 Summary of students’ and teachers’ findings with respect to laboratory work and technology

A number of common threads can be seen as the advantage of Tain:

- Firstly it makes life easy, for example assessment is made easier because Tain does the graphing, something which will be marked later. Another example, the disadvantage of thermometers revolved around the lack of ability to read continuous values. This is only a perceived problem by the students. The assessment task could be completed without continuous values. Their practicals require this function thus it becomes a handy necessity. Or it could be ease of operation. For example, the advantage of the multi-meter was easier to see results or the disadvantage was the dial settings were too complicated. This is a unique problem of the multimeter. If practicals still used voltmeters and ammeters built for one purpose then this problem might not arise. However such equipment has not been available for a number of years. The students’ belief supports Cuban’s (1993) contention that computers are introduced due to the quest for a more efficient education using the power of electronics to teach more quickly and efficiently.

- Secondly it was more accurate. The Year 12 group supported these advantages. Regardless of what age group (Year 11 or 12), what year (1996 or 1997) or what topic (Science, Physics or to a lesser extent Chemistry). Students have a belief that technology is progress thus supporting Roth and Lucas’ (1997) comment that some students believe that technological progress also improved scientists’
instruments and resulted in increased precision of measurement, bringing them nearer to the truth.

Students see Tain as progress and that will make their life easier, and that technology manifests itself in the form of computers. When students walk into a Physics classroom that has Tain interface equipment attached to computers, they see this as a positive experience. It will make their work easier to do and be better because it is more accurate. In a circular argument it is more accurate because it is attached to a computer. The students do see problems with Tain but they revolve around the software being old. They believe that all the software needs is a further update.

Students' experience of a rapid succession of updates, from 386 to 486 to Pentium© cause them to believe that such an advance will occur in Tain interface. The evidence given by the Physics coordinator does not support this idea of rapid software updates.

The Tain computer equipment has a number of features that make it successful in practical classes, for example its ability to take many readings over a period of time. The work of Tobin (1987) into high school science commented on a number of assertions relating to practical work that could be extrapolated to cover Tain.

'Assertion 3: Teachers endeavoured to cover the curriculum in the prescribed time whether or not learning occurred.' (Tobin, 1987 p.24)

The focus of the implemented curriculum tended to be covering planned content rather than ensuring that students developed depth of understanding. This is important. If the introduction of learning technologies will help cover practical work over a shorter time then teachers may embrace it. If a teacher ends up with technical problems, which shortens the time to complete the syllabus, the teacher may not adopt it. This shows the importance of the first year of introduction of learning
technologies. If the teacher does not get technical assistance, the teacher will not adopt it. If his job depends on the adoption of learning technologies the teacher might persevere. A number of teachers (David and Shaun) mentioned the importance of the technician being in class if anything went wrong. Note that these arguments are dependent on whether the Tain teaches the concepts better. Yet these arguments were not put forward as problems with Tain in section 5.

'Assertion 4: Laboratory activities are not an integral part of the science program.' (Tobin, 1987 p.25)

The purpose of laboratory work seemed to be an appendage to the program, but did not contribute to the knowledge to be learned. The answers from both teachers and students indicate that the actual learning that occurs through Tain is an after though. More important are the results and the processing of the results. The learning from the Tain is secondary to the assessment outcome of writing up the practical.

'Assertion 7: Algorithms and procedures were used to reduce the cognitive demands of the work.' (Tobin, 1987 p.27)

Menu driven technology like Tain certainly qualifies as reducing cognitive demands, even though a number of students criticised the menu driven software as arcane. The move to menu driven software is also explained by Atkins (1993). His evaluation of the use of interactive technologies observed that much research in this area fails to provide a curriculum context. He felt that 'research tradition in educational technology has become locked into a restricted means/ends view which holds learning to be unproblematic and value free'.

Latour (1987) would see this move to more technical procedure software in a more cynical light. Latour (1987) points out that when controversies flare up the literature
becomes more technical. While early datalogging literature in journals tended to be of the technical nature, there was still very little literature around. If you consider literature as including instructions then Latour is correct on this point. The only controversy for teachers and students was the complexity of the software, so literature was written in the form of mindless instructions to divert the controversy. The literature provided from Tain was in the form of suggested practical sheets. According to the Physics co-ordinator, these were too simplistic and were not instructive enough. However some of the practicals were used as a basis for what was developed. The difference between Tain and the school’s instructions were the latter were more prescriptive, more detailed. Tain literature had to be less technical so it could be adopted by whatever computer system was at that school.

The success of learning technologies in Physics could be due to its ability to shorten the time on practicals. Tain does this by shortening procedural tasks. Doyle (1983) defined procedural tasks as those that involved the use of standard routines to generate correct answers. As a consequence students were able to obtain the correct answer without necessarily understanding the science involved in the problem. The perceived need by the teachers to have more time to cover course content resulted in less time being available for laboratory work. Discussion of the problems with students indicated that they had scant knowledge of scientific principles, but had learned approaches to obtain correct answers.

‘Assertion 8: The cognitive demands of the works were low.’ (Tobin, 1987 p.29)

Teachers designed laboratory activities to be of a cookbook type with a strong emphasis on following procedures in order to collect data. There was little emphasis on planning an investigation or interpreting results. These older type practicals took
up most of the time with data collecting with only the last five minutes for interpretation. Something not done by data collecting using a computer.

Lynch's (1983) research on practical work promotes three reasons behind its use.

- **Orientation 1: Practical Work as a Visual Aid.**
  In this case, practical work is seen as a means of further reinforcing the understanding of concepts and principles. However the small amount of research on this topic throws some doubt on this.

- **Orientation 2: Practical Work as a Means of Inculcating Laboratory Skills and Techniques.** Procedure for Tain once learnt could be applied to other areas. Experimental science involves a number of handling and measuring skills that can be set up as Tain procedures.

- **Orientations 3: Practical Work to Promote Scientific Thinking.**
  This orientation incorporates notions like 'problem solving' and 'working like a scientist'. Little thought is put into the technology process of instruments i.e. the design and testing procedures of instruments.

Students have a limited view of technology, in the main, as things rather than process. The students' interpretation of technology as 'the interpretation of scientific findings'. This is aligning with the viewpoint that Technology is applied science. Similarly the question on Gardner's (1994) categories indicated that the Year 11 supported the applied science category of technology. As Rennie and Jarvis (1996)
indicate, the use of unfamiliar words in teaching and learning is a problem in education, created when teachers use specialist words that also have different familiar meanings. For example consider the definitions of technology or learning technology. The problem for children’s understanding of definitions arises from a mismatch between a word with both general meanings and specific scientific use. The stated definition of technology varied slightly from country to country, but were not the one given by the students or teachers.

Regardless of why the link between the nature of science and technology implicit in the interface equipment is lost. The students are unquestioning users of technology and the reality it creates. These ideas come to the students via the media supporting the findings of Aikenhead (1997). These ideas might be ingrained before they get to Year 9 Science.

The unquestioned up take of technology might be culturally based. Depit (O'Loughlin, 1992) points out that the speech genres of working-class children and children of color have to be abandoned to achieve success. Children have to adopt the language of the white middle class to effectively use computers. In the case of Asian students, their sociocultural framework mimics the speech genres of the white middle class. These students effectively use computers in school and thus achieve success. Given the sample of students questioned in this thesis has above 50% Asian background, this might explain Tain's successful uptake.
5.3 Change aspect and influence of power on use of technology: Discussion of the actants determined.

5.3.1 Introduction

The following section uses Callon's (1986) Actor Network Theory (ANT) to identify the actants responsible for the introduction of interface computer technology (Tain) into the school. One of the criticisms of ANT is that while it identifies the links between actants, it does not attribute weightings of power to each actant. Fujimura (Star, 1991), a sociologist, has written:

'I want to examine the practices, activities, concerns and trajectories of all the different participants - including non-humans. In contrast to Latour, I am still sociologically interested in understanding why and how some human perspectives win over others in the construction of technologies and truth, why and how some human actors will go along with the will of other actors, and why and how some human actors resist being enrolled. I want to take sides, to take stands.' (Star, 1991, p.29.)

Fujimura is commenting on the fact that Latour does not take sides.

Up to now the analysis has identified power levers responsible for changes but have not really identified which were the most powerful, for example the social or the instrumental? [Latour (1992) would not make a distinction between human and non-human.] This is one flaw with Latourian analysis. Because of this flaw Latourian analysis (1987) is he cannot explain the power of the belief in "progress" which is
attributed to technology.

5.3.2 Discussion of students' viewpoints on technology

The students' viewpoint on technology as computers and progress seemed well established before year 11 Physics as indicated by the Year 9 Science students' similar viewpoint. Both the students and the teachers identify the media as a strong influence.

Contrast these findings with the research on students' beliefs on the nature of science. Lederman's (1992) review of many studies, for example Rubba (1977), Rubba & Andersen (1978) and Lederman (1986a, 1986b), showed that a large proportion of students had a simplistic and naive absolutist view of scientific hypothesis and theories and that scientific research reveals incontrovertible and necessary absolute truth. Aikenhead (1997) looked at student views on the influence of culture on science. His conclusions found that the minority of students embrace the traditional ideology of science held by so many science teachers. The mass media exerts a greater influence on student views than science classes exert, and their images varied in a way that reflects the stereotypes and caricatures of the mass media (Aikenhead, 1988). These results mirror the students' beliefs on the nature of technology.

The question remains as to what power these beliefs have on accepting or rejecting Tain interface technology? Research on the nature of science never had to answer the question of a belief system in introducing a new syllabus. It would seem reasonable to expect that introduction of a computer interface which brought with it
connotations of progress for the students would be easily accepted. However no specific research can be found to support this idea.

5.3.3 Curriculum/literature

Literature as a form of power can be broken down into a local and global form. The global form is the curriculum booklets on technology and also policy statements that come from the state education department. They are instructions to school on how to implement and operate the subject. The local literature is in the form of computer interface literature. These are instructions on how to operate the computer technology interface.

5.3.3.1 Global

The introduction of technology as fulfillment of the school’s charter involved many players who are not necessarily recognized. Fullan (1991) points out that the biggest development on the educational science has been the increased presence and activity of the state in educational reform. Perhaps because of this there was an assumption from interviews with the teachers that the directive was passed down from the Ministry down to the School and then down to the faculty. In actuality the faculty was at least six months ahead. This was ascertained through interviews with the parties concerned: the Physics coordinator and Physics technician. It was also proven by the release of the VBOS learning technologies directive (1998) after Tain had been introduced. But the perception of the teachers of the faculty was different. Some of the Physics teachers were unaware the introduction of Tain computer
technology was not due to a Ministry directive and formulated their own views as to how technology was introduced.

According to Hord and Huling-Austin (1987), educational change is a long and tedious process that does not end with the adoption of a new curriculum or a new approach to teaching. This is supported by the lack of importance of technology curriculum in the Physics department. Hord and Huling Austin (1987) found that it takes three or more years for teachers to make a substantial change in their teaching. The case study covered only the first two years of Tain's full introduction. Hence substantial change was not observed by the interviewed teachers.

Cronin-Jones (1991) identified several categories of beliefs that appeared to influence curriculum implementation: beliefs about how students learn and their ability level, the teacher's role in the classroom, the relative importance of content topics. The Physics teachers' beliefs about Tain (section 4.4.4) do not really mention how the students will learn with Tain. They are more concerned with the abilities of Tain over older equipment; for example that it is more accurate. The teachers' beliefs about technology seem to override their beliefs about learning. None of the teachers thought Tain would be beyond the students' ability level. If anything there was concern that the students would know more than the teachers. However Tain did not change the teacher's role in the classroom. The class remained as teacher centered as previous equipment, only the importance of the laboratory technician grew in the running of the practicals.

McRobbie and Tobin (1994) saw the curriculum shaped by cultural myths such as time, being a scarce commodity, with a high priority goal being to cover prescribed content. Tain did nothing to change this according to both students and teachers,
some arguing it took more time others less. McRobbie and Tobin (1994) also point to this need to prepare students for the next educational level and to succeed in examinations. Whilst examinations were not mention by teachers, the Physics coordinator stated that Tain was introduced at Year 11 Physics for use in Year 12 assessment. McRobbie and Tobin (1994) recognize in framing of goals of curriculum, the micro culture of a classroom interacts with macro culture that includes the actions of others such as administrators at school, district, and state levels, professional organisations of science teachers, fellow teachers within the department, and school, parents, and members of the community at large. McRobbie and Tobin (1994) did not indicate what are the most important restraints in this culture.

5.3.3.2 Innovative curriculum

Research on the development, use, and assessment of curricula designed to improve student conceptions of the nature of science has shown opposite results (Klopfer & Cooley, 1963, Jones, 1965, Aikenhead, 1979). The assumption made by this research was for the most part, that the teacher, as a variable, was ignored. There was no research on curricula designed to improve student concepts of the nature of technology. The introduction of Tain was not, according to the teachers, designed to do that. As to Tain's effect on changing concepts of the nature of technology, no change in the student's views was noticed over the two-year period.

A review of 27 state curriculum guidelines (Bybee et al. 1991) indicated curriculum guides show little emphasis on the history of science and technology. The VBOS
curriculum examined in this case study does not emphasis on the nature of technology.

5.3.3.3 Local-Textbooks as curriculum

Gallagher (1991) reported that given the dominant role played by textbooks, very few mentioned the history and development of scientific ideas, none talk of technology as a process. In this case study, the author surveyed student and teacher understanding of the subject and examined curriculum guidelines and current instructional materials such as Physics textbooks. The author found no mention of the nature of technology in textbooks or practical instruction sheets at VCE level.

5.3.3.4 State involvement in curriculum

Jarvis (1996) points at definitions embracing all human activities, whereas others see technology as a problem solving activity. These are but two of the different prior knowledge backgrounds from which to build a definition of technology. Hence it is important to become more informed about what students understand about the meaning of ‘technology’ to see how effective changes in the curriculum have been. To see whether students have multiple meanings for technology.

5.3.3.5 Problems with literature

Literature, be it curriculum statements or textbooks, does not seem to be a major actant in this case study. Latour’s (1987) view on literature could help to explain this.
Latour (1987) is talking about scientific literature such as refereed journals. His point, however, is true as far as educational literature is concerned. Text, in any form, as a form of power should be included. By using this more general term the instruction literature, which was provided to students on how to operate Tain, and which was developed locally, can be a lever of power. All the educational literature from VBOS on Learning Technologies and even educational journals discussing the merits of learning technologies, create an atmosphere where Tain is welcomed into the Physics department. However it is true that the literature from VBOS promoting interface computer technology came after the move by the Physics co-ordinator to introduce it. For the Physics co-ordinator, the Physics teachers’ conference had more of an influence. For the rest of Victoria the introduction of learning technology might have been more dependent on literature. This is a good example of what Latour (1987) talks about bringing friends in, thus appealing to higher and more numerous allies as an argument from authority. As data logging interfaces are very briefly mentioned in the educational literature, this literature is not a powerful lever. But after the two years of operating Tain the confidence of the Physics co-ordinator was built up to the point where he could say ‘We are leading the rest of the state’. Further proof of the weakness of literature as a lever, is the fact that Tain has not been adopted as a universal instrument by all schools or faculties. The Physics coordinator predicts that this Tain system is already out of date. Despite visions of simpler datalogging equipment being used, the Physics co-ordinator has not replaced the system in four years. This is due to the cost to change over and a problem of readily available different data loggers. Only the Picoscope (Virtual Cathode Ray Oscilloscope-CRO) has been added to the system, simply because it can replace a
CRO. This problem is hinted of by Latour's (1987) second rule of method. This rule is that the fate of facts and machines is in the hands of the later users. If Tain was taken up by the Science or Chemistry Faculty (determined by other levers such as assessment) or by more schools, then its future would be confirmed. If the Physics faculty published their practicals in say a teacher's journal the take up of Tain may be greater, but no one had the time or inclination to write such an article. Its future is assured in Physics as it is introduced into more and more practical uses (Over a two-year period the number of practicals using Tain increased by 50%).

5.3.4 Principal/School

One teacher suggested the Principal as the main instigator for the introduction of interface computer technology. There was no evidence of this. The Principal did mention that computers were only necessary in subjects like Accounting. The Principal is confirming views proposed by Cuban (1993), who identified a number of key impulses in the advocacy of a particular program for using electronic technologies. The first impulse is the desire to keep schools up-to-date with the work place ensuring students are prepared to compete in a changing job market. No one questioned their reality until these interviews. The Principal was an initiator Principal as indicated by Fullan (1991). Initiator principals worked in collaborative ways with other change facilitators, in this case the Physics co-ordinator. Certainly the Principals viewpoint on the nature of technology was in line with the rest of the teaching staff and students, it is fair to speculate that this would mean that he would not block the Physics enterprise.
Research by Gusky (1986) indicates that often the change teachers face come from external sources such as an entrepreneurial school administration. The ideas embodied in these changes may not complement the existing practices or ideology of the classroom teachers yet teachers are expected to be able to take on board the beliefs and practices inherent in the changes and make them their own. In this case the only forward thinking of the school which helped was the networking of cables put down for classes to be linked to the school system. The external source was the physics co-ordinator.

The physics co-ordinator’s motivation mimics Cuban’s (1993) second impulse and third impulse for change. He was a neo-progressive who was on the quest for a more efficient education using the power of electronics to teach more quickly and efficiently. His technician also supported such views.

5.3.5 Teacher/technician

McRobbie and Tobin (1994) argue that the beliefs of a teacher affect their classroom practice, but that this is also constrained by environmental/cultural influences. This analysis does indicate a link between the two belief systems but cannot prove influence. The staff (with the exception of the principal) and the students have a science background; therefore it is not unusual that their viewpoint on technology is so similar.

The teachers also believed in viewing technology as computers and progress. The contention is not that the teacher’s viewpoint becomes the student’s. However it could be said that the teachers might reinforce the established beliefs of the students.
What power the teachers' belief might have on their acceptance of new ideas has been studied. Teachers respond to teaching situations by drawing from their past experiences upon which they formulate decisions for action in an attempt to change the current situation into one which is better suited to their own beliefs, values, and vision of what the teaching situation should be. Gusky (1986) suggests that teachers change classroom practices before they change their beliefs and attitudes. It is only after they observe positive changes in student learning outcomes that teachers develop a commitment to the change and are then more likely to retain it. In this case the teachers' beliefs supported the change to computer technology.

Cuban (1993) predicted that the computer, like its predecessors, would be tailored to fit the teacher's perspective and the tight contours of school and classroom settings. In this case study this turned out to be true. Computers were only used for a minimal number of practical periods.

Visions orient the teacher's overall conduct by providing frames that enable the teacher to conceptualise his or her actions (Nespor, 1984). So the teachers' vision of technology as progress might help their acceptance of the new interface technology. Alfred Bork (1995) states this view on technology would lead to little focus on learning. Bork (1995) was concerned about a vague belief in the magic of technology by parents, administrators, and teachers, and not on the role it will play.

Brickhouse (1990) also recognize the power of the teachers' beliefs as being moulded by their own experience as a foundation of learning. However because of the advanced age group of the teachers (average age 45) very few teachers would have gone through schooling with computers in class.

Fensham (1994) states the following:
reform of Science education starts with the conceptions of curriculum that science educators have of science and of science teaching and learning, and develops as these conceptions change as a result of the new experiences and challenges that the key persons encounter from inside and outside the school system (Fensham 1994, p.303).

This could be extended to indicate the influence of teachers’ beliefs on technology education.

There was some diversity dependent on the other subject discipline of the Physics teacher. However even this was limited by the fact that most Physics teachers’ second method was either Information Technology or Mathematics.

Latour (1987) warns that the whole process of enrolment is wasted if others gain credit for it (Ibid. p.118). A number of members of Physics staff commented on the fact that the Physics technician was the main person behind the success of the Tain implementation. Yet to the Principal his individual effort was not recognised. It became a faculty success not the success of an individual. This was important to the technician in that it could affect the amount of money he got. But was his original role to set up the practicals? Two years later the Principal was made aware of the technician’s computer work. The technician was changed from part time to full time, his job now incorporating computer software maintenance. The Physics teacher, who attributed his own success in the introduction of interface computer technology in gently manipulating the Physics coordinator, was a story that no one else knew. To him the lack of recognition was not important.

Latour (1987) was not happy with what he called the diffusion model stating that the blackbox is translated, by each owner, into something different. A powerful example
of the translation model is tied up with the users of machines and their different behavior. For example the computer literate teacher might view Tain as a tool which should be used for as many applications as possible and devote lessons in the computer laboratory to maximise involvement of Tain results. The computer illiterate teacher might find Tain difficult and avoid its use. However in this case Tain replaced a number of older practicals. The teacher standardised the behavior of the students by introducing an instrument with a specific order of operation. Thus the teacher guaranteed the behavior of the operator, the student. Similarly it could be argued that computer illiterate teachers must use Tain because it is in the syllabus and the one laboratory technician will only set up equipment for Tain equipment not the older practicals.

It is interesting to contrast the research on beliefs of teachers on the nature of science with this study on technology. Lederman’s (1992) review found that the majority of teachers’ conceptions tended to be the substantive content of science as fixed and unchangeable. This agrees with the logical positivism, that teachers were too busy imparting factual information to their students to be interested and/or concerned about instruction on the nature of science (Anderson, 1950, Behnke, 1961). Little research has been done on teacher’s beliefs on the nature of technology yet the findings of this thesis would mirror those for the nature of science.

5.3.6 Assessment

In their interviews students did not mention the link of assessment with the introduction of computer interfaces. Most Physics teachers mentioned that the main
reason for introducing Tain computer interfaces at Year 11 Physics was so as they could use them in assessment tasks in year 12.

In Chemistry the weakest link in the introduction of interface computer technology could be a number of things. It could be lack of funds. It could be lack of assessment or it could be lack of neo-progressives. The Chemistry co-ordinator said that most of the Chemistry funds were spent on consumables such as chemicals. The assessment task at Year 11 does not rely on learning technologies, thus no need was perceived to implement them in Year 11 Chemistry. Chemistry examination questions revolved around old practical technology such as pipettes, burettes and glassware.

The work of Tobin (1987) into high school science commented on a number of assertions relating to assessment. One of the assertions was: 'The assessment system was used to motivate students and had a focusing effect on the implemented curriculum.' (Tobin, 1987 p.24)

At all Year levels, and in all classes, teachers constantly motivate students by referring to tests and exams. Work identified as likely to be tested had higher status than work not so identified. So any learning technology would have to be tied to real and important assessment for both the students and teachers. Otherwise it would not be adopted. Perhaps this is why Physics adopted learning technologies and Chemistry did not.

Another of Tobin's (1987) assertions was 'Laboratory activities are not an integral part of the science program.' (Tobin, 1987 p.26)

The purpose of laboratory work seemed to be an appendage to the program, but did not contribute to the knowledge to be learned. It could be argued that the lack of importance of practical work to the examinations would mean that Physics teachers
were not so concerned with changes introduced to them.

5.3.7 Equipment

5.3.7.1 Introduction of Tain interface

The power of the interface can be classified into two types:

- The instrumental (local) power - the power the box has to mould scientific thought and
- The social (global) power - the boxes' ability to act as a pawn in a greater context of introducing learning technologies.

Both of these types of power can be analyzed under the framework of Latour (1987). Looking at Latour's (1983) rules of method and principles we can see further as to the social construction of the Tain interface. It follows Latour's description of science as power (or what the author argues is technology as power) by process via this blue print:

1. Move one: capturing others' interests
2. Move two: moving the leverage point from a weak to a strong position

But the major interest is in the relative power of each different lever Latour (1983) mentions. This is something Latour (1983) does not investigate and is a perceived
weakness of his analysis.

5.3.7.2 Social influence of Tain

Latour’s (1987) chapter on machines comes closest to explaining the success of the Tain instrument in implementing social change through technology. It is the fact that the interfaces are machines that make them a powerful lever. Latour’s comment: ‘The total movement of an artefact, will depend to some extent on your action but to a much greater extent on that crowd over which you have little control’ (Ibid., p.104.) can explain the success of Tain. This success was highly dependent on the outside social forces. Tain was developed by Brian Taylor to fulfill a perceived gap in Physics practicals. What a small number of technically able teachers put together could now be bought over the counter as a ready-to-go machine. It was brought to the attention of our Physics co-ordinator at Physics conferences. Its capacity was first limited by its DOS command system. It was limited by a menu driven system. The capabilities were greater than rival machines like Pasco as Taylor was able to adapt the interface to local needs rather than make teachers change their practicals to the machine. Pasco was a similar instrument to Tain. Pasco was developed in America, but did not have the same amount of flexibility. It was not multipurpose; you had to buy separate instruments for separate functions. The Australian representative of Pasco at the 1997 Physics conference indicated the reason for this. She was there to sell Pasco as a package that could do certain practicals that were available in the United States of America. However she did not have the ability to change the machinery for Victoria. Taylor as Tain’s representative was happy to try modifying the machine if it could be done and would lead to greater sale. Whether it remains
successful depends on how it can further adapt to take on the term 'learning technologies'. The Tain machine was around for 2 years but was not used in class due to lack of computer facilities and technical staff to write up the practicals. As the machine proved itself at Year 11, students started to adapt its capabilities at Year 12. Thus you have further no-cost technical staff (the students) coming up with uses which the co-ordinator can use free of cost. The machine can be used for many different practical subject areas. It was first used in mechanics and but was also used in electricity. Is it used in different areas because it is more efficient? The students and staff are undecided as to which areas of the syllabus it works best in. Research has given reasons why Tain might be good for electricity. In using data logging for electricity Barton (1990) suggested the following advantages are:

- No difficult circuits
- No problems in reading the scales
- No time consuming graph plotting.
- Removing the above barriers makes work more accessible to younger and less able students.

Only one of the above advantages was mentioned by teachers in the study. However no research on the comparison between areas of the syllabus could be found.

Is Tain used universally to give students (and teachers) more practice of the tacit knowledge of the Tain system? This point is hard to prove. This is why the commercialisation of this instrument in all subject areas is such a strong lever. Once teachers (and students) learn one set of commands which they can use for mechanics, electricity and heat, they do not want to go back to a system where they had to learn about one instrument for electricity (multimeter), one for mechanics (ticker tape) and
one for heat (thermometer). Was Tain universally used as an excuse for the cost of buying it? According to the Physics co-ordinator and technician, no. It costs as much to run as the old practicals.

Latour (1987) believes that you need ‘... to enroll others so that they participate in the construction of the fact.’ (Ibid. p.108) These allies can be human or non-human. Tain has enrolled the power of IBM as an ally. Tain equals computers because Tain interface is attached to the computer. Thus Tain equals spreadsheets and Tain equals graphs. Tain equals all other capabilities that students and staff associate with computer. For the Principal and co-ordinator, Tain equals technology implemented. This should not be overstated. For most participants these allies were minor to the implementation of Tain. The tacit knowledge of IBM software, which most of the students had, allowed easy implementation of this system. The availability of cheap old IBM computers allowed the physics co-ordinator to readily set up the network, though Bork (1995) would argue this hardware usage is due to little focus on the students. The students were the last things to be considered after the hardware was purchased.

Most important was the link of computers with progress. This viewpoint which was commonly expressed in section 5.1 by both students and teachers, would facilitate easy acceptance of Tain.

Latour (1987) mentions that it is just not good enough to enroll allies but you must keep them in control. He further states that: ‘A chain is only as strong as its weakest link’ (Ibid. p.121.). It is interesting to think of what is meant by the weak link in this example. Interesting because it depends on what the goals of the participants are. The students identified the weakest link as the software. The students’ tacit knowledge
was of the more powerful and more recent Windows environment, as used in their computers at home or in the library. However the software they used was the menu driven software. In menu command you can at least identify problems more quickly. But a more difficult problem with the software was not identified by either the teachers or the staff. Much was made in section 3.6.2 of MBL allowing improved analysis skill due to the graphing been done by the computer. Hodson (1993) states the search for correlation and theory building can be done by computerised data management systems. By displaying data in a variety of ways, plotting graphs, performing calculations, analysing data, collecting data, and even monitoring and controlling experiments, computers can eliminate much of the ‘noise’ associated with complex apparatus, the boredom of long wait times and the ‘mathematical noise’ of lengthy calculations.

The Tain software did allow for immediate graphing to be displayed on the computer screen, but the students could not print the screen. The students had to take away the digital data and process it through a spreadsheet program to reproduce the graph they had seen on the computer screen. One of the major advantages of MBLs was not available with Tain, yet no one mentioned it as a weak link. Bork (1995) identified this problem as Software-Based Failure. There are a variety of problems with software. The difficult graphing software of Tain may work with very good students or with extremely skilled teachers, but what of those who struggle putting physics formulae into spread sheeting?

It is possible to surmise that if the system was turned over to a Windows environment the above problem would not occur. However this leads to hardware updates that become too expensive for the Physics department to contemplate. Tain,
according to the physics co-ordinator, is not interested in developing this until the market demands it. It can use the cheapness of 286 and 386 computers to allow market penetration. A fair question to contemplate is would people buy Tain if it required a Pentium© computer? Cooper (1993) suggested a relationship exists between instructional theory and its dependent technologies, bounded by three factors: instructional design methodology; the physical technology with which the instruction is implemented or mediated, and the programming mechanisms used to develop instructional software conveying the subject content. These are the exact three areas that have been identified above.

The physics teachers identified the weak link as more educational or procedural. They mentioned more the loss of skills in moving from the old practical to the new. This is similar to an argument against the costly introduction of MBLs by Beichner (Weller, 1996). Beichner (Weller, 1996) found that MBL ‘simulation’ exercises in projectile motion were no more effective than convention laboratory. The researcher surmised that kinesthetic feedback might be the most important part of the MBL learning experience. The physics teachers also mentioned the distraction of the computer to the task. Research would suggest this concern, Nakhleb and Krajicik (Weller, 1996) compared three different technologies in titration: MBLs, pH meters and chemical indicators. The MBL students also had more inappropriate connections in their concept maps than the pH meters or chemical indicator students. The researchers speculated that this was because of the high level of involvement of the MBL students with the technology. Computers may cloud issues but this was not apparent in this case study. The physics teachers also mentioned the ability for
students to easily copy work in a digital form. No research could be found to substantiate these views.

5.3.8 Ontology of computer technology-local change

In section 3.7 ontology of computer interface technology was defined as important to explain the relationship between science and technology. Ontology of instruments can be important to explain the relationship between theory and reality. There were a number of ontology theories introduced in section 3.7. In this section their relevance is compared to the data.

5.3.8.1 Instrumentalism

Instruments are the centre of Latour’s (1987) black box and the argument over the boundary between “construction of knowledge” vs. “constructed nature of reality”. Is what Tain produces due to epistemology or ontology? In the view of the students and teachers it’s a mixture of both.

An example of an instrument as epistemology would be Latour’s (1987) statement:

‘A machine, as its name implies, is first of all, a machination, a stratagem, a kind of cunning, where borrowed forces keep one another in check so that none can fly apart from the group.’(Ibid. p.127.)

This machine automatically brings into line the behaviour of the operator. The operator must obey the instruction booklet if the machine is to function. Any independent or aberrant behaviour by the operator will stop the machine functioning. The machine cannot easily be reopened; it was designed to be operated by students
and as such the operators would not necessarily know how they work. Latour (1987) states that if the blackbox is successful it gains its own impetus and inner strength in what he calls the model of diffusion (Ibid., p.132.). The significant thing about scientific instruments is, once they are available they diffuse throughout the educational world as they are used to set up other scientific practicals. They become an unquestioned tool. It is true that the degree of diffusion can be dependent on such things as the cost, complexity and the size of the instrument. The success of the Tain was magnified by the fact that it was very robust and didn't cost a large amount. They were also easy to operate and multi purpose.

The above example would be of what House (1991) calls the Central Notion of Causation. This implies we are determined by custom alone. The powers by which bodies operate are entirely unknown. We have no knowledge of anything but phenomena and our knowledge of phenomena is relative and not absolute. If such objects can be verified, it must be solely through their relation to sense data. Hence all knowledge is based on fallible experience; hence all knowledge is mere supposition. It is a relativist viewpoint, even though House (1991) aligns himself with the realists described in section 5.3.8.3.

An example of an instrument leaning towards ontology would be Latour (1987) statement, in the beginning of his chapter on laboratories:

‘You doubt what I wrote? Let me show you! The very rare and obstinate dissenter who has not been convinced by the scientific text is led from the text into the place where the text is said to come from. I will call this place the laboratory.’ (Ibid. p.64.)
The machine /instrument is the portable laboratory, the text maker. This is the potent but unidentified power level. Inscriptions are created by the machine thus are hard to dispute. Students do not question the graphical readings of the Tain interface. They take it as fact/reality. They do not question how the velocity was calculated they succumb to the reputation of the computer. The interviews with students showed that they were not concerned about how the information was obtained, but when pressed the majority of students could explain how Tain determined velocity. However Hodson (1993) would not care if the students did not understand how Tain got the results. Hodson (1993) draws attention to differences of authentic and inauthentic labor. The former is an integral part of the learning and makes a valuable and direct contribution to it. The latter is necessary simply in order to proceed with the learning task; it is additional to the learning and has no particular value in itself. Hodson (1993) argues that the needs and interests of the student should be uppermost. The Tain interface is replicated into 14 clones (other interfaces). The students accept that they will produce identical results; they do not necessarily know how the integrated circuits produce results. All they need is the knowledge to set up and follow the instruction sheet. The science sociologist H.M. Collins (1982) recognised this and calls this requisite knowledge ‘tacit knowledge’ and compares it to the skill knowledge necessary to ride a bike. Once students and staff have spent valuable time learning how to operate Tain they do not learn other methods for other practicals such as electric circuits. This is why students say Tain is easier. There is only a small amount of tacit knowledge required to operate Tain. A knowledge which equates essentially to being able to use computer software and read instructions. The students accept the results of Tain as they say it is more accurate. They accept it more than the
old practicals of ticker tape, as they can understand the mistakes that can occur. For example, the students can see the dot on the ticker tape smudging and can conclude this will make the results less accurate. They cannot get into the Tain interface and unpack it. It is a tamper proof, impenetrable laboratory that can not be questioned. The acceptance of this laboratory could be the viewpoint of a pragmatist or a realist.

5.3.8.2 Pragmatism

A pragmatist might not be so precious about this concrete reality but more concerned with agreed meaning or reality and the outcomes of this meaning. Someone who believes in positivism agrees that objects have constructed labels but are still real objects (Laudan, 1990).

Peirce (1905) as cited in Segal (1997) stressed the importance of ‘clarifying meanings of intellectual concepts’ by tracing out ‘their conceivable practical consequences’ (p.13). Of the study sample, the teachers and principal came over as pragmatic in their attitude. The teachers were more concerned with the accuracy of the Tain than what values it might teach their students about reality. Given the assessment tasks and physics syllabus did not mention concerns of values the attitude of the physics teachers is reasonable. Even the chemistry co-ordinator would not adopt Tain for pragmatic reasons, not for reasons based on the reality Tain taught. However there are two critical points which would cancel out suggestions of these groups being pragmatists. The first is their concrete attitude towards the signals coming from Tain. This attitude would put them in the positivist camp. The views of teachers and students towards the objects being measured by Tain were not tested here. They were not questioned on the traditional distinctions between knowledge
and opinion. Secondly, Segal (1997) states that pragmatists recognise and emphasis the central importance of values already held by scientists in determining their future actions. No proof was available to indicate this was going on in this case study. Rorty (1991) would argue that progress is the move of teachers and students from a positivist view on Tain to a more pragmatic viewpoint. In Rorty’s (1991) terms, the understanding that objectivity equals universality gives the teachers and students’ power. However there was little proof that any of the sample population was making that move. The teachers were pragmatic in their use of Tain to simplify their practical classes, but they did not teach a pragmatic philosophy about the equipment being used. Rorty’s (1991) progress would seem impossible for a number of reasons. Firstly most of the teachers would not recognize the pragmatic philosophy, as it has not been taught to them in any stage of their teacher education. Secondly, in an already crammed syllabus there is little time to teach extra, especially when it is not connected to statewide assessment.

5.3.8.3 Realism

According to Segal (1997), a realist ontology incorporates the following views:

1. Knowledge is a social and historical product, facts are theory-laden, and the task of science is to invent theories to explain the real world and to test these theories by rational criteria developed within particular disciplines.

2. The real world is complex and stratified so that one is always discovering more complex layers of reality to explain other levels.

3. In this conception of causation, entities act as a function of their basic structure. The task of science is to determine this structure so that one can
understand how the entity acts, which must always be in terms of tendencies and probabilities’ (Maicas & Secord, 1983, as cited in House, 1991, p.2)

Realists believe there are actually entities electrons, pragmatists don’t necessarily believe in actual entities. It is this final point which signals the main difference between that of a pragmatist and that of a realist. As mentioned previously, none of the sample population was asked their opinions on reality. However their acceptance of computers as being more accurate than older practicals, their acceptance of technology consisting of artefacts would tend to suggest that they are more aligned to a realist philosophy than a pragmatist’s. Realists would view the instrument as a physical tool that measures factual entities such as electrons.

Scientific realism does not stop at the surface events, like naive realism, but examines the underlying patterns and tendencies. There is little to suggest that the impact of introducing interface computer technology into this school had been studied. The only few examples would be, some teachers’ concern over students being distracted by the computers and not understanding the theory used; and perhaps when questioned on the relationship between science and technology a large proportion took the view that the two interacted, a more theory laden opinion than the technology as applied science viewpoint.

Latour (1987) talks about appealing to nature. He talks about the two faces of Janus being:

‘On the left side scientists are realists, that is they believe that the presentations are sorted out by what is really outside, by the only independent referee there is, Nature. On the right side, the same scientists are relativists. They believe representations to be sorted out among themselves and the
actants they represent, without independent and impartial referees lending
their weight to any one of them' (Ibid., 1987, p.252.)

Interviewing teachers and students suggested their belief in Latour's (1987) left-hand
side of the Janus. Neither teachers nor students felt they were being lead in a fruitless
pursuit by adopting Tain. It was a case of Tain reproducing Nature. Their philosophy
would be defined as technological determinism. In the words of sociologist Bruce
Bimber (Bijker & Laws, 1992), technological determinism would be defined as
believing in the nomological account of technology, which rests on the laws of
nature rather than on social norms. Bimber (Bijker & Laws, 1992) goes on to
compare Nomological determinism with Thomas P. Hughes (Bijker & Law, 1992)
term 'technological momentum' which describes the increasing capacity of
technological systems to influence societies as those societies grow in size. This idea
of momentum does fit the beliefs of the students and teachers. They believed that
computers were progress thus they believed that Tain was progress.

5.3.9 Constructivism

The importance of constructivism to science education researchers is well
documented by Milne and Taylor (1995). It is a methodology not an ontology
(Golinski, 1998). As a methodology it could be used to create the progress as
expressed by Rorty (1991) in students understanding of technology, technology's
relationship with science and the part played by instruments such as Tain. Tobin
(1990, 1993) and Driver (1988), suggest we develop our knowledge of the natural
world by reflecting on the viability of new ideas that spring from our attempts to
make sense of new and problematic experiences. Knowledge is not to be found in books; it does not exist out there, separate from us as claimed by objectivists or realists. Resnick (1994) summarised the characteristics of this approach in three statements:

- Learners construct understanding. They do not simply mirror what they are told or what they read. To understand something is to know relationships.
- Bits of isolated information are forgotten or become inaccessible to memory.
- All learning depends on prior knowledge.

Prior knowledge may include beliefs about technology and computer interfaces.

Gil-Perez (1996) suggests the view of science learning as conceptual change in three basic steps:

- An elicitation phase of pupils’ ideas, making them conscious of the plausibility and productivity of those ideas
- A restructuring phase, creating cognitive conflict, generating pupils’ dissatisfaction with their current ideas and preparing them for the introduction of scientific concepts.
- An application phase which gives opportunities for using the new conceptions in different contexts and consolidating them.

Constructivist teaching may have occurred in this case study, however it occurred around teaching the subjects of temperature, movement and electricity and not about technology or computer interfaces. The introduction of Tain interfaces could have allowed creating cognitive conflict about what is real and what is measured, what is science and what is technology. Instead the Tain just replaced older practical equipment such as thermometers without any question being asked of the students as
to the nature and role of the technology. Indeed the Tain introduction did little to cause cognitive conflict in the physics teachers accepting it. The reasons for this have been illustrated before; the question of technology is not on the syllabus, there is not enough time to introduce new material into an already crowded syllabus, there was no assessment tied to the topic, in the minds of the teachers and students there was no real reason to cause conflict as the introduction of Tain was one of progress and greater accuracy in practicals.

The only part of constructivist teaching on technology that occurred was the actual case study itself. Answers by the students to the technology questionnaire were an elicitation phase of pupils' ideas, making them conscious of the plausibility and productivity of those ideas. Answers to the questionnaire on practicals could have been a restructuring phase, creating cognitive conflict, generating pupils' dissatisfaction with their current ideas. However there was no third phase of consolidation, to place these ideas in other contexts. Any conflict in the students' mind by the questionnaires may have been cancelled out by the voice of authority inherent in classroom pedagogy and texts. They will also learn that the voice of authority, whether teacher or text, is privileged and authoritative (O'Loughlin, 1992).

5.3.10 Summary

The discussion on actants of power presented a complex picture of what was necessary to introduce Tain interface technology into a school. Each actant had a purpose in Tain's introduction. While it is obvious that some of the actants, for
example the Physics co-ordinator, the Physics laboratory technician and assessment, were important. Not obvious was that if you took away one of the minor actants, for example curriculum or textbooks, whether these changes would have been enough to stop Tain's introduction. The complexity of identifying the most powerful actants can be illustrated by a number of examples. Whilst the support of the Physics teachers would seem paramount to successfully introducing Tain, which actant would sway the teachers' support was not. Would the teachers be swayed by Tain being used for assessment or by their belief that Tain as more accurate and progressive? The answers to these questions are hard to measure. In this case study the interviews only identified the powerful actants, the interviews did not ascertain which actants were most important.

Similarly the section on the ontology of instruments was able to categorize some of the philosophies (or belief systems) which allow Tain to be a powerful actant. Such beliefs as instrumentalism means that the staff and students believe in the inscriptions of the computer-based technology are representations of reality. Or perhaps the staff or students are pragmatists who don't necessarily believe the inscriptions are reality but have not got the time to think these arguments through. They just want to complete the assessment task and are not rewarded for thinking the process through. Whist such musings on the power of these philosophies as actants are of interest to the author of this thesis, all the data collected and interviews obtained indicated that none of the actors in this network philosophized about the ontology of the technology they used.
Chapter 6

Conclusion
6.1 Students' concepts of technology

As illustrated in the previous chapter, the range of students' concepts of technology was found to be quite limited and predictable. Regardless of age or subject, the beliefs on technology which stood out were computers, progress and making life easier. The students' views backed the limited research (Rennie, 1987, Rennie & Sillitto, 1988) on this topic. Some English commentators (Solomon & Aikenhead, 1994) suggest English students will identify technology with problem solving, whereas the Australian students reported in this thesis identify technology with tools or artefacts. There were examples of situated or contextual learning. For example the Year 12 Physics students were more likely to mention electronics, as it was a topic in their syllabus. Students elected various answers to technology whilst doing the technology questionnaire (Rennie, 1987). This was only because the students' attention was drawn to these categories, however this expanded range was not supported when students were interviewed. The response to the technology questionnaire indicated that Year 9 Science students were more uncertain about the benefits of technology than their senior students.

When specifically questioned on the Tain interface the Year 11 and Year 12 students were positive towards its introduction. They saw the use of Tain as progressive because it introduced greater accuracy to the practicals. Students did not feel that any particular Physics topic was better served by Tain.
6.2 Teachers’ concepts of technology

As discussed in the previous chapter, the range of teachers’ concepts of technology was also limited similar to views held by the students they taught. The teachers’ beliefs of technology revolved around computers and making life easier. Unfortunately there little research on teachers’ beliefs. Rennie (1987) found that science teachers expressed similar views to that of this case study. Rennie and Jarvis (1995a) found that primary teachers were more confused about technology due to the influence of their National Curriculum (Department for Education, 1995). There seemed to be a contextual influence in the teachers’ answers. Those teachers with Information Technology as a second teaching method were more likely to mention technology’s problem solving capacity.

If one was to compare the overall Physics teachers’ views with that of their students, there was very little in the way of difference. However the sample was too small to make a real comparison. Both students and teachers suggested the media had more of an influence on students’ beliefs.

Teachers’ views on the advantages and disadvantages of Tain learning technology varied more than the students’. The Physics coordinator expressed fanatical enthusiasm, whereas some teachers were initially dubious of its value. The majority of Physics teachers still thought that Tain lead to progress. The differences in teachers’ views did not affect their students’ enthusiasm for technology.
6.3 Science and technology

As already discussed in earlier chapters, according to Gardiner (1994) most people tend to associate technology with science in terms of 'applied science'. Teachers' and the students' responses confirmed this association. This further reinforces the idea of technology perceived as being artefacts or tools.

Technoscience, the view expressed by Latour (1987) and best explained by Gardiner's category of science and technology being interdependent, did not rank highly in the belief system of the teachers or students. Yet von Glaserfeld (1995) would suggest that technoscience is the best model to work towards due to its transparency. The technoscience view has advantages in that it can be used on instruments to look at the relationship between science and technology. It can also be used to explain more global concerns such as cultural differences between science and engineering. However, the research would indicate that acceptance of this view is distant.

6.4 Power structures

In the introduction to this thesis the following four questions were asked:

1. Why the push for technology in 1994?
2. Why in three years was the task complete?
3. Why does technology equate to computers?
4. Why was Tain only fully introduced to Physics department?

The research undertaken and the findings presented in this thesis have helped to answer the first question, the push in 1994 coincided with the school charter's
mention of technology as one of its goals. Contrary to the beliefs of some teachers that technology was a reaction to a directive from the Principal to obtain a bonus, the push came mainly from two neo progressives, the Physics coordinator and the Physics technician. This confirms Cuban's (1993) findings that the impulse for change is the push from the neo-progressives who wish schools to be places where students are active learners busily constructing knowledge that makes sense to them.

The Physics coordinator and Physics technician were able to present to the Physics staff a workable package that they could slot into their teaching of the syllabus. This coincided with the school charter. A controversial move of replacing old practicals with new was diffused. Why this controversy was diverted could be attributed to a number of complex reasons. The Physics staff (and the students they taught) believed that technology equalled progress, ease of work and computers. Physics staff took it on because, even though some were wary of its worth, they could see potential benefit to a major assessment project in the Year 12 syllabus. The lack of response from the Chemistry department could be attributed to three reasons. Firstly, there were no neo progressives on the staff, secondly there was no assessment task tied to technology and thirdly, there was no penalty for not introducing technology.

To answer the second question in the list on the previous page, despite the Principal's report saying technology had been successfully introduced the program was not completed in three years. Further work has been done since. For example, the introduction of the Internet as a means of dispensing worksheets to students.

Why did technology equate to computers? The data collected would suggest that the media influenced the association between technology and computers. The media influence was supported by the evidence of Aikenhead (1997). But it is also true to
say that not all students and staff equated technology with computers. The link between technology and computers was formalized later by Education Department booklets on learning technologies.

6.5 Instruments

Concerns about Tain computer equipment being accepted due to positivistic determinism of both the teachers and the students were confirmed. Students and teachers willingly accepted the instrument without question. There is much to applaud about the use of Tain, such as the instant feedback via graphs and the ease in collecting results over a long time. However Tain should only be introduced if teachers and students questioned the assumptions behind the machine. The assumption revolves around such questions as what reality does the instrument present? Or what theory is built into the machine? The Actor Network theory of Callon (1986) and Latour (1987) helped to clarify these questions. Latour (1987) also recognises that instruments like the Tain interface are blackboxes, which due to their machinations present results that are not questioned. This was evidenced when students equated the use of Tain with enhanced accuracy. Latour (1987) believed that computers and their power were used by Tain computer interfaces to give legitimacy to Tain.

However this study on students' and teachers' beliefs regarding Tain computer interfaces showed none of these reality questions were being pursued in the classes. Due to lack of time, lack of desire or knowledge on the teacher's behalf and lack of assessment power it is difficult to see such questioning occurring. Teachers have
limited time to address a full curriculum and if the material is not to be assessed they may not discuss it. The reality and value of Tain or Tain data is not assessed, therefore little time is allocated to discussion of Tain technology. The case study would suggest that this investigation into the nature of technology has come across similar problems as case studies on the nature of science (Lederman, 1992).
Chapter 7

Implications of the Study and Areas for Further Research
7.1 Introduction

The implications discussed in this chapter will sound very similar to the implications drawn from research on the nature of science 20 years ago:

- Introduce philosophy of technology to teacher training
- Introduce studies on instrumentation to Physics
- Introduce the history of technology in the Science syllabus to confront views of technological determinism

These same arguments were put forward previously by Lederman (1992), for 'science'. Research has shown no real changes have occurred in the study of the nature of science. So why should it be different for technology? The failure regarding the study of the nature of technology has been primarily due to lack of time to introduce these topics into an already crowded syllabus. These topics have a lack of status within the science community as mentioned by Lederman (1992), or these topics have no allies, to use Latour's (1987) language. An example of this is systems technology. The definition of technology in this VCE subject is broader than that of applied science. However as systems technology is used in technical trades only a small proportion of students are exposed to it.

7.2 Curriculum and Assessment

Culture can change beliefs in technology. Rennie and Jarvis (1995a) indicated that English children looked at technology more as a process than their Australian counterparts. As indicated by Solomon (1993) the English curriculum promotes technology as a process. The expectations of the community, students,
administration, and colleagues, as well as the dictates of the curriculum, give
direction for choosing actions (Lantz and Kass, 1987). However teachers adapt a
curriculum in ways they think are most appropriate for each specific teaching
situation (White, 1988). The way in which Physics and Chemistry teachers reacted to
the School Charter is evidence of this.
The curriculum does dictate assessment policies of both Physics and Chemistry. The
case study presented apparent evidence of the importance of assessment in
determining the introduction of learning technologies. The implication of assessment
is if you want to help introduce learning technologies into science classrooms then
tie an assessment task to it, preferably at a senior level.

7.3 The sociology of technology and constructivism

The case study was effective in identifying the links of power in the Actor Network
Theory. This radical sociology could provide social constructivism with a fuller
picture of the construction of knowledge. For example, students and teachers
mentioned progress as a motivator for the introduction of technology. The case study
was limited in terms of providing an explanation of progress. This problem is due the
heavy reliance of the case study on Latour (1987), who does not deal with explaining
progress. None of the philosophies mentioned in the literature review explained what
progress is, with the exception Pickering’s (1995) engagement with the issue of
temporality.

The other problem with the Actor Network Theory of Callon (1987) is it could not
attribute importance to each of the links in the technology network. Thus it is
impossible to account for the process of resolution of the disputes as other than the disclosure of a pre-existing reality (Golinski, 1998). Golinski (1998) indicates that the solution to the problem of the process of resolution might be to draw on the social reflection of historians.

7.4 Areas of further study

7.4.1 Are the results transferable?

There are a large number of shortcomings with this research thesis investigating the nature of technology.

For a start the sample school was all male and over 50% of students were of Asian Australian background so it is not an indicative Australian school. All the Physics teachers were male. A further study investigating female students and students from other cultural perceptions would add to the body of literature on the perception of technology. More research should include the viewpoint of students studying Chemistry and Biology.

The sample size of three Year 11 Physics classes and their teachers was too small to make generalisable comment about the relationship between a teacher's viewpoint and their students. As a case study the results are not transferable. However, the case study reflects the situation in one school, and it could be argued that no two schools are the same. Furthermore the one case thesis was not intended to provide generalisable data, but intended to help address the dearth of available literature on students' and teachers' perceptions of technology as well as the agents of change.
7.4.2 Teachers' beliefs on technology

The previous research on teacher's beliefs on technology was minimal, so there was little to compare it with. The data provided in this thesis, though limited, provides some indication of teacher beliefs. Therefore it has added to the literature on:

a) teacher beliefs on a variety of concepts

b) beliefs of technology of a variety of agents

7.4.3 Assessment

More research needs to be done on the link between assessment and the successful introduction of technology. The case study described suggested that technology (i.e. computers) was tied to assessment tasks of science concepts and skills and therefore considered an important tool. It would be interesting to investigate whether subjects Science and Chemistry introducing learning technologies require a link with assessment to avoid controversy regarding its use in science classes.

7.4.4 Other case studies

By 1998 the Science coordinator was considering introducing Texas Instrument graphic calculators connected to datalogging probes rather than Tain computer technology. A comparative study investigating the Science department's decision not to use Tain, three years after the Physics department would help to identify different levers of power.

Similarly at the end of 1999 the new VBOS Chemistry Assessment Task reintroduced practical work into year 12 Chemistry assessment. A case study
investigating the effect of this event on the use of learning technology and Chemistry might add weight to the argument about the importance of assessment in determining change.

The Physics faculty of the sample school has introduced further technology. The Internet is been used by Physics students to download all handouts and past examinations. This emphasises the "technology is progress' attitude mentioned by most of the sample in the nature of technology section. However the Internet has nothing to do with assessment or with the Physics curriculum. It appears to be a cost saving mechanism by the Physics co-ordinator. A case study into how successful this type of technology is and what it does to the students' and teachers' beliefs would add to this area of research.

Rather than just using Actor Network Theory there may be there is a need to move towards the historians' rich narrative and combine it with Pickering's (1995) vision of the "mangle of practice".

### 7.5 Summary

Since this case study was completed other case studies about the introduction technology to other faculties besides Physics have appeared. Building on the information obtained in this case study would allow a number of points to be investigated:
1. It would allow more specific research to be done on the Physics faculty, perhaps allowing the development of the historian's rich narrative.

2. It would allow a broader sample size to investigate the beliefs in the nature of technology.

3. It would allow a comparison of beliefs on the nature of technology over a longer period of time.

4. It would identify whether the same actants were universally powerful.

It is not unreasonable to assume there are similar cases of the introduction of learning technologies at other schools. Using the methodology and results obtained in this case study would allow for an expansion of knowledge on the nature of technology.
Appendices
Appendix A

WHAT TECHNOLOGY MEANS TO ME

Name: 	 School: 	 Class:

Technology can mean different things to different people. When you read the word ‘technology’ what comes into your mind? What does technology involve?

Please tell us what technology means to you by writing about it or by drawing a picture. You might like to do both.
Appendix B

TECHNOLOGY QUESTIONNAIRE

Name ____________________ School ____________________ Class ____________________

Here are some questions for you. For each question, circle the number which is the right answer for you.

Part A: What is technology?

<table>
<thead>
<tr>
<th></th>
<th>STRONGLYagree</th>
<th>AGREE</th>
<th>CAN'T</th>
<th>DISAGREE</th>
<th>STRONGLYdisagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technology mainly concerns computers and similar equipment.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Making models and testing them is part of technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>Technological appliances can only be used by qualified people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>Working with materials is an important part of technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5.</td>
<td>Without electricity, there would be no technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6.</td>
<td>Technology involves designing solutions to problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7.</td>
<td>Most people have little to do with technology in their everyday lives.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8.</td>
<td>In technology there are opportunities to design new products.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9.</td>
<td>Two hundred years ago there was no technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10.</td>
<td>Technology means inventing new ways of doing things.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Part B: What do you think about technology?

<table>
<thead>
<tr>
<th></th>
<th>STRONGLYagree</th>
<th>AGREE</th>
<th>CAN'T</th>
<th>DISAGREE</th>
<th>STRONGLYdisagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>I am interested in technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Technology makes the world a better place to live in.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>I would like to learn more about technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>Technology has brought more good things than bad things.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
</tr>
<tr>
<td>5.</td>
<td>I would like a career in technology later on.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>6.</td>
<td>It is worth spending money on technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7.</td>
<td>I like to read books and magazines about technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8.</td>
<td>Inventions in technology are doing more good than harm.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9.</td>
<td>I would like to join a hobby club about technology.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10.</td>
<td>Technology is needed by everybody.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
Appendix C

YEAR 11 PRACTICAL QUESTIONNAIRE, 1996

NAME:

QUESTIONS ON PRACTICALS

1. Which practical did you enjoy most. The ones with the carts or the one with the Tain interface? Why?

2. Which practical explains the Physics concepts better to you? Why?

3. Which practical is easier to do? Why?

4. What is the advantage of using the Tain interface?

5. What is the disadvantage of using the Tain interface?

6. Is the Tain better to use for electronics pracs or force/motion pracs? Why?

7. Explain how the ticker tape machine can determine velocity?

8. Explain how the pulley of the Tain interface can determine velocity?
The following is an attempt to review the recent introduction of Tain interface practicals. The Physics department is interested in your feedback as to which practical serves learning best. The answer to this question might vary for different topics but we are looking for fitness of purpose in the best practical for the best learning situation.

Please compare the methods and the form of the results obtained. Read the instructions and try them.

1. Heating and temperature.

Heat flow

Thermometer versus thermocouple
See work sheet See work sheet
advantages advantages
disadvantages disadvantages

How does the instrument work i.e. measure the physical quantity of temperature?

2. Mechanics

F=ma
Dynamics carts and ticker tape versus Tain interface

See Practical Physics prac 12 +13, p.21-23. see worksheet

advantages advantages

disadvantages disadvantages

How does the instrument measure the physical quantity i.e. acceleration?

ticker tape Tain

3. Electricity

Series versus parallel

Meters versus Tain

See Practical Physics Prac 52, p.87 See work sheet

advantages advantages

disadvantages disadvantages

How does the instrument explain the formula for resistors in series and parallel?

General questions Q1. What is technology?

Q2. What technology do you use in Year 11 Physics?
Q3. How effective has been the use of computers in Physics? What are the advantages? What are the disadvantages?

4 Does Tain interface teach physics concepts better than the practicals it replaced? What topic areas (electricity, mechanics, etc.) are better suited to TAIN?

Q5. Students surveyed said that technology was computers, machinery and progress. Where do you think they picked up these viewpoints?

Q6 Which viewpoint(s) of technology and its relationship to science shown below do you agree with?

POINT A: Gardner (1994) would argue that people can think of the terms science and technology are representing the same concept. Due to people lacking the ability to distinguish between the two.

POINT B: Science and technology as distinguishable.

Gardner manages to summarise four possible relationships as:

(i) science precedes technology i.e. technology capability grows out of scientific knowledge; this position, often called the technology as applied science (TAS) view, is widely held and influential.

It is sometimes presented as the definition of technology. Gardner argues the first tends to be the dominant view.

Supporters of the TAS view point to artefacts and systems that have followed scientific discoveries. The artefact’s operation is often ‘explained’ in terms of one scientific principle, determined by the science topic which is the focus of the study.
(ii) science and technology are independent, with differing goals, methods and outcomes (the demarcationist view). Gardner's (1994) second position was science and technology are independent. The demarcationist view treats science and technology as distinct fields, pursuing different goals, utilising different methods and carried out by different social groups. Science is analytic, concerned with the generation of knowledge; technology is synthetic, making things for utilitarian motives. An example of science ignoring technology in curricula is the American PSSC Physics course.

(iii) technology precedes science; this materialist view asserts that technology is historically and ontologically prior to science that experience with tools, instruments and other artefacts is necessary for conceptual development. Position three is the reverse of the first. It is that technology precedes science. Its basic premise is historical. That humans have been making artefacts, such as tools, ever since our emergence as a species. Other examples are that the technology of metal extraction preceded the development of the chemistry of metals by a millennia. The strongest argument is actually ontological: technology is held to be necessary for generating scientific ideas. Ihde (1983, 1991), a powerful advocate of this view, regards artefacts and instruments as shapers of thought.

(iv) technology and science engage in two-way interaction; this interactionist view considers scientists and technologists as groups of people who learn from each other. Position four is the interactionist view, which proposes that technologists and scientists can learn from each other. This interaction has flourished during the past century. The American historian of technology, E.Layton (1977, p.21), points out that 'Science and technology have become intermixed. Modern technology involves
scientists who do 'technology and technologists who function as scientists'. In fields such as electronics it is difficult to untangle the scientific and technological contributions. Layton also highlights the importance of social interactions between scientists and technologists for generating innovations.
Appendix E

YEAR 12 PRACTICAL QUESTIONNAIRE, 1997

NAME:

General questions
Q1. What is technology?

Q2. What technology do you use in Year 11 Physics?

Q3. How effective has been the use of computers in Physics? What are the advantages? What are the disadvantages?

4. Does Tain interface teach physics concepts better than the practicals it replaced? What topic areas (electricity, mechanics, etc.) are better suited to TAIN?

Q5. Students surveyed said that technology was computers, machinery and progress. Where do you think they picked up these viewpoints?

Q6. Which viewpoint(s) of technology and its relationship to science shown below do you agree with?

POINT A: Gardner (1994) would argue that people can think of the terms science and technology are representing the same concept. Due to people lacking the ability to distinguish between the two.
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Gardner manages to summarise four possible relationships as:

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Appendix F

Interview schedule

Year 12 Physics class (21 total)
18th November 1997 - 7×7 minute interviews, 19th November 1997 - 7×7 minute interviews, 25th November 1997 - 7×7 minute interviews, 26th November 1997 - 3×7 minute interviews

Year 11 Physics class (Total 24 students)
13th October 1997 - 7×7 minute interviews, 14th October 1997 - 7×7 minute interviews, 15th October 1997 - 7×7 minute interviews

Staff (Total 11)
1st December 1997 - 45 minute interview each with Principal and Physics teachers David, Shaun, Geoff and Ian.
2nd December 1997 - 45 minute interview with Chemistry coordinator, Chemistry technician and Physics technician.
3rd December 1997 - 45 minute interviews with Physics teachers, Justin, Paul and Adrian.
15th December 1997 - 2nd 45 minute interview with Principal and Physics teachers David, Shaun, Geoff, Adrian and Ian.
16th December 1997 - 2nd 45 minute interview with Chemistry coordinator, Chemistry technician and Physics technician and Physics teachers, Justin and Paul.
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KEMP, SHAUN

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