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Pupils' Experiences of Technology

Exploring dimensions of technological literacy

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Abstract

Technology is the driving force behind much of the change taking place in the world today. Consequently, across society, calls are being made to ensure technological literacy is a meaningful and central part of schooling to adequately prepare pupils to become part of an increasingly technologically driven world. However, studies have shown that large parts of society perceive technology primarily in terms of computers. Thus, to be considered technologically literate is likely to be superficially interpreted as knowing how to use computers.

One strategy used to broaden pupils' experiences of technology, and influence their levels of technological literacy, has been to take technology-based activities into school classrooms. Here, through a structured process, pupils supposedly have the opportunity to interact with technological artefacts. Yet, little research exists about how pupils experience technology that can be used to inform the development of such interventions. However, empirical evidence drawn on to develop these structured activities has proved successful in making a positive impact on pupils' experiences of technology.

In order to understand how pupils experience technology, and thus be able to significantly inform the development of technologically based activities for them, this study investigates pupils' conceptions of technology and their experiences of interacting with technological artefacts.

The research approach that was adopted to investigate these questions was phenomenography, which facilitated data of pupils' experiences of technology being collected from their perspective. Situated in contemporary South African society, fifteen pupils were interviewed after being selected to ensure maximum variation with respect to their socio-economic backgrounds. Interviews began with a discussion around photographs that pupils had taken of what they perceived to be technology in their lives. Immediately thereafter, they interacted with a structured technological activity. This was followed by a further discussion around their experiences of this and other interactions with technological artefacts.

The introduction of photographs into the interview processes was found to make a significant contribution towards the methodological development of phenomenography. It

proved successful in constituting a shared experience of the abstract concept, technology, and allowed pupils to reflect over their experience of technology in a meaningful way. A further contribution to this research approach was the ongoing development of the use of structural themes in the analysis process.

The results of the phenomenographic analysis of the data were the constitution of two sets of categories of description. Within each set, the categories were hierarchically related and qualitatively different from each other. The hierarchical relationship between these categories was defined by their structure, which in turn was constituted through structural themes that highlighted the relationships between the different dimensions of variation. In terms of the pupils' conceptions of technology, the structural themes consisted of the role of people, the purpose of technology, the impact of technology, and the character of technology. Similarly, the structural themes for pupils' experiences of interacting with technological artefacts consisted of the context of the interaction, the purpose of the interaction, ownership of the interaction, the interface with the interaction, and the process of interaction.

The results showed that pupils conceive of technology in five ways, from least to most complex: as an artefact, the application of artefacts, the process of artefact progression, as using knowledge and skill to develop artefacts, or as the solution to a problem. Interacting with technological artefacts was experienced in four ways, again from least to most complex: as taking place through direction, through instruction, through tinkering, or through engaging.

The results of this investigation mean that the anecdotal views that people may hold about technology and the possible ways of interacting with technological artefacts can now be located in solid empirical research. The results make an important contribution; on the one hand, to the theoretical underpinning of the structured activities that pupils interact with, and on the other, to the ability to inform teaching practice, the approach to recruiting students to technology-based programmes, as well as the contribution made to the broader research perspective of pupils' levels of technological literacy.

Acknowledgements

In 1994, I was a Master's student in the Department of Mechanical Engineering working on my dissertation 'Computer generated 3D animated holographic stereograms' when Associate Professor Andrew Sass approached me and asked if I wanted to be part of establishing a new first-year course, Introduction to Mechanical Engineering. This changed the course of my life. Andrew, you are my mentor and friend. You have played a pivotal role in my development as a person and as an academic and showed me how it is possible to be productive and have fun while doing it. While you were Head of Department, you introduced the idea of 'growing our own timber' and I was one of those fortunate enough to be chosen to join the academic staff of the Department under this plan. It was while working with you that my interest in pedagogy became an ever-increasing focus of my research work. You have seen my PhD topic change from 'Virtual-reality computer integrated manufacturing systems' to what it is now and supported me throughout. You truly are a great man and I regret not having completed this PhD before you retired at the end of last year. Thank you for everything.

In 2002, Dr Jenni Case, shortly after returning from Monash University where she had been awarded her PhD, found a PhD student out of his depth dabbling in 'this social science stuff' and offered to take him under her wing and guide him down the path of 'enlightenment'. Jenni, it has been a great journey. I do not know if I am the person that you would necessarily have chosen as your first PhD student, but I have learnt so much from you about all aspects of the research endeavour. Under your supervision and guidance, I have finally developed that 'research voice' you talk so much about. I hope your other postgraduate students appreciate what an excellent supervisor they have in you.

I have been privileged to have Professor Cedric Linder from Uppsala University in Sweden play an active role in ensuring my PhD is of high quality. Cedric, I will never forget the first time you asked me, 'So, what is your knowledge claim?' You have been incredibly insightful about all aspects of my research and you continuously challenged me to perform at my best. I really do value all the time you made available for me in Sweden, Cyprus, and of course in South Africa, to critique the various stages of my investigation. Thank you.

This thesis uses the phenomenographic research approach. At the critical time while I was trying to make sense of this methodology, Åke Ingerman was doing post-doctoral research in the Department of Physics at the University of Western Cape. Åke, thank you for the *many* hours we spoke about phenomenography in Sweden, Namibia and South Africa. You are a good friend and I look forward to collaborating with you on many projects in the future.

During the many years I have been working towards my PhD, my area of interest has shifted from purely technical to pedagogic in nature. Along the way, I was fortunate to have Professor Jasson Gryzagoridis and Professor Duncan Fraser provide supervision and guidance. Thank you both for the time and energy you put into helping me develop what became this thesis.

I had to interview a number of school pupils to collect the data required for this thesis. I was overwhelmed by the response I got from the principals and teachers at the various schools I approached in the Western Cape to participate in this investigation. I cannot mention you by name, but I want you to know that I am grateful for how welcoming and accommodating you all were. I thank you sincerely.

In August 2001, the Centre for Research in Engineering Education (CREE) was participating in a series of video conferences with Professor Shirley Booth, Dr Anders Berglund, and others in Sweden, focussed on issues relating to the research approach I used in this thesis. As fate would have it, Debbie Collier, an academic in the Law Faculty, was called in to help us use that Faculty's video conferencing facility. Some time later, we found ourselves serving on a number of the same committees. We became good friends and later married in September 2004. As of December 2005, we have a wonderful little boy, Matthew. Debbie, you have been my pillar of strength through the emotional highs and lows of this PhD. We have spent many evenings sitting together in our study while I toiled away on my thesis. I would not have been able to go through this without you by my side providing the much needed love and support you have given me. I love you so much.

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Chapter 1

Introduction

He had come from [India] where mathematics and mechanics were natural traits. Cars were never destroyed. Parts of them were carried across a village and readapted into a sewing machine or a water pump. ... Most people in his village were more likely to carry a spanner or screwdriver than a pencil. A car's irrelevant parts thus entered a grandfather clock or irrigation pulley or the spinning mechanism of an office chair. *The English Patient*, Michael Ondaatje, 1992.

Technology has been called 'one of the most powerful forces shaping society today' (International Technology Education Association, 2000, p.2). However, in something of a contradiction, it has also been observed that large parts of 'society' may be considered technologically illiterate (de Vries, 2006; Garmire, Pearson, & National Academy of Engineering (NAE), 2006). It could be argued that one reason for these poor levels of technological literacy is that the current generation of children do not spend time tinkering with technological artefacts while they are growing up as previous generations may have done. Many children today may have their attention monopolised by the pressures of modern society such as shopping malls, movies, gym and other such activities. However, the quotation at the start of this chapter illustrates how this stereotypical view is not necessarily the case across all of society. Here a rural village in India typifies the spirit of tinkering assumed missing from 'modern life'. Poorer communities often have to 'make do' with resources they have access to which typically involves activities of the nature described in the quotation. Unlike the inhabitants of a rural village, people in affluent societies often consider computers to be the primary manifestation of technology, and to be technologically literate in their eyes means to be able to 'use a computer or information technologies proficiently' (Weber, 2005, p.28). I would argue, however, that technology is more than simply about computers; and it is more than a villager 'readapting cars into a sewing machine'. Technology encompasses these perspectives amongst many others. Just what then is technology? What does it mean to be technologically literate in the context of interacting with sewing machines, water pumps, or computers for that matter?

For this thesis, I define technological literacy as being in a position to understand the nature of technology, having a hands-on capability and capacity to interact with

technological artefacts, as well as the ability to think critically about issues relating to technology. This model of technological literacy will be fully developed in Chapter 2.

The research presented in this thesis investigated school pupils'¹ conceptions of technology and their experiences of interacting with technological artefacts. This chapter describes the origins of my interest in this area. It presents the rationale for the research carried out and argues for the relevance of the knowledge claim to be made. The chapter concludes by presenting an outline of the chapters to follow.

1.1 Background to the study

This thesis evolved from my involvement in a novel course for first-year students in the Department of Mechanical Engineering at the University of Cape Town. The course, Introduction to Mechanical Engineering, was developed in 1994 (Reed & Sass, 1999; Sass, Reed, & Mchunu, 1997) and I took over as convenor in 1996. Apart from a recent period of three years, I have been the convenor of this course ever since. The aim of the course is to have students develop better understandings of what the mechanical engineering discipline entails in order to establish a foundation for developing competent engineering skills. The course attempts to introduce students to the real world of engineering by showing how engineers set about doing their work and how they analyse and solve problems. Student involvement, active learning, rapid feedback and high expectations are key aspects of the course. It also consists, in part, of a number of hands-on assignments each with a range of activities. Typically, these include the disassembling and reassembling of artefacts such as model aircraft engines, pumps, hydraulic trolley jacks, the building of model aeroplanes, as well as using Lego to construct systems allowing the demonstration of concepts such as levers, pulleys and gears. Other activities include looking at lift and drag characteristics with a wind tunnel, building and then testing amplifiers with an oscilloscope, and a number of spreadsheet-based modelling and optimisation problems.

¹ I have used the word *pupil* to describe children of school-going age. The word *student* is used to describe people who are enrolled at a tertiary educational institution.

1.1.1 Departmental visits by school pupils and public relations activities

My involvement in the Introduction to Mechanical Engineering course has influenced how I deal with school pupils who periodically visit our Department. Typically, pupils come to find out what studying mechanical engineering entails. However, there are also occasions where groups of pupils come to our Faculty to see what interests them or simply come on a school visit to the university to see what opportunities for study exist. Amongst these groups are pupils with a diverse range of interests in engineering, or even technology in general. Occasionally, they express no particular interest in these areas at all. Group sizes during these visits typically range from one to 40 or more. Many university staff see these visits as tiresome and hence there is often not much enthusiasm brought to the visits by those assigned this duty. Tours often end up being of the ‘walk and talk’ nature where a staff member leads a group of pupils around their Department telling them what they were seeing as they walked through various laboratories and other places of ‘interest’.

Since the activities in the assignments in the Introduction to Mechanical Engineering course are modular in nature, I was able to adapt some of the activities for the pupils to actually *do* something during their visit rather than just *seeing* things as they walked through laboratories. My primary aim was to have the visiting pupils get a more hands-on feel for some of the things that they would potentially get involved in if they chose to become mechanical engineering students. Initially, I tried to develop a range of activities that would provide some idea of the scope of mechanical engineering, but with experience I realised that some activities were more successful in enthusing the pupils than others. My aim became to select activities that not only gave an idea of the scope of mechanical engineering, but were also fun and rewarding. Initially, I designed tasks for pupils to use specific technological artefacts to achieve some goal. I soon realised, however, that there was more happening during these activities than simply the *completion* of a set task. For the pupils who were hesitant in their interaction with the activity, often the activity encompassed more than just involving an artefact and provided a *safe entry* to a technological interaction. With this came a realisation that they could do what may have appeared at first quite daunting.

1.1.2 Developing a general awareness of technology amongst pupils

From these initial experiences, I realised that some activities were particularly successful in stimulating interest in those pupils who did not have a strong interest or background in technology. I noted that some pupils who may never have considered a career in a technological field started to consider mechanical engineering as their future career. For example, one pupil had not wanted to take part in the activity because she did not feel that engineering held any interest for her. The activity required her to use computer-aided drafting and computer-aided manufacture (CAD/CAM) software to design a brass radio knob (See Figure 1). This component would then be manufactured on the Department's computerised numerically-controlled (CNC) lathe. Her response to the activity is shown in the following quotation:

I did not believe how sophisticated technology actually was until I saw what can be done, and that it is only a small aspect. It was an educational experience which I learnt a lot from. The computer programme was amazingly put together and it was rewarding to have the result being made almost instantaneously. I was not very excited about going in the beginning but when I got there, I found it extremely fascinating and enjoyed every minute of it.

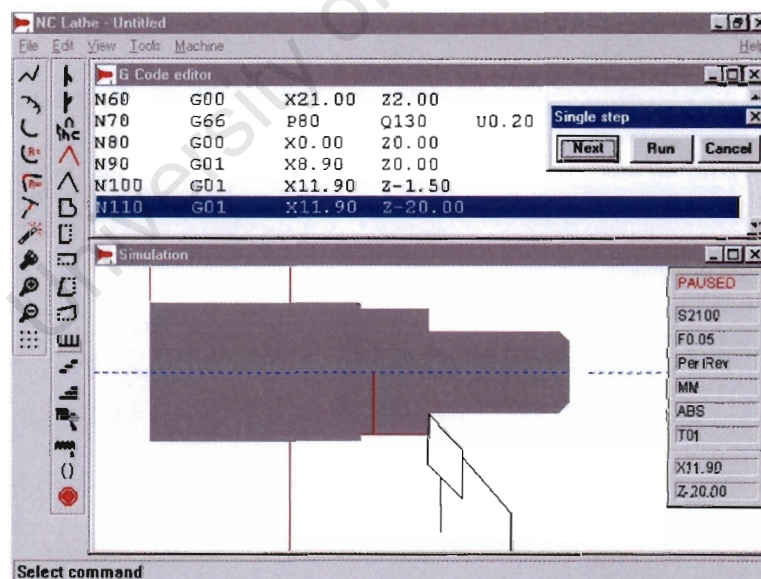


Figure 1 – CAD/CAM development of a brass radio knob

Other feedback of this nature made me realise that one cannot take for granted how pupils (or students for that matter) approach and interact with technology. There were many individuals with whom I interacted through these Departmental visits that appeared to be uncomfortable in technological environments. However, once they had completed the

activities, I got the sense that they had all developed a capability that was better than the position from which they had started.

1.1.3 Taking ‘technology’ to schools

Through the process of having pupils interact with what had developed into a structured set of technological activities, I began to appreciate the impact I was having on even those who may not initially have had any interest in or enthusiasm about technology. As I have indicated, there is the general view that pupils today do not necessarily have the opportunity to learn about technology through the direct experience of tinkering and engaging with technological artefacts and systems in informal social settings as past generations may have done (Pearson, Young, NAE, & National Research Council (U.S.), 2002). It occurred to me that my structured set of activities could be used as a way of being able to help many more pupils develop greater levels of technological literacy. In order to achieve this goal, I realised that it would be valuable to take the set of activities to school classrooms where a greater number of pupils could interact with them (Reed, 2000).

Selecting activities to be included in the structured programme of activities to take to schools was based on anecdotal evidence gathered over a decade from more than 1 000 pupils visiting the Department. The final structure of this combined activity consisted of the control of components such as lights, fans, buzzers, and heaters using the output port of a computer, as well as the design and manufacture of a brass component. As this activity took place off the university campus, there was the addition of video-conferencing to enable the manufacturing process to be shown in real-time even though there were no CNC machines available at the school (See Figure 2).

This interaction with schools began during 1999, and by 2003, many pupils from a number of different schools had been exposed to technology in this way. As a result of the success of this project, in 2004 I received funding from the Motorola Foundation to roll out this structured programme of activities to even more schools in the area. My goal continued to be to help develop a greater level of technological literacy amongst those who participated in this programme. As was the case for those pupils who had interacted with the activities while visiting my Department, even those who initially seemed to be the most apprehensive or unsure about interacting with the artefacts in the activities, appeared to

have a rewarding experience through this process. This included pupils who had overtly shown no interest in being involved at all.

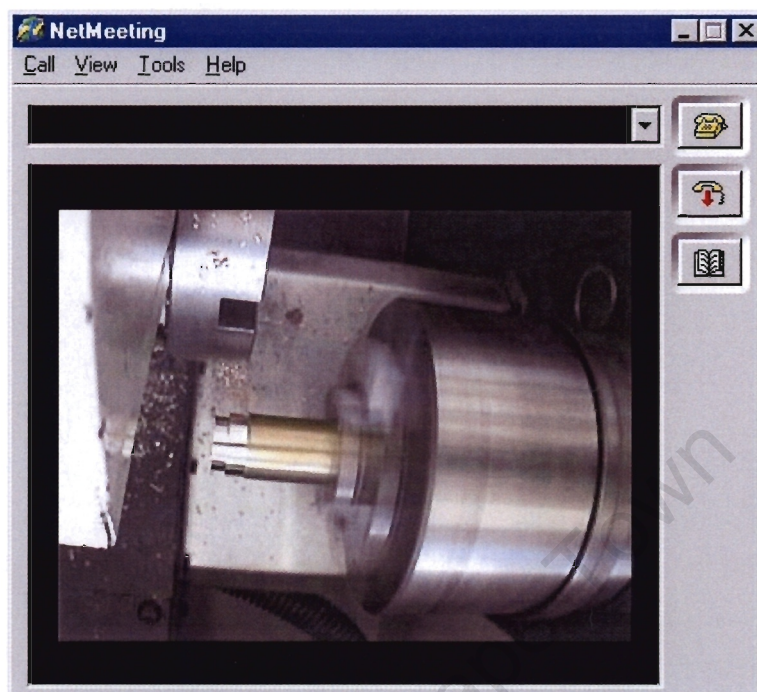


Figure 2 – Video conference showing a brass radio knob being machined

1.2 Rationale for the study

Being committed to improving the programme of activities I was taking to schools, I came to appreciate that it was not possible to continue working from anecdotal evidence as had been the case up to that point. There was the need to draw on relevant research in this area to give a sound theoretical underpinning to the approach adopted. The two relevant areas of research concerned *how pupils conceive technology* and *how pupils interact with technological artefacts*. Both these areas fall under the broader framework of technological literacy. The first research area focuses on what is generally termed ‘the nature of technology’, while the second focuses on issues of technological capability and capacity and critical thinking. Together these can be seen to constitute dimensions of the broader notion of ‘technological literacy’, which although much debated for its exact meaning (see, for example, Barnett, 1995), is very useful umbrella concept for the concerns of this thesis, as will presently be demonstrated.

Much of the debate around technological literacy has centred around whether technology is an appropriate subject for inclusion in the school curriculum (for example, Barnett, 1995;

Gagel, 1997; Lewis & Gagel, 1992). These studies have been drawn on in developing the background for this thesis, but are not explicitly reviewed in this chapter since the study is more generally concerned with pupils' technological literacy as it stands in society, without particular regard for the effects of formal education. In the South African context, this subject has had a somewhat short and contested tenure, particularly in the secondary school curriculum, and so it is appropriate to not be constrained by these concerns in this thesis.

With regard to studies of technological literacy, Garmire et al. (2006) have identified as many as 28 assessment instruments that looked to assess various aspects of technological literacy. These, together with other literature in the area, have been reviewed and the most relevant to this study are drawn on below.

1.2.1 Literature related to pupils' conceptions of technology

Two relevant studies that deal with the question of how pupils conceive technology are the Pupils Attitudes Towards Technology (PATT) research and two Gallup polls that looked at what Americans (in the USA) understand technology to be. The PATT research looks at not only *attitudes towards* but also *concepts of* technology. The 'concepts of technology' categories against which pupils' responses were correlated were developed from a 'literature study of the meaning of the concept of *technology*' (de Vries, 1988 as cited in Bame, Dugger Jr, de Vries, & McBee, 1993, p.47 – emphasis in original) as well as from interviews with experts in the field of technology and technology education. The largest PATT study to date took place in the USA with 10 349 participants. A critical result of this study was that pupils' responses to the *concepts* questions did not correlate with any of the concept categories developed as the basis for this part of the PATT instrument. Another feature of the PATT instrument is a section where pupils are asked to write what they think technology is. Here again, none of the responses to this question 'correlated with anything' (Bame & Dugger Jr, 1989, p.315) in the concept categories. These validation problems resulted in the original concept categories not being used in any further analysis of the results. Given that these categories were derived from a literature study of the concept of technology, as well as through interviews with technology professionals, and that pupils' responses show a lack of correlation with these categories, there is scope for further work to be undertaken in this area. Other PATT studies have argued that the results generally

have a 'relatively low reliability and validity' (van Rensburg, Ankiewicz, & Myburgh, 1999, p.149).

The second of the studies to address the question of how pupils conceive technology were Gallup polls in 2001 and 2004 that looked at what Americans think about technology (Rose & Dugger Jr, 2002; Rose, Gallup, Dugger Jr, & Starkweather, 2004). Unfortunately, this poll did not include responses from pupils of the age of interest in this study, but still gave insight into what young adults understood technology to be. More than two thirds (68%) of respondents said that the first thing that came to mind when they heard the word technology was computers, while the eight next highest responses were electronics (5%), advancement (2%), the internet (2%), education (1%), new inventions (1%), science (1%), television (1%), and future (1%). There appears to be a focus on computers as being synonymous with the word technology. However, even though 'computers' are so dominant in the responses, one can see a range of different views of technology being presented.

1.2.2 Literature related to pupils' interaction with technological artefacts

Interacting with technological artefacts relates directly to issues of capability and capacity, what I have identified as a dimension of technological literacy. A review of the literature showed, however, that limited research related specifically to how pupils interact with technological artefacts has been undertaken. With specific reference to pupils of the age focussed on in this study, there is recognition amongst researchers, organisations and governments that something needs to be done to develop technological literacy amongst pupils. Pearson et al. (2002) indicate that there is almost 'no reliable data about the level of technological literacy amongst American children' (p.6). There is no doubt that society recognises the need for 'maximising technological literacy' (Rose et al., 2004, p.11). It has been argued (Waetjen, 1993, p.8) that the development of technological literacy should primarily be through a technology education curriculum. To this end, the International Technology Education Association (ITEA) has developed technology 'standards' (ITEA, 2000) that they feel need to be part of a school's curriculum to address what they see is a lack of technological capability amongst pupils. Technology educationalists typically use these 'standards' to develop necessary technology education curricula. However, anecdotal evidence from those who have interacted with my structured programme of activities to date,

shows that it would appear as if pupils are leaving school without necessarily achieving this technological capability.

1.3 The focuses of the study and relevance to the knowledge claim

Given the research undertaken to date on pupils' conceptions of technology and how pupils interact with technological artefacts, it would appear as though there is a need for further scientific study in this area. Programmes of activities of the nature described above need to be embedded in a theoretical framework that is scientifically obtained and not simply based on anecdotal evidence and assumptions about how interactions are best structured. This thesis focuses on understanding pupils' experiences of technology within the broader framework of technological literacy to be able to answer the following questions:

1. How do pupils conceive technology?
2. How do pupils experience interacting with technological artefacts?

Being able to make a knowledge claim based on an empirical investigation of these questions will not only inform practice in this area but will also contribute to the research community in general. The following sections give an idea of the range of applicability of such research findings.

1.3.1 Informing teaching practice

The principal consequence of an understanding of these questions will be the ability to refocus technological interventions to ensure that they have the greatest possible impact on pupils. As described earlier, it has typically been anecdotal evidence that has been used in the development and refinement of these structured programmes of activities. In selecting the technological artefacts within each activity, assumptions are made about what pupils understand technology to be. Should there be a number of different ways pupils conceive technology, it would be important to recognise and account for this in each activity.

Assuming a common understanding of the nature of technology may not be appropriate as anecdotal evidence to date shows that pupils interact with the technological artefacts in each activity in a number of different ways. Understanding *how* pupils interact with an activity would allow the tailoring of each activity to account for this and directly nurture those who are more hesitant in their interaction to have a positive interaction.

Similarly, an understanding of how pupils interact with technology can be integrated into first-year university courses such as the first-year Introduction to Mechanical Engineering course referred to earlier. University students are not significantly older than the pupils and anecdotal evidence has shown that they too approach and interact with technological artefacts in a number of different ways.

1.3.2 Recruitment of students

With respect to the recruitment of students, the goals for pupils interacting with structured programmes of activities such as those described above are threefold. Firstly, the activities can make an impact in enthusing and interesting pupils who want to know more about mechanical engineering as a career option. Secondly, one of the criteria used in selecting the activities was that they be fun and rewarding to participate in. This was done in part to help encourage those pupils still to make up their minds about whether to follow a technological career, that it was worthwhile to do so. Hopefully then, given the nature of the activities they had been involved in through this programme, mechanical engineering would be the field of study chosen. Finally, one of the desired outcomes would be to get those who did not appear to be technologically inclined, to be at least interested in learning more about technology. That way, pupils not interested in becoming mechanical engineering students would go away with a level of technological literacy that they did not have before.

Furthermore, understanding more about how pupils conceive technology and how they interact with technological artefacts will enable the development of tools for identifying suitable applicants from those applying to study mechanical engineering. Current successful senior mechanical engineering students could be profiled with respect to how they conceive of technology and interact with technological artefacts and this could provide a benchmark against which to judge the suitability of each applicant.

1.3.3 Contributing to a research perspective

As indicated earlier, there is limited research relevant to this investigation of how pupils conceive technology and how they experience interacting with technological artefacts. Accordingly, there is scope to make a significant contribution to this area of research, as it would appear that internationally it is not a well-developed research perspective. The

findings of this study will be applicable beyond mechanical engineering, or engineering for that matter, to all technology-related programmes at both senior-secondary and tertiary educational institutions.

1.4 The structure and outline of the thesis

This chapter introduces the thesis and develops the argument for answering the research questions posed, namely how pupils conceive technology and how they interact with technological artefacts. The context for the study is addressed, as is the relevance of my knowledge claim.

In Chapter 2, a comprehensive model for what it means to be technologically literate is developed. The dimensions that make up this model are discussed, firstly with the presentation of a framework that can be used to define the word ‘technology’ in the context of the nature of technology, and secondly by looking at issue of capability and capacity, as well as critical thinking. The chapter concludes by analysing and commenting on pertinent empirical investigations undertaken in this area to date.

Chapter 3 discusses the methodological framework used for this thesis – phenomenography. Phenomenography as a research approach is discussed in detail, followed by issues relating to data collection and data analysis. Here particular attention is given to the trustworthiness of phenomenographic research and I present a comprehensive approach for ensuring rigor through being able to ensure the credibility and dependability of results.

The compound method I developed to collect the data necessary to undertake a phenomenographic analysis is presented in Chapter 4. The chapter begins by describing how photographs and a structured activity were used to ensure a shared and meaningful experience for pupils of the phenomena under investigation. It continues by discussing the basis for selecting the participants for this study and thereafter describes in detail the data collection strategy used in the investigation. A detailed discussion follows on how the data were collected through the use of photographs, the design of technological artefacts and a series of semi-structured interviews. The chapter concludes with a section discussing how the trustworthiness of the results was ensured.

Chapter 5 presents the results of the two phenomenographic analyses (one for each of the research questions) of the data collected using the methods developed in the previous

chapter. The chapter begins by illustrating the outcome space for each set of results in tabular form, following which the full outcomes of each of the analyses are presented in detail. The qualitatively different ways of experiencing the phenomenon are characterised by the presentation of a number of categories of description. Thereafter, the structural themes that run through and help constitute the categories are described.

Chapter 6 provides an illustration of how the resultant categories of description can be utilized to underpin other studies that investigate further issues relating to pupils' understanding of the nature of technology and their levels of technological literacy. The development of a questionnaire that can be used to classify individuals in terms of their conceptions of technology as well how they interact with technological artefacts (in other words, determining their *technological profile*) is presented.

In the final chapter, Chapter 7, the research findings are discussed. The results presented in Chapter 5 are also related to the relevant literature discussed in Chapter 2, and the relevance of the findings in terms of the criteria outlined in Chapter 1, namely the ability to inform practice, the approach to recruiting students, as well as the ability to contribute to a research perspective, are elaborated on. Finally, the contribution this thesis makes to phenomenography as a research approach is highlighted, and the chapter concludes by presenting possibilities for further research followed by selected concluding remarks.

Chapter 2

Literature Review

This thesis investigates how pupils conceive technology as well as how they experience interacting with technological artefacts. In the previous chapter, the theoretical constructs drawn on to develop the research questions were presented as involving the nature of technology, technological capacity and capability, and critical thinking. This chapter therefore begins by starting to develop a model of what it means to be technologically literate. As a major component of this model is an understanding of the nature of technology, the chapter continues by looking at a framework that can be used to define what the word ‘technology’ means in this context. This is followed by a discussion of the remaining dimensions that complete this model of technological literacy, which will form a comprehensive conceptual framework to be used in interpreting the empirical results during the discussion in Chapter 7. The final section of this current chapter focuses on analysing and commenting on pertinent empirical investigations undertaken in this area to date.

2.1 Technological literacy

As technology is ‘one of the most powerful forces shaping society today’ (ITEA, 2000, p.2), people need to be able to integrate fully into an increasingly technological world in order to be able to proactively take their place within society. The ability to participate in this increasingly technological world requires people to have some level of what is generally referred to as *technological literacy*.

One view of what it means to be technologically literate is to be able to think about technological issues from various perspectives and to be able to appreciate the ‘interrelationships between technology and individuals, society, and the environment’ (Technology for all Americans Project (TAAP) & ITEA, 1996, p.11). Being technologically literate can, on the individual level, for example, help consumers make better-informed decisions. Furthermore, on a societal level, decisions on global issues that affect the environment, for instance genetic engineering, can be discussed and debated from a position of understanding. Being technologically literate can ensure that an

individual's opinions and decisions are well informed and developed from a sound knowledge base.

However, the competence required in order to be considered technologically literate remains difficult to articulate as there is no one universal set of requirements that satisfies technological 'literateness'. What persons need to *be* would vary depending on the socio-cultural context in which they found themselves. For example, a technologically literate inhabitant of a tribe in Papua New Guinea would have very different characteristics to a technologically literate inhabitant of Sydney in Australia. For my study, what is required is a model of technological literacy that goes beyond the description given above; one that can be used to inform the empirical study that looks to understand how pupils experience technology in general.

2.1.1 Towards a model of technological literacy

The view of technological literacy presented earlier (being able to think about technological issues from various points of view and being able to appreciate the interrelationships between technology and individuals, society, and the environment) is a useful starting point in the development of a more comprehensive model of technological literacy for this study. However, a feature of this view is a lack of 'action' being required on the part of a person for that person to be considered technologically literate. The National Academy of Engineering (NAE) address this issue by describing their own three constitutive dimensions of technological literacy as involving 'knowledge, ways of thinking and acting, and capabilities' (Pearson et al., 2002, p.14). Similarly, Hayden (1989, p.231 - emphasis added) highlights the necessity of having the knowledge and ability to be able to 'select, properly *apply*, then monitor and evaluate appropriate technologies' in a given context as a requirement for technological literacy. Together these highlight the *act* of physically doing something as part of being technologically literate but do not refer to the relationship between technology and society, and more generally the environment, as per the TAAP and ITEA definition on the previous page. Pearson et al. (2002, p.12) do however touch on these aspects when they include in their definition of technological an ability to 'think critically about technological development' (p.12). I would argue that aspects of all these views of technological literacy are valid in contributing to a comprehensive model for this study.

By considering the various ‘requirements’ for technological literacy presented above, I argue that to be technologically literate, a person must be in a position to understand the nature of technology, have a hands-on capability and capacity to interact with technological artefacts, and to be able to think critically about issues relating to technology. The major dimensions of this model of technological literacy are discussed below.

2.1.2 The nature of technology

This section looks at developing a framework for conceptualising the nature of technology; one of the dimensions of technological literacy. The results of the Gallup poll, presented in the previous chapter, on what Americans think about technology shows that there are a number of different ways of understanding technology. Computers may have constituted the dominant understanding in this survey, but electronics, education, new inventions, science, and the future, amongst others, also feature prominently. This varied range of understandings is indicative of the problem; definitions of technology vary widely and range from computers and the internet to the effect that genetically modified crops are having on food production in Africa. Attempting to define the intrinsic, or characteristic, qualities of technology (that is, the *nature* of technology) is a particularly complex exercise given that these definitions can be understood in terms of things, ideas, or even actions.

Studies such as the Gallup poll typically describe views drawn from across all parts of society and reflect what can be considered as a lay view of technology in general. In order to present a more ‘considered’ view on the essence of the nature of technology, it is necessary to turn to philosophy where philosophers have reflected in detail on the fundamental issues relating to the nature of technology.

A philosophical enquiry about technology

Although the philosophy of technology, as a separate branch of philosophy, only developed towards the end of the last millennium, one of the earliest philosophers to include a discussion of *technê* (from the ancient Greek τέχνη, the etymological root of the word technology) was Aristotle in his *Nicomachean Ethics* (Aristotle & Irwin, 1985). It is worthwhile to reflect on this early treatment of ‘technology’ as it shows that more than 350 years BC philosophers had begun to engage with the fundamental essence of the meaning

of technology. In his *Nicomachean Ethics*, Aristotle describes three approaches to knowledge, namely *technê*, *epistêmê*, and *phronesis*. Flyvbjerg (2001, p.56) characterises these respectively as *technical 'know how'*, *theoretical 'know why'*, and *practical knowledge and practical ethics*. A key section in the *Nicomachean Ethics* is where Aristotle argues that *technê* is

a state involving true reason concerned with production. ... Every craft (*technê*) is concerned with coming to be, ... something whose origin is in the producer and not in the product. ... [and] since production and action are different, craft must be concerned with production. (Aristotle & Irwin, 1985, 6.4.1140a1-24)

Aristotle argues here that *technê* is concerned with bringing something that did not exist before, into existence. He means more than just an activity in the form of a systematic putting together of parts, but also an inherent knowledge required by a craftsman in order to bring a product 'to be'. Parry (2003) argues that Aristotle is making a distinction between an *activity* and *making*; here an *activity* is an end in itself while *making* has an end where the product is 'separate from the activity of making'. This early discussion of technology illustrates how, amongst the Greek philosophers of the period, the essence of technology was considered as more than a product, or indeed the production of that product, but also consisted of a knowledge component – a conceptual framing.

Whereas the early philosophers (such as the ancient Greeks above) reflected on technology as just one aspect of their activity, the philosophy of technology as a distinct branch of philosophic reflection emerged during the 1970s. At this time, there were two schools of thought as to the nature of technology. In the first school, in the phrase 'philosophy of technology', 'technology' was taken to be the *subject* of philosophic reflection. Thus, the philosophy of technology was the 'philosophy generated by and belonging to technology' (Ferré, 1995, p.3). Here philosophers embraced the idea of technology being a science and placed importance on technical knowledge, processes and on the resultant artefacts. Often the philosophers in this school had technical backgrounds and reflected on the "philosophy of *technology*" rather than on "*philosophy* of technology" (Mitcham, 1994, p.25 – emphasis in original). In the second school, in the phrase 'philosophy of technology', 'technology' was understood as the *object* of philosophic reflection. This has been described by Mitcham (1980) as relating to attempts by philosophers to take technology *itself* as a 'theme for systematic reflection' (p.304). In this school, philosophers

tried to understand modern technology from a hermeneutic perspective. De Vries (2005) has described this school as looking at the link between technology and its 'social context' (p.6).

More recently, philosophers of technology have attempted to bring together these well developed, but differing focuses on the nature of technology. One such philosopher is Carl Mitcham (1994) who wrote what is considered the seminal work in the area of the philosophy of technology, *Thinking through technology: The path between engineering and philosophy*. In this book, he proposes a comprehensive framework that incorporates both schools described earlier and is 'capable of adaptation to alternative positions on major issues in the philosophy of technology' (p.159).

Towards a framework describing the nature of technology

Any framework developed to describe the nature of technology should be able to accommodate peoples' views of technology such as are typical of the Gallup poll and those presented as the 'concepts of technology' in the PATT studies in the previous chapter. Mitcham's (1994) framework allows for the systematic classification of peoples' differing views on the nature of technology in terms of the domains of *person*, *society* and *nature*. Within each of these three domains are specific aspects that relate to peoples' views of technology that are typical of both the Gallup poll and PATT studies. These domains are shown diagrammatically as Figure 3 (after Mitcham, 1978, p.234, 1994, p.160) where it can be seen how the domains are constituted in terms of *technology as knowledge*, *technology as an activity* (such as making or using artefacts), *technology as artefacts* (or objects), and *technology as volition* – an individual's will (or choice) to use technology to an end.

In the context of the domain *person*, 'knowledge' and 'volition' are internal processes mediating a person's activities. In the case of the construct 'technology as knowledge', at the most fundamental level, this is a person's cognitive ability to make or use an artefact. As an example, people who make or use artefacts in a technological context develop rules of thumb, or where appropriate, descriptive laws, defining their technological knowledge. A more complex view of 'technology as knowledge' is the constitution of technological theories which either 'systematise descriptive laws or provide a conceptual framework to explain them' (Mitcham, 1980, p.313). With respect to the construct 'technology as

volition' (or will), the slogan 'guns do not kill people, people kill people' is a good example of how here it becomes human will or explicit choice to *use* technology (in this case a weapon).

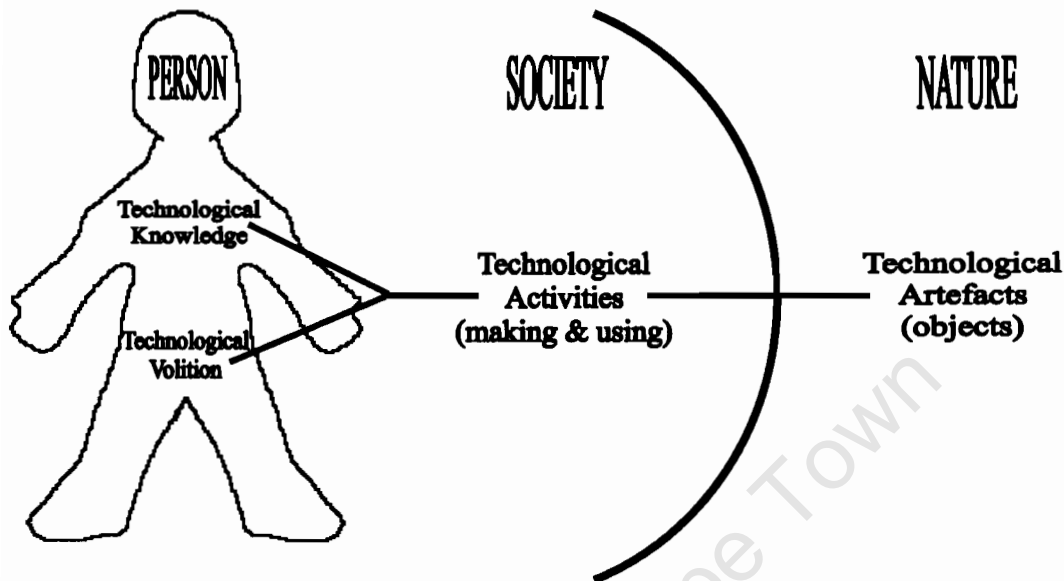


Figure 3 – Schematic representation of the domains describing the nature of technology (after Mitcham, 1978, p.234, 1994, p.160)

Within the domain *society*, it is through the 'technological activity' (or process) of making and/or using artefacts (as illustrated in Figure 3) that a person has direct involvement with society in general. The process of design and invention (the action of making) together with the process of production and the utilisation of technology (the process of using) are both key aspects of the construct 'technological activities'.

The effect of technology as knowledge, volition and activity is a 'technological artefact' (or object) that takes on significance beyond the person that created it. This artefact exists in the natural world which is shown as the domain *nature* in Figure 3. The view of technology as being an artefact is, for many, the most commonplace view of technology and typical of the lay view of technology found in the Gallup poll referred to earlier.

The aim of this section was to describe a framework with which to conceptualise the nature of technology. Taken together, the constructs described above (technology as *knowledge*, technology as *volition*, technology as *an activity*, and technology as *artefacts*) within the domains of *person*, *society*, and *nature*, allow the intrinsic, or characteristic, qualities of technology, the *nature of technology*, to be defined. As one of the research questions is to

investigate pupils' conceptions of technology, having a framework of this nature will be important when interpreting the results obtained from the empirical investigation.

With the framework for the nature of technology complete, the next section discusses the remaining two dimensions of technological literacy.

2.1.3 The dimensions of capability and capacity, and critical thinking

The remaining dimensions of technological literacy, *capability and capacity*, and *critical thinking*, are closely related to one another. *Capability* refers directly to an interaction with technology, and hence an interaction with the constructs in the framework of the nature of technology defined in the section above. *Capacity* implies that people experience a sense of 'power' to perform the interaction. The requirement to *think critically* about technological development draws on the ITEA definition of technological literacy, which, in turn, links back to the nature of technology in terms of individuals, society and the environment.

By referring explicitly to the definition of the nature of technology in the context of the model of technological literacy developed earlier, technological literacy is, thus, a capability to 'put into action' the knowledge, activities, artefacts and volition inherent in the nature of technology, as well as the capacity to do so.

2.2 Empirical studies that have informed this investigation

The first part of this chapter developed a model that described what it means to be technologically literate. This was followed by a discussion of the dimensions that constitute this model. In this section, I begin by looking at empirical studies that have investigated pupils' understanding of the nature of technology, a dimension of technological literacy, followed by those studies that have attempted more generally to assess levels of technological literacy in a way relevant to this study. Garmire et al. (2006) have reviewed as many as 28 different assessment instruments from across the world that have in some way or another tried to assess technological literacy. Their finding was that 'none of these instruments is completely adequate to the task of assessing technological literacy' (p.4). The more important of these, and other studies reviewed in the literature, that do address the research questions are presented below, along with a discussion of how

they contributed to a greater understanding of the context in which this current investigation took place.

2.2.1 Empirical studies of pupils' understanding of the nature of technology

A thorough search of the literature revealed no empirical studies that have, to date, directly investigated pupils' understanding of the nature of technology as defined earlier in this chapter. There have, however, been studies that have addressed specific aspects of the nature of technology that are relevant to the current investigation. The most significant of these are the series of Pupils' Attitudes Towards Technology (or PATT) studies that not only looked at *attitudes towards*, but also the *concepts of* technology held by pupils. The second body of research that contributed to this investigation were the Gallup polls of 2001 and 2004 conducted by the International Technology Education Association (ITEA) that surveyed what Americans (in the USA) think about technology.

These are now discussed leading to the presentation of a number of possible generic approaches to investigating pupils' understanding of the nature of technology.

Pupils' attitudes towards, and conceptualisation of, technology

The PATT questionnaire developed from an investigation into the understanding of pupils' attitudes towards, and conceptualisation of, technology carried out on 13-year old children in the Netherlands (Raaij & de Vries, 1985, p.1). From this research, Raaij and de Vries developed a questionnaire that has been used in about 30 countries (Garmire et al., 2006, p.199), including African countries such as Botswana, Kenya, Nigeria, South Africa, and Zimbabwe. The PATT questionnaire is one of the most widespread series of empirical studies undertaken to assess issues relating to pupils' attitudes and concepts of technology.

The questionnaire itself consists of three substantive parts. In the first part, pupils are asked to describe, in the form of an essay, what they think technology is. In the second, 57 questions with Likert-type responses are included to assess attitudes towards technology. In the third part, 31 questions, again requiring Likert-type responses, are included to gather data on pupils' concepts of technology. Of the three parts, only the first and third are directly relevant to this investigation.

In the original study (Raat & de Vries, 1986, 1987) that laid the groundwork for what became the PATT questionnaire, five scales that described the *concept of technology* were defined. These scales were based on a literature review and a consultation with experts in the field of technology and technology education which was undertaken by Raat and de Vries. These scales are (as originally described):

1. Technology is an activity that is essential to mankind. Its creation is one of the features of mankind. In our opinion, three thoughts are brought to mind:
 - a. the way we look at technology depends on our view of mankind and society,
 - b. technology is an activity belonging to both man and woman; after all, they both have the features of mankind; and
 - c. just as mankind, technology has gone through a certain development in the course of history.
2. There are three 'pillars' connected with technology: matter, energy and information. Technology is always concerned with an alteration in shape and/or position of matter, energy and information.
3. Technology and science are interrelated. This concerns both the knowledge and the procedure. Technology and science exert a mutual influence on one another.
4. Important skills in technology are: i. designing, ii, working in a practical-technical way, and iii. handling technical products.
5. Technology has a large impact on society and is itself influenced by society.

(Raat & de Vries, 1987, p. 163-164)

From these five scales, the following four scales that were then used in the PATT instrument, evolved:

1. Relationship between technology, human beings, and society (technology and society).
2. Relationship between technology and science (technology and science).
3. Skills in technology (technology and skills).
4. The raw materials or 'pillars' of technology (technology and pillars).

(Bame et al., 1993, p.40)

From these four scales, 31 questions with specific questions related to each of the scales, were developed. Details are sketchy about the process through which this took place (Raat & de Vries, 1987), but the indications are that qualitative interviews of pupils were part of the process and that validation took place using data obtained by the use of open-ended questions on the subject.

The results of the largest PATT study to date, in which more than 10 000 participants in the USA took part, showed that the 'concept of technology' aspect of the questionnaire

gave results that were not as useful as expected. I would argue that of particular concern was that, in a report arising from a factor analysis of data collected in Virginia, the preliminary data analysis revealed that pupils' responses could not be clustered into *any* of the four 'concept of technology' scales (Bame & Dugger Jr, 1989, p.314) described earlier. In fact, the results indicated that only one scale comprising all 31 statements was possible from the pupils' responses. Another feature of the PATT instrument was a section where pupils were asked to write a description of what they thought technology was. These descriptions were then reviewed during the analysis to determine how many of the 'concept' scale characteristics of technology were included (Bame & Dugger Jr, 1989, p.312). This 'review' process consisted only of 'counting key words' (de Vries, 1991, p.175) and grouping them into '*a posteriori* categories' (Rennie & Jarvis, 1995, p.757). Once again, in the preliminary data analysis of the PATT-USA study, 'none of the categories of responses to the essay question correlated with anything' (Bame & Dugger Jr, 1989, p.315) in the 'concept of technology' scales.

These strong assertions about the 'validity' of the 'concept of technology' statements were made by Bame and Dugger based on their preliminary analysis of only *part* of the complete data set of more than 10 000 responses. However, once their final analysis was complete, they report that 'validation of the [concept] scales has been a problem because of the nature of the items' (Bame et al., 1993, p.47), thereby supporting their original position. The 'concept' scales developed by Raat and de Vries (1987) were thus not being reflected in the data collected from the pupils who completed the questionnaire and thus consequently, only the sole concept scale to emerge was used in any further analysis of the results.

Based on this discussion, it would appear that, although originally recognised as an important aspect of the PATT instrument, the determination of pupils' 'concepts of technology' was not successful. This may be due to the essay question and scale-based questions not correlating with the original 'concept' scale characteristics of technology as determined by Raat and de Vries (1986). Part of the problem could have been that the concept scales determined through a literature review and consultation with professionals, although 'correct' in that sense, possibly bore little relation to how the pupils actually *did* conceptualise technology. A direct consequence of this would be that the pupils' responses to the questions that derived from these concept scales would not correlate with the

original scales. Looking to understand pupils' concepts of technology is still worth pursuing, however it would be a worthwhile exercise to rather reconstitute these concept scales from the perspective of the pupils themselves.

An additional concern with what is essentially a quantitative questionnaire, is the cross-cultural applicability of a questionnaire that uses a structured, fixed-response format developed for use originally in a specific context related to teaching aspects of technology in physics education (Raat & de Vries, 1986). Many of the PATT studies undertaken to date compare their results with those of other countries. Granted, the different questionnaires are 'tailored' to a national/local setting (hence the PATT-USA (Bame et al., 1993), PATT-HK (Volk, Yip, & Lo, 2003), etc.), but even within a sample there are various cultural and socio-economic groups present that may make comparisons problematic. The PATT questionnaire used in South Africa has been an un-adapted PATT-USA version where the data had 'relatively low reliability and validity' (van Rensburg et al., 1999, p.149). As was the case regarding the issues associated with the 'concepts of technology' scales discussed earlier, basing the questionnaire on *pupils'* understanding of these various constructs may address these issues.

What Americans think about technology: The Gallup poll

In 2001 and 2004, the International Technology Association (ITEA) commissioned the Gallup organisation to conduct a survey of Americans to determine what they think about technology. The results obtained from the two surveys (Rose & Dugger Jr, 2002; Rose et al., 2004) were similar in nature. In the survey, the first five questions were focussed on the 'public's understanding of technology' (Rose & Dugger Jr, 2002, p.1). One of the central questions asked was what first came to mind on hearing the word 'technology'. The top mentions in each of 2001 and 2004 are shown in Table 1.

The results shown in Table 1 support one of the central findings of the survey that 'there is a definitional difference in which the public thinks first of computers when technology is mentioned, while experts in the field assign the word a meaning that encompasses almost everything we do in our everyday lives' (Rose et al., 2004, p.11). This focus on computers is further highlighted in another of the questions asked. Here, people were explicitly given the choice between a broad definition of technology (of the type an expert might have given) and one that defined technology as involving computers and the Internet. The

Table 1 – First mentions upon hearing the word ‘technology’ (Rose et al., 2004, p.2)

List of mentions	2004	2001
Computers	68%	67%
Electronics	5%	4%
Advancement	2%	–
Internet	2%	1%
Education	1%	2%
New inventions	1%	2%
Science	1%	1%
Television	1%	–
Future	1%	–
Space	1%	1%
Job/Work	1%	1%
Cell phones	1%	–
Health	1%	–

results of this question are shown in Table 2. Sixty-three percent of people chose the definition of technology as being about computers and the Internet.

Table 2 – Response to the question of which of two definitions of technology was ‘correct’ (Rose & Dugger Jr, 2002, p.2)

	Total group	18-29 year olds	Age 50 and older
Definition	%	%	%
Computers and the Internet	63	56	67
Changing the natural world to satisfy our needs	36	44	32
Don’t know/refused	1	–	1

Measuring pupils’ ‘perceptions’ of technology

Rennie and Jarvis (1995) discuss a number of possible approaches to measuring aspects related to pupils’ ‘perceptions of technology’ (p.755). These include questionnaires, open-ended (or free-response) questions, drawings, the use of lists of words, and interviews.

The first of these approaches uses questionnaires such as the PATT. Another approach is the use of open-ended questions also similar to that found in part one of the PATT questionnaire. Rennie and Jarvis (1995) argue that questions of this nature reveal a ‘range of perspectives which ... [reflect] the multidimensionality of the questionnaire results’ (p.757). As they are, in their research, particularly interested in the ‘perceptions’ of young children, they discuss how another approach is the use of drawings as an effective way to

elicit young childrens' ideas about technology, especially if they are not yet old enough to express themselves clearly through written responses. However, they caution that research evidence has shown that the 'actual instruction given' (p.758) to children is crucial to how they respond. A third approach of exploring 'perceptions' of technology is to ask pupils to identify which of a list of words are associated with technology. This approach has been used in conjunction with other approaches, and if the list of words is 'carefully structured', it is possible to 'tap understandings on a range of aspects' (p.758). The final approach Rennie and Jarvis (1995) discuss is that of interviews. They argue that when carried out correctly, 'interviews are an indispensable means of obtaining detailed information about how students think' (p.758).

2.2.2 Empirical studies of pupils' levels of technological literacy

The results from the 2001 and 2004 Gallup polls conducted for the ITEA could be interpreted as indicating that society (in the USA, but arguably similarly elsewhere) is largely not technologically literate (cf. Pearson et al., 2002, p.1). However, Pearson et al. (2002) indicate that there is almost 'no reliable data about the level of technological literacy amongst American children' (p.6) to be able to make a claim about the technological literacy levels of children. Even so, there is little doubt that society recognises the need for 'maximising technological literacy' (Rose et al., 2004, p.11), but for many this means 'being able to use computer or information technologies proficiently' (Weber, 2005, p.28). Indeed, government policy in almost every country includes statements recognising the need for technologically literate citizens. Herein lies the paradox, since, even though society may believe that it is important to be technologically literate (Rose & Dugger Jr, 2002, p.1), I would argue that society tends to base this recognition on a flawed understanding of the nature of technology; technology is not only about computers. Furthermore, Boser et al. (1998) have argued that there is 'no widely accepted standardized instrument suitable for assessing the broader construct of technological literacy' (p.5). They go on to argue that consequently, it is often the 'affective domain' (cf. attitudinal studies such as PATT) that is used 'as an alternative way to assess technological literacy' (p.5), often without satisfactory results.

One significant study that *has* investigated pupils' levels of technological literacy was undertaken in 2001 by Saskatchewan Education in Canada. In this study, Saskatchewan

Education looked to assess levels of technological literacy and provide ‘a snapshot of their [pupils’] skills, knowledge, attitudes and practices’ (Saskatchewan Education, 2001, p.1). For this investigation, they define technologically literate pupils as pupils that have the ability to ‘understand how technology and society influence one another and ... [are able to] use this knowledge in their every day decision making’ (p.1).

Four dimensions were used to assess pupils’ levels of technological literacy. These were (Saskatchewan Education, 2001, p.iv):

1. understanding, describing and adapting technology;
2. accessing, processing and communicating information;
3. responsible citizens and technology; and
4. using technology, including computers.

The study consisted of 3 500 Grade 5, 8 and 11 pupils from 182 schools. For the study, the participants were split into two groups. The first group completed open- and closed-response questionnaires in response to the first and third dimensions, and submitted work completed in the classroom in response to the second dimension. The second group (in response to dimension four) had to perform word processing and Internet tasks as well as use an artefact of technology, and then design, plan and build a model of technology.

In the context of this thesis, dimensions one and four are the most relevant and will be discussed in greater detail below.

Understanding, describing and adapting technology

In assessing the first dimension of technological literacy given above, defined here as *understanding, describing and adapting technology*, and relating more generally to the area of the nature of technology, a questionnaire consisting of both open- and closed-response questions was administered. In the open-response section, the questions were similar in nature to the essay-type question of the PATT questionnaire, as well as the drawing option described by Rennie and Jarvis (1995), both of which were discussed earlier. Figure 4 illustrates the questions asked as well as a sample response from a Grade 8

pupil. The responses to the questions were assessed using the five levels shown in Table 3. Thirty-one *stakeholder representatives*² who formed the panel that undertook the development of the criteria (or standards) that were used to assess technological literacy developed these assessment levels.

**Table 3 – Assessment criteria for ‘understanding, describing and adapting technology’
(Saskatchewan Education, 2001, p.64)**

Level 5	[Pupil] ³ has broad categorization of technology providing strong contrasting examples. Their definition of technology is sophisticated and includes 3 criteria. [Pupils] provide a reason(s) for developing technology, they identify that technology is man-made and that technology is a process. They explain in detail the operation and features of a technological product. They consider functional and related limitations of a technology and suggest specific ways of how the product could be improved.
Level 4	[Pupil] has large categorization of technology providing some contrasting examples. Their definition of technology is broad, but only includes 2 criteria from the Level 5 criteria outlined. They explain in same detail the operation and features of a technological product. They consider functional and related limitations of a technology and suggest a general idea of how the product could be improved.
Level 3	[Pupil] identifies technology that affects a few areas of life or society. Their definition of technology is general and includes only 1 [criterion] ... from the Level 5 criteria outlined. They generally explain the operation and features of a technological product. They consider a functional limitation for a technology, but have no suggestions on how the product could be improved.
Level 2	[Pupil] identifies a number of general examples of technology. Their definition of technology is vague and only references examples to define it. They describe some features of a technological product and consider only related limitations for the product.
Level 1	[Pupil] identifies a couple [of] general examples of technology. They state no clear definition of technology.

² The *stakeholder representatives* for the Saskatchewan study included various civil society and governmental organisations with educational as well as technical expertise (Saskatchewan Education, 2001, p.62)

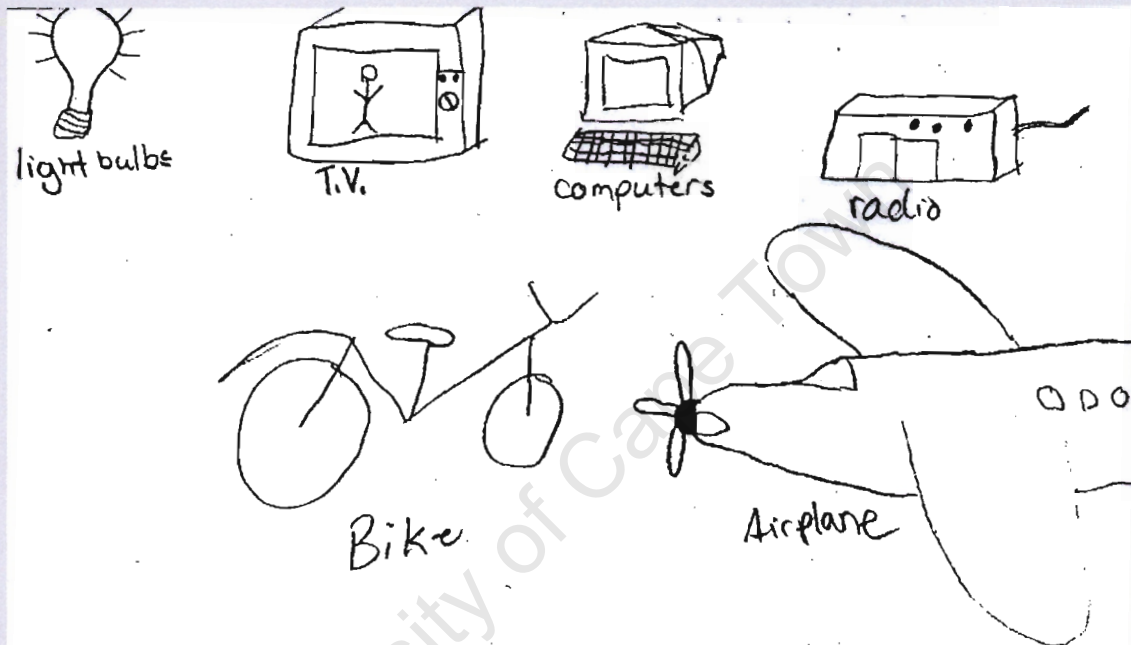
³ For consistency, the word *student* has been replaced by the word *pupil* in this table.

Grade 8 Exemplar – Level 5



- **Technology means different things to different people”.**

When you read the word “**Technology**” what comes into your mind? Tell what technology means to you by drawing pictures and writing about it in the space below.



Please write your definition for technology: *it is the science of objects that are used to help people in their everyday lives. These objects are improved when people get more knowledge about certain things.*

Figure 4 – An example of the response to the open-response question about technology (Saskatchewan Education, 2001, p.24)

For the closed-response question, a list of 28 items was given for pupils to consider. Of these items, 23 were examples of technology. The assumption behind this question was that the more of the 23 items pupils selected, ‘the broader view of technology they have’ (Saskatchewan Education, 2001, p.25). Table 4 shows the results of the percentage of pupils in Grade 11, the same Grade as the pupils participating in the present investigation,

who indicated that an item was *definitely technology* (p.25). Only six items from the list of 28 are included below as no other results were made available.

Table 4 – Percentage of Grade 11 pupils who indicated that an item is *definitely technology* (from Saskatchewan Education, 2001, p.25)

Item	Grade 11
Computer	99.5%
Bridge	61.9
Clock	77.3
Old stone axe	31.3
Aeroplane	94.5
River	2.0%

Once again, the view of computers as technology is clear with almost all the participating pupils indicating that it is ‘definitely technology’. However, an old stone axe, which most experts would have no hesitation in describing as technology, was only mentioned as ‘definitely technology’ by less than a third of pupils.

A follow-up closed-response question asked pupils to select the best description of technology as:

1. similar to science;
2. processes and products that extend human capabilities;
3. computers, televisions, radios and other electronic devices; and
4. conceptual ideas and theories of machines and artefacts.

Option 2 from this list was considered by the *stakeholder representatives* to be the best answer. Grade 11 pupils selected option 2 62% of the time.

The *stakeholder representatives*, as well as developing the assessment criteria shown in Table 3, also determined that performance of pupils at ‘level three’ would be considered ‘sound, good and consistent work’ (Saskatchewan Education, 2001, p.22). Furthermore, they also decided that the percentage of pupils who should be performing at this level should be 79%. Figure 5 shows the results of this dimension of technological literacy across all levels. Referring to ‘Level 3 and above’ in Figure 5, the chart indicates that 81.2% of pupils were performing at or above the required level; more than the minimum required.

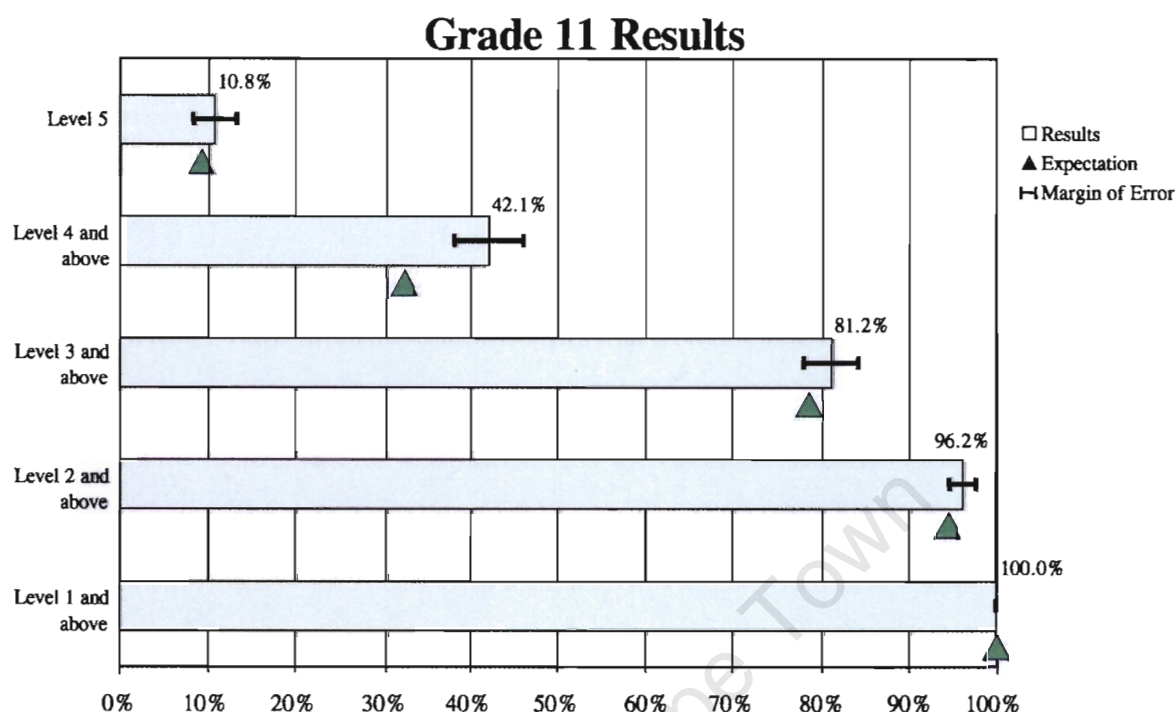


Figure 5 – Results of dimension one, ‘understanding, describing and adapting technology’ (Saskatchewan Education, 2001, p.23)

Using technology, including computers

To assess their fourth dimension of technological literacy, *using technology, including computers*, pupils were given a series of tasks to perform. The five tasks were word processing, Internet searching, using a product of technology, and finally the design, planning and building of a model of technology. In the context of the current investigation, the task ‘using a product of technology’ is the most relevant to highlight in detail.

The activity for this task involved the time and alarm setting function of a digital alarm clock, as well as the use of the clock’s radio function. The activity aimed to test whether pupils could follow an instruction manual to complete a task (being functionally literate). Pupils were given specific exercises to complete as well as a problem that the alarm clock could help them solve. The assessment criteria for this dimension of technological literacy are presented in Table 5.

Table 5 – Assessment criteria for ‘using technology, including computers’ (Saskatchewan Education, 2001, p.66)

Level 5	Follows instructions and reference booklets to complete complex tasks when using technology. Thoughtfully applies technology towards a situation and shows a sophisticated understanding of the impact of applying this technology. Utilizes many advance features of computer technology to complete tasks and solve problems.
Level 4	Follows instructions and reference booklets to complete a broad range of tasks when using technology. Applies technology towards a situation and shows an understanding of the impact of applying this technology. Utilizes some advance features of computer technology to complete tasks and solve problems.
Level 3	Follows instructions to complete general tasks when using technology. Applies technology towards a situation and shows an awareness of the impact of applying this technology. Utilizes few advance features of computer technology to complete tasks and solve problems.
Level 2	Follows instructions to complete simple tasks when using technology. Applies some Level 2 technology towards a situation and shows no awareness of the impact of applying this technology. Completes basic tasks with computer technology.
Level 1	Demonstrates minimal skills in using and applying technology to a situation.

As for the dimension of technological literacy discussed earlier, pupils were expected to be in ‘Level 3’ or greater to be considered doing ‘sound, good and consistent work’ (Saskatchewan Education, 2001, p.22). In this instance, 76.8% of pupils were expected to meet or exceed this level.

In this activity, ‘Level 2’ was attained by following the instructions to set the radio and alarm. ‘Level 3’ was attained by the pupils showing how they had located specific information in the instruction manual, or solved a particular problem ‘using the technology as an aid’ (Saskatchewan Education, 2001, p.40). An example of the type of problem for pupils to solve using technology is the following:

You are preparing to go to bed and have decided you want to wake up at 6:30 AM and listen to the radio for 2 hours straight while lying in bed. Unfortunately the clock radio is located across the room from your bed and you don't want to get up to adjust it in the morning. How can you preset the clock radio the night before to meet your needs for the next morning? (Saskatchewan Education, 2001, p.42)

Less than 3% of Grade 11 pupils managed to solve this problem. The overall results for 'using technology, including computers' shows that in Grade 11, only 52.5% of pupils managed to meet or exceed 'Level 3' where almost 77% of pupils had been expected to be able to do so. Even at 'Level 2', while almost 93% of pupils met or exceeded the requirements, more than 95% had been expected to do so. As a result, these pupils could not be considered proficient in this dimension of technological literacy.

2.2.3 The relevance of these studies to my investigation

It is apparent from the studies discussed earlier that the part of the Saskatchewan Education study that endeavoured to understand how pupils conceived of technology managed to provide more useful data than the PATT studies, even though both made use of predetermined categories in the classification of the data. In fact, the PATT-USA study showed that there was so little correlation between the results and the 'concept of technology' scales which they were supposed to represent that no further attempt was made to include the predetermined scales in any further analysis.

As in the case of the Saskatchewan Education study, the PATT questionnaire included a free-response, or essay, section that in the case of PATT was meant to be assessed with reference to the 'concept' scales which are those derived from literature as well as through interviews with professionals in the field. However, once the 'concept' scales as such were shown by the PATT-USA not to be useful, the expectation could have been that the essay section would be analysed differently for future uses of the PATT questionnaire. In fact, in a recent use of the PATT questionnaire in Hong Kong (Volk et al., 2003), where a modified form of the PATT-USA questionnaire was used, the 'concept' questions were not included at all. However, the essay question remained, but there appeared to be no mention made of 'concepts' developing from it in the presentation of the results. With the 'concept' section omitted, there appeared to be no further attempt made to analyse the qualitative data, only the quantitative data relating to pupils' attitudes towards technology, was analysed.

I have argued above that a large part of the reason why pupils could not distinguish the concept scales was that they were based on a literature review and consultation with experts in the field of technology and technology education. As such, they did not necessarily represent the ways that pupils conceive of technology. A more useful approach could have been, in the first instance, to determine the ways in which pupils *did* conceive of technology and then develop the questions for the 'concept' section of the PATT questionnaire from that perspective.

In contrast to the 'concept' sections of the PATT questionnaire (both the Likert-type questions and the essay section) which appeared not to give useful results, the section of the Saskatchewan Education study that looked at 'understanding, describing and adapting technology' provided richer data on how pupils conceived of technology. This study was conducted in the context of determining pupils' levels of technological literacy, but the model developed earlier in this chapter shows how understanding the nature of technology is of central importance to the idea of being technologically literate. It is interesting to note the important role that pictures drawn of technology by pupils played in the question about the meaning of technology (see Figure 4).

The Saskatchewan Education study confirmed the focus that many pupils have on computers as representative of technology. However, unlike in the PATT study, the use of other approaches to data collection resulted in a number of other understandings of technology being represented.

Another aspect of the Saskatchewan Education study was the focus on the *use* of a product of technology as an aspect in the determination of the technological literacy of pupils, which links to the dimension of capability and capacity outlined above. The process used in collecting this data was firstly to have pupils perform simple tasks by following a set of instructions, whereafter they were set more challenging tasks that required interpretation of instructions. This process of providing a structured path into the activity appeared to be successful. An interesting result of this exercise was that Grade 11 pupils were very much less able to 'use products of technology' than had been expected.

One feature of the Saskatchewan Education data collection process that needs to be highlighted is the assessment criteria against which levels of capacity and capability of the pupils are measured. As discussed earlier, these consist of a set of levels developed by the

stakeholder representatives (Saskatchewan Education, 2001, p.62). These are, as such, an 'absolute scale' against which to judge levels of capability and capacity. However, there is no guarantee that pupils of this age will conceive of technology or interact with technological artefacts in terms of the levels developed by the stakeholders. What may have been more relevant, or useful, would have been to determine, from the pupils' perspective, the range of ways that it was *possible* to conceive of technology or interact with technological artefacts and to base levels of technological literacy on this scale. This scale could then have been compared and contrasted with the scale determined by the stakeholders. This would as a result give a better indication as to the *actual* technological literacy levels of pupils and not simply the levels based on what 'experts' *expect*.

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Chapter 3

Research Methodology

In educational research and, more generally, in the social sciences, 'methodology' is taken to be a discipline whose function is to examine the underlying rationale for the methods which produce valid knowledge. In this sense, methodology aims to prescribe what are justifiable methods and procedures that ought to be used in the generation and testing of valid knowledge. (Carr in Clough & Nutbrown, 2002, p.vii)

3.1 Introduction

The first chapter presented the argument for the importance of understanding how pupils conceive technology and how they experience interacting with technological artefacts. These issues were developed and formulated in that chapter as the research questions for this thesis. Chapter 3 presents the research methodology used to investigate these questions. In order to answer such questions, it is necessary to adopt a conceptual framing that has an interpretive *understanding*, as opposed to prediction, as a central focus. Such an interpretivist view seeks to understand how the world is experienced in terms of the relations that people make with the world. Here, the meaning derived through interpretation becomes central to the research focus. The meaning comes about through our relational interaction with the realities in our world. Interpretivism provides the broad epistemological orientation for this study and it is from this position that the methodological approach used in this study was selected.

In this spirit, the research questions presented in the first chapter aim at obtaining an interpretive understanding of pupils' interactions with the world through their eyes – from their experiential perspective. Research of this nature is referred to as second-order research (Marton, 1981) because the focus is on the variation in the ways of experiencing a phenomenon and not the phenomenon itself. Thus, this thesis explores the variation in the relationship between pupils and an aspect of the world as it is experienced by pupils. In other words, in this thesis, I am not making statements about a phenomenon, but rather about pupils' experiences of that phenomenon. Making statements about a phenomenon is a significant part of using a first-order perspective where a researcher studies a

phenomenon directly – research in the natural sciences is often of this type where a researcher believes they are describing things as they are.

Thus, the research approach known as phenomenography (Marton, 1981) was chosen. Phenomenography is a research approach that has at its core these characteristics and has a particular view on the object of research that makes it ideally suited to answer questions of this nature. A comprehensive description of the phenomenographic approach is presented below.

3.2 Phenomenography as a research approach

Phenomenography has developed from the student learning research undertaken by Marton and his colleagues in the mid-1970s at the University of Gothenburg in Sweden. In this research, Marton et al. (Marton & Säljö, 1976a, 1976b; Säljö, 1979) moved from studying learning with a quasi-cognitive-psychological framing to studying the variation in *ways of experiencing*⁴ learning. This was a marked innovative departure at the time from the classical approach to investigating learning. The outcome of this research was that Marton and colleagues described the now well known and widely used qualitatively different ways that students experienced learning (Marton & Säljö, 1976a; Säljö, 1979). This result was possible because they were no longer looking at the individual as central to their research, but rather the students they investigated were a collective supplier of fragments for how learning was experienced. Marton has described phenomenography as follows:

Phenomenography is a research method adapted for mapping the qualitatively different ways in which people experience, conceptualise, perceive, and understand various aspects of the world around them. ... [P]henomenography investigates the qualitatively different ways in which people experience or think about various phenomena. (Marton, 1986, p.31)

Phenomenography as a research approach grew out of strongly empirical roots (Hasselgren & Beach, 1997, p.192). However, as the approach became more widely used, an emphasis was placed on developing its theoretical underpinnings. Marton, in his seminal paper on

⁴ As is common in phenomenography, *experiencing* is used as a synonym for conceiving, conceptualising, understanding, and comprehending (Marton & Booth, 1997, p.114). The use of each is dictated by the object of research.

phenomenography (Marton, 1981) and two other publications (Johansson, Marton, & Svensson, 1985; Marton, 1986) laid much of the early foundations for the ontological and epistemological basis of phenomenography. During 1991, the Warburton Symposium was held to discuss the variations in method used in phenomenographic research up to that time. Arising from this symposium, a monograph (Bowden & Walsh, 1994) was published (and subsequently republished in 2000) which critically interrogated issues in phenomenography and included critiques of aspects of the approach that need addressing. From 1993 to 1995, the journal *Nordisk Pedagogik* published a series of articles under the theme 'Reflections on phenomenography' that dealt in depth with the ongoing debate around methodological issues. These were subsequently republished as *Reflections on phenomenography – Toward a methodology?* (Dall'Alba & Hasselgren, 1996). In the late 1990s, Marton and Booth published what has become a widely acclaimed, authoritative book on phenomenography, *Learning and awareness* (Marton & Booth, 1997). In this book, they present phenomenography in terms of an epistemology that is embedded in an anatomy of awareness. At the same time, a special issue of the Australasian journal Higher Education Research and Development (HERD) which focussed on phenomenography was published.

The outcome of the critique around phenomenography has been to expand the theoretical basis for the approach (cf. Marton & Tsui, 2004). My position on phenomenography (Reed, 2006) has developed from the critical debate that took place in these publications as well as through discussions I have had with a number of Swedish scholars in the field.

Central to phenomenography is that it aims to describe the key aspects of the variation of the experience of a phenomenon rather than focus on the richness of individual experiences. Figure 6 (Trigwell, 2006) illustrates phenomenography in relation to philosophy, method and outcome vis-à-vis other approaches used to investigate human experience. This description of the phenomenographic approach will form the point of departure for a detailed discussion of phenomenography to follow.

In summary, phenomenography looks to characterise the variation in ways of experiencing the world from a second order perspective. Phenomenography is the study of qualitatively different ways in which people ‘experience various phenomena in various situations’ (Marton, 1996, p.168) and these experiences are ‘relations between people and the world, reflecting one as much as the other’ (p.168). This relationship between person and world means that what is experienced does not exist within the individual but rather is constituted through the relationship between person and world. Furthermore, the basic unit of phenomenography has been described as ‘experiential, non-dualistic, an internal person-world relationship, a stripped depiction of capability and constraint, non-psychological, collective but individually and culturally distributed, a reflection of the collected anatomy of awareness inherent in a particular perspective’ (p.172).

3.2.2 The object of phenomenographic research

The traditional phenomenographic research approach aims to describe the significant, or critical, features of the different ways of experiencing a phenomenon and the term ‘conception’ is one of the terms typically used to refer to these ways of experiencing this phenomenon – a specific aspect of reality. The essence of a ‘conception’ has been described as ‘discerning something from its context, relating it to some context, discerning its parts and relating them to each other and to the whole’ (Marton, 1996, p.179). Thus, conceptions (or ways of experiencing) can be thought of as making up the *unit of analysis* in phenomenography and refer to ‘whole quantities of human-world relations’ (Johansson et al., 1985, p.249). As such, phenomenographic conceptions cannot be seen, ‘but remain tacit, implicit, or assumed’ (p.236). How then can phenomenography have *variation* in conceptions of phenomena as the object of research if these conceptions cannot be studied directly? Conceptions are typically represented, or characterised, in the form of categories of description; as Säljö (1996) notes, ‘categories of description are intended as tools for describing conceptions’ (p.25). These categories of description are the nominal outcome of a phenomenographic analysis. It must be stressed, however, that categories of description are not directly synonymous with conceptions (Bowden, 1996; Sandberg, 1997) but the categories of description characterise the conception. In other words, categories of description are best thought of as ‘denoting’ conceptions (Johansson et al., 1985, p.249).

Figure 7 illustrates how I see the relationship between categories of description and ways of experiencing a phenomenon in the world. Marton and Booth (1997) have argued that the category of description is ‘a reasonable characterization of a possible way of experiencing something [a phenomenon in the world] given the data at hand’ (p.136). This is illustrated in Figure 7 where the ‘researcher’ is shown to *collect data* of individuals reflecting over their experience of a phenomenon. Säljö (1996, p.28) has argued that ‘phenomenography implies [the] decontextualisation of “conceptions” via “categories of descriptions” into “outcome spaces”’ – an outcome space being a hierarchically ordered set of categories of description. The interrelationship between these ideas, the outcome of a phenomenographic analysis, is discussed in the following section.

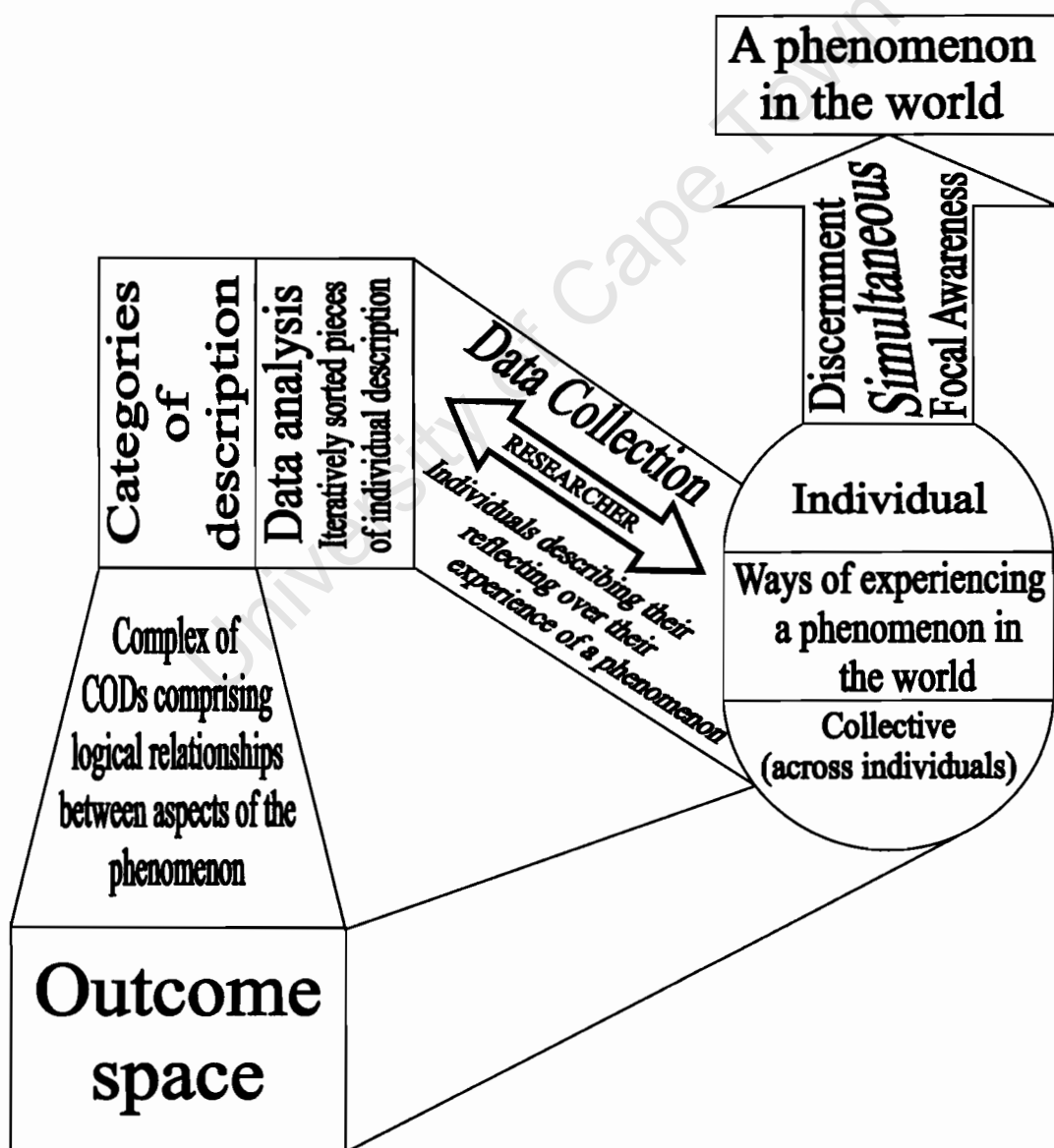


Figure 7 – How I see the relationship between ways of experiencing a phenomenon in the world and the outcome of a phenomenographic analysis

3.2.3 The outcome of a phenomenographic analysis

Phenomenographic research has as its outcome a set of categories of description that characterise the variation in the way a phenomenon may be experienced. This 'complex' of categories of description form what is referred to as an *outcome space*. The categories contain distinct groupings of descriptions of an experience of a phenomenon. Central to an outcome space is that the categories will have logically related parts that yield a hierarchy. This hierarchy reflects an increasing complexity in terms of this logical relationship. The nature of the categories are important and Marton and Booth (1996, p.125) indicate that categories of description need to fulfil three criteria for them to be phenomenographic. The first is the requirement for the categories to be logically related. Another requirement is that they be parsimonious, i.e. the minimum number of categories that fully describe the variation in the ways of experiencing the phenomenon must be used. Finally, each category must completely describe a distinctly different aspect of the experience of a phenomenon, i.e. each category of description must be qualitatively different from the others.

Ways of experiencing, and hence categories of description, have been shown in many studies of many different phenomena, to be limited in number with respect to a particular phenomenon (Trigwell, 2000, p.76). In other words, for any phenomenon, there are a limited number of qualitatively different ways that this phenomenon could be experienced. Furthermore, it is not enough simply to determine a set of qualitatively different categories to have a phenomenographic result. In fact, it is not so much the categories *per se* that are important, but rather the differences and similarities that serve to link and differentiate one category from another, i.e. the structure and meaning related to the categories – the logical relations between them.

3.2.4 Bringing structure and meaning to an experience

In describing an experience through a set of categories of description, it is possible to describe the structure of the experience as well as the meaning of the experience. This follows from the fact that in order to experience a phenomenon *as* a phenomenon (i.e. its *structure*) it is important that a person discern this phenomenon from its environment in order to be focally aware of the relevant aspects simultaneously. To give it *meaning*, it is important that this phenomena be seen in the context of the situation in which it is found. It should be apparent from this discussion that structure and meaning are intertwined as one

and are only separated analytically (Marton & Booth, 1997, p.87). Since it is possible for a researcher to separate them analytically to be able to describe the experience fully, both a *structural* aspect and a *referential* (meaning) aspect to categories of description may be constituted within an outcome space. More specifically then, the structural aspect is the discernment of the whole of what is being focussed on from the context in which it is located as well as the discernment of the parts and the relationship between these parts and the whole – called the internal and external horizon of the category. These relate to the inter-relationship between ‘parts’ that make up the phenomenon in the case of the internal horizon, and the relationship of these ‘parts’ to the context in the case of the external horizon. The example of coming across a motorcar engine on a scrap heap serves to illustrate the interrelationship between these ideas. The external horizon of seeing the engine in the scrap-yard extends from the immediate boundary of the experience (the engine sitting amongst the pile of scrap) through all other contexts where engines have been encountered before that moment. Marton (1994, p.4426) refers to this external horizon as the ‘delimitation [of the object] from [the context] and relating [it] to a[n expanded] context’. The internal horizon consists of the engine itself: its shape, parts, configuration, etc. In the words of Marton and Booth (1997, p.87), it has a ‘structural presence’. The referential aspect brings meaning to the experience by focussing on the form of the structure and the context in which it is situated.

3.2.5 The structure of awareness

The internal and external horizons discussed above are related to what has been constituted as a structure of awareness (Booth, 1992; Marton & Booth, 1997). Within this structure of awareness, the internal horizon consists of the parts of a phenomenon (and their relationship with each other) that are in focus. The external horizon is everything that surrounds the phenomenon, including its context (the limit of its extents).

In order to develop this idea of there being structure to the awareness of an experience, it is necessary to describe how, from a phenomenographic point of view, a person becomes aware of a particular situation they may find themselves in. It is possible to be simultaneously aware of many things, but not necessarily all in the same way. Some things are focussed on (i.e., they are figural, or central) and some things are relegated to the very limits of awareness (i.e., they recede to ground). When focussing on a phenomenon, all the

aspects that are simultaneously in mind, based on the experience of the situation, are referred to as being part of a thematic field. While focussing on this phenomenon, there will be aspects that you will not focus on as fully because they are not directly related to the phenomenon. These non-related aspects are moved to the margin of awareness. Within the thematic field, some aspects will come to the fore and become central to one's focus of awareness. These are referred to as the 'theme of ... awareness' (Marton & Booth, 1997, p.98). Figure 8 shows how it is possible to illustrate these regions of the structure of awareness graphically. It is important to note that these are not three distinct (or delineated) areas as they may appear in the figure. They should be thought of as forming part of a continuum, an 'infinitely differentiated figure-ground structure' (Marton, 1994, p.4427).

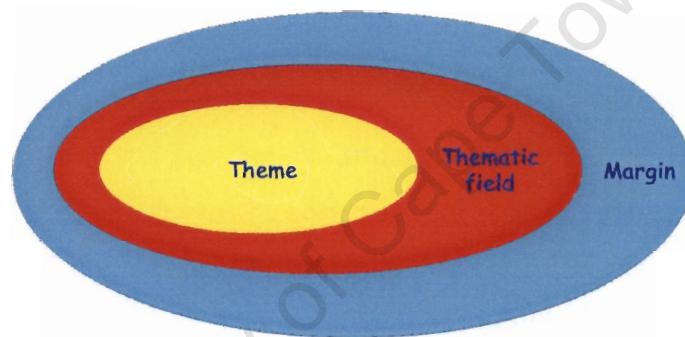


Figure 8 – The structure of awareness (Booth, 1992, p.266)

The ideas just described are best illustrated by means of an example. At another location in the scrap-yard of the previous example is a shed containing all manner of second-hand motorcar parts. You are particularly interested in a replacement engine for your motorcar. As you enter and look around, you notice a large table with a wide range of compatible engines. At this moment, you are focussing on the engines collectively; the number of cylinders, their size, their physical condition, etc. The table of engines makes up the thematic field with other parts in the shed now relegated to the margin. While you are focussing on the table of engines, one falls off the edge of the table onto the floor. At this moment, your focus shifts to that particular engine. This engine, and *its* characteristics, now becomes central to your awareness. Thus, within the thematic field, these aspects make up the theme of awareness – you are still aware of the other engines, but in a limited way.

3.2.6 Summary

In this section, I presented phenomenography as a research approach that takes on a non-dualist perspective to describe the key aspects of the variation in ways of experiencing a phenomenon. The result of a phenomenographic analysis is a logically and hierarchically related set of categories of description describing the variation in the ways a phenomenon is experienced. These categories of description are limited in number, internally and logically related and form, as a collective, an outcome space capturing the ways of experiencing the phenomenon.

Phenomenography as a research approach not only carries methodological implications but also typical methods of data collection and analysis. The discussion above has dealt with methodological considerations and the discussion below shifts to methods of data collection associated with this research approach.

3.3 Issues of data collection

When searching for variation and ways of experiencing, the phenomenographic approach requires that the data be a collection of peoples' experiences of a phenomenon as described by those people. What then makes a particular method appropriate as part of a phenomenographic research approach? It is one that has a data collection strategy that facilitates a person *reflecting* on their experience of a phenomenon. Marton and Booth (1997, p.129) have spoken of people being required to reflect over their experience of a phenomenon in a state of 'meta-awareness'. This form of reflection is not necessarily something that happens spontaneously, but enabling it is the key to an appropriate method of data collection. According to Marton (1994), 'The more it is possible to make things which are unthematized and implicit into objects of reflection, and hence thematized and explicit, the more fully can awareness be explored' (p.4427).

A typical phenomenographic study could first have people perform a task or engage in some activity and then describe how they had gone about this task or activity. Marton and Booth (1997) describe how initially, 'the phenomenon that the ... [person] is being asked to handle is ... brought to awareness by the interviewer in an open and concrete form. ... [Thereafter, the person] herself has to discern the phenomenon and distinguish it from the situation as a whole' (p.130). They go on to state that in the first part, 'the phenomenon is

anchored in the interview situation, whereas in the second, ... it transcends the situation' (p.130). It is helping pupils reach this state of 'meta-awareness' that needs to be central to a phenomenographic data collection strategy.

An analysis of published phenomenographic studies shows that data are collected in two predominant ways: through an interview or through the text written by the person in response to specific questions. Other methods have been used, such as reviewing film footage of a sequence of activities (cf. discussion in Marton and Booth (1997, p.50-51 & 131) on work by Lindahl, 1996), but these are less common. Since my investigation used interviews as the method of data collection, this approach will form the focus of the discussion that follows.

3.3.1 The nature of the phenomenographic interview

As I argued earlier, the key to the phenomenographic interview is to enable participants to reflect on their experience of a given phenomenon. The interview should allow aspects of a person's experience of a phenomenon to be thematised where it may not have been without the interview. Critical to achieving this is the researcher and interviewee establishing a shared or 'joint' (Bowden, 1996, p.58) definition of the phenomenon under discussion. It should be recognised that the experiences captured by the interview are 'jointly constituted by the interviewer and the interviewee' (Marton, 1994, p.4427) and are thematised through a 'conversation between two partners about a theme of mutual interest' (Kvale, 1996, p.125). Säljö (1996) has referred to this 'theme' as involving 'shared topics of discourse' (p.23). What is also important in the context of a phenomenographic study is that there is a shared experience of the phenomenon amongst the interviewees (Marton, 2004).

The typical phenomenographic interview is of a semi-structured nature with only a few key questions predetermined. That is not to say that the phenomenographic interview is without focus. The object of study (as described earlier) is held central to the interviewer's focus at all times and guides the interview situation. The majority of the interview is thus centred around following up and exploring different aspects of the interviewee's experience as thoroughly as possible. The process of continuous probing and directed following up of comments makes the phenomenographic interview by nature more intimidating than a traditional qualitative interview. In this vein, Francis (1996) has warned that care must be

taken to 'treat the interviewee as a reporting subject rather than an interrogated object' (p.38).

3.3.2 The importance of context in a phenomenographic interview

As phenomenography has developed as a research approach, the phenomenographic use of the interview as a legitimate way of exploring a person's experience of a phenomenon has been one aspect that has been the target of socio-cultural critique, perhaps no more so than by Säljö (1996; 1997). Central to Säljö's concern is the 'relationship between discourse and experience' (1997, p.174) and the issues that arise from his belief that the phenomenographic interview is in essence primarily a social construction defined by the social norms of the interview context. He cautions that researchers need to be careful about what they decide a conversation is indicative of especially considering the weight phenomenographers place on the interview conversation. Säljö suggests that phenomenographers do not recognise the 'primacy of talk' (1996, p.20) in an interview situation.

An example Säljö uses to illustrate his position is an interview that he undertook with a student about a physics problem. The student had 'no difficulties in presenting the expected and authorised kinds of reasoning in spite of the complexities of the problems involved' (Säljö, 1996, p.20). A chance question from Säljö asking if she understood what they had been discussing resulted in the reply, 'No, I don't understand it at all, but this is the way they talk around here and then I do that too' (p.20). A response of this nature to an interview question provides cause for concern given the importance that phenomenographic researchers place on data collected during an interview. This is especially relevant considering that a phenomenographic analysis is performed without 'access to anything except utterances from individuals made in specific situations and with varying motives' (Säljö, 1997, p.177).

Säljö continues his argument by referring to the asymmetric power situation often found in an interview situation and arguing that utterances in a interview could quite conceivably signify something other than indicated by what is said. For example, these 'utterances' could be an 'attempt to fulfil one's communicative obligations' on being asked a question, or simply the result of not wanting to 'lose face' when being asked a challenging, or possibly abstract, question (Säljö, 1997, p.177). In short, he cautions against simply

accepting an interview conversation ‘as indicating a way of experiencing rather than as, for instance, a way of talking’ (p.178).

These critiques of the phenomenographic interview can be addressed by ensuring that ‘context’ as a necessary element of a phenomenographic study is kept in mind during implementation of the research approach. Both Marton (1996) and Säljö (1997) indicate that the early phenomenographic studies placed participants in situations with a meaningful context and that there was thus ‘something meaningful for the interviewer and interviewee to explore together’ (Marton, 1996, p.171). The importance of creating a shared experience for the participants in the phenomenographic study to reflect on during an interview, is thus stressed. Säljö (1997) argues further that phenomenographic results ‘become interesting’ when there is a ‘discursive practice in which people are trying to *achieve* something ... rather than when they are being asked abstract questions in interview situations on almost any topic’ (p.179 – emphasis added).

3.3.3 Characteristics of the sample

The outcome of a phenomenographic analysis is the variation in the ways of experiencing a phenomenon. Thus, one of the critical questions to be answered is *who* to interview about their experiences of a phenomenon. The key to answering this question is to recognise that, as the focus is on *variation*, purposeful sampling allows ‘critical cases’ (Cohen, Manion, & Morrison, 2000, p.103) to be selected for the investigation based on the judgement of the researcher. Including these critical cases in the purposively selected sample will thus give the best data to contribute to the constitution of the full extent of the various ways of experiencing the phenomenon.

A somewhat contested issue relating to the characteristics of the phenomenographic ‘sample’ is *how many* people to interview about their experience of a particular phenomenon. The phenomenographic approach does not necessarily require all data to be collected prior to the commencement of an analysis. In a number of cases, an analysis begins on a subset of the data and the categories of description as constituted are subsequently further developed and refined based on the inclusion of additional data. A researcher can conceivably continue to conduct interviews until, in a phenomenographic sense, ‘maximum’ variation has been achieved. This is similar to the grounded theory approach of ‘theoretical saturation’ proposed by Glaser and Strauss (1967) which is often

used to indicate when enough interviews have been completed. Saturation occurs when 'no additional data are being found ... [and] the researcher becomes empirically confident that a category is saturated' (p.61). There is a marked similarity in the quanta of interviews undertaken in the typical phenomenographic study. Trigwell (2000, p.66) argues that between fifteen and twenty people is the ideal number to interview for two reasons. Firstly, by preselecting critical cases he ensures maximal variation in his sample. He continues by claiming that 'ten to fifteen would be the minimum to create a reasonable chance of finding variation in the range' (p.66). Secondly, he argues that increasing the sample size increases the volume of data to analyse to unrealistic levels.

Linder (2006) has pointed out that variation in implied contexts and the voicing of different ways of conceptualizing some phenomenon are both essential parts of phenomenographic-based interviews. Thus, he argues, it is neither surprising nor uncommon for it to be possible for different categories of description to emerge from a single interview discussion. The logical question to ask is what would have happened had this individual not been amongst those interviewed. The answer to this involves a number of issues. I argued earlier that the content of an interview is a conversation constituted between the researcher and the person being interviewed. During the interview, the interviewee's description of their experience of a phenomenon is not necessarily constant throughout the interview. It may vary, and possibly even change, as some aspects are brought into focus and become figural (and others move to ground) during the interview conversation. As a result, even though a particular person is one of those interviewed, there is no guarantee that during the conversation they will express what may turn out to singularly constitute a category of description. Similarly, any other person interviewed could potentially at any time help to constitute the same category. The process of developing categories of description involves looking at fragments of an interview in the context of that interview as well as in the context of all the other fragments from all the other interviews. Just because it appears as though a category may have been constituted by an individual, this is not necessarily so. It is constituted in terms of the relationship between that experience of the phenomenon in the context of all the other experiences of that phenomenon. The best chance of ensuring the complete variation of the ways of experiencing a phenomenon remains sensibly to select the participants in the study to ensure as much variation as possible. It is the collective experience of the participants that is analysed. An individual is simply a contributor to this collective.

3.3.4 Summary

In this section, I argued that the data collected during a phenomenographic interview is required to be a person's reflections of their experience of a phenomenon. The interview should be structured in such a way as to allow aspects of a person's experience of a phenomenon to be thematised explicitly. I argued further that the approach followed for a phenomenographic study should ensure a shared experience, within a meaningful context, of the phenomenon in question so that during the interview conversation, there is something of meaning to explore.

With reference to issues of sample constitution, since a phenomenographic analysis focuses on variation, I suggested that it is appropriate to use purposive sampling to identify 'critical cases' to interview. Some researchers have convincingly argued that the number of 'critical cases' in a phenomenographic study should be in the range of 10 to 20 to ensure that there is variation in ways of experiencing a phenomenon across the range of those interviewed. However, there is no sign in the broader phenomenographic literature that this argument is widely accepted as a phenomenographic benchmark.

The next section moves from data collection to focus on the analysis of the data collected during these interviews.

3.4 Phenomenographic data analysis

This section describes the analytical process followed to develop the *hierarchically related, critically different set of categories of description* that I indicated earlier are the outcome of a phenomenographic analysis. Although phenomenographers may use a number of subtly different approaches to analysis (cf. Bowden & Walsh, 2000; Walsh, 2000), they share the same underlying philosophy. Some researchers have compared the various approaches leading researchers have used to perform their phenomenographic analyses (cf. Åkerlind, 2005). My approach is anchored in the most traditional of these.

3.4.1 From interview to transcript

Once the series of interviews for a project is completed, the normal next step would be to transcribe the conversations that took place. Then, one of the first decisions that would need to be taken, is to specify how accurately to make this transcription, as the act of

transcription is itself an 'interpretive process' (Kvale, 1996, p.160). Here I would argue that phenomenographic analysis does not have the same focus on linguistic elements as a method such as discourse analysis. But, with due recognition given to Kvale's (1996, p.165) concerns that the oral language of an interview is decontextualised into the written word, the transcripts need to accurately capture how a person has reflected over their experience of a phenomenon during the interview.

I discussed earlier how phenomenography is a research approach with not only methodological positions but also with methods of data collection and analysis. In this vein, the initial stages of a phenomenographic analysis have a number of similarities to a grounded theory approach (Denzin & Lincoln, 1994; Glaser & Strauss, 1967). Once a researcher has a set of interview transcripts in front of them, it becomes necessary to draw appropriately on the aspects of phenomenography that deal with the process of analysis.

3.4.2 Fragments of conceptions?

After the interview conversations have been transcribed verbatim, there is some difference in opinion amongst researchers about what the next step entails. In the classic formulation of the phenomenographic approach, Marton (1986; 1994) suggests first selecting from the transcripts those sections where the interviewees have focussed on reflecting on their experience of the phenomenon in question. All the excerpts that relate to the experience of the same phenomenon are then placed in what he refers to as a 'pool of meaning' (Marton, 1994, p.4428). This pool of meaning is a collection of fragments that have been lifted from their context in the interviews.

Revealing the structural aspect of conceptions (or ways of experiencing) in the process of constituting categories of description involves taking the fragments in the pool of meaning and interpreting these firstly in relation to each other, and secondly in relation to the interviews from where they came, i.e. their original context; and then iterating between the two. Svensson (as discussed by Marton (1996), p.179) refers to the discernment of a phenomenon in terms of parts, wholes, and context as the defining characteristic of a conception. Clearly then, the process of iterating between the pool of meaning and the original interview is an attempt to bring to light critical aspects of these conceptions. Marton has described this iterative, interpretive process of analysis as being 'two sides of the same coin' (Marton, 2006) where fragments are considered in relation to each other,

while simultaneously keeping in mind the whole interview to be conscious of the original context. As a result, even though the categories of description have essentially been lifted out of the original context, the *constitution* of the categories of description was not undertaken in a decontextualised manner.

A number of researchers have different approaches as to how they relate parts to the parts and parts to the whole. Prosser's (2000) approach is to deal first with transcripts as a whole in order to divide the transcripts into what he calls 'related parts' (p.45) and not to place *fragments* in a 'pool of meaning'. That is not to say that one approach is better than the other as it is simply a different way of keeping track of the 'two sides of the same coin' idea developed above. In Prosser's 'relational' work (cf. Prosser & Trigwell, 1999), the 'related parts' approach seems to be most suitable. In his approach, parts are then directly related to each other and in relation to the categories being constituted. In this approach, the 'pool of meaning' becomes a set of sections of interviews – each still firmly located within the context of the interview from which it originated.

Bowden (2000b) on the other hand 'prefer[s] to deal with the whole transcript all of the time' (p.12). This is not at odds with the 'two sides of the same coin' analogy as he is still looking at and comparing the parts with the parts and the parts with the whole. He simply does not want to deconstruct the interviews. He looks at 'any particular utterance' (p.12) in the context of what was said in the interview as a whole and argues that placing excerpts in and working from a 'pool of meaning' runs the risk of complete decontextualisation from the original transcript. In response to critique of this nature, Marton (1994) has reiterated the requirement during analysis in the 'pool of meaning' approach to 'make sense of particular expressions in terms of the collective as well as of the individual context' (p.4428).

It is clear that there are a number of different approaches to dealing with the 'two sides of the same coin' analogy presented earlier. However, when one interrogates these approaches, it is apparent that they are essentially doing the same thing and simply dealing with the parts/parts, parts/whole relationship differently. For this investigation, I followed the traditional phenomenographic approach making use of the 'pool of meaning' as described earlier. The specifics of how I implemented this approach are discussed in Chapter 4.

The rest of the discussion in this chapter further addresses my approach to the analysis of phenomenographic data.

3.4.3 Constituting an outcome space

My process of constituting categories of description in a phenomenographic analysis differs from what Prosser (2000) terms a 'shopping basket' (p.45) approach to analysis – an approach where categories would have been determined based on a content analysis of the data. A phenomenographic analysis is quite different in that it follows aspects of a grounded theory approach (Denzin & Lincoln, 1994; Glaser & Strauss, 1967). This difference is primarily because, in the analysis, the way in which an individual experiences a phenomenon is only part of the way that phenomenon can be experienced and the categories of description represent the variation in all the different ways of experiencing the phenomenon. The predetermination of these categories of description would make the analysis run counter to the second-order nature of phenomenography and end up simply being a researcher's constitution of the ways of experiencing a phenomenon – something akin to a phenomenological study.

The first step in the process towards constituting an outcome space is to populate the pool of meaning with fragments from all the interviews that refer to an experience of the phenomenon in question. This is achieved by carefully reading the transcripts and looking for 'meaning units' in the text that relate to this phenomenon. These sections of text could be a single answer to a question or part of a longer conversation. The key here is that the interviewee should be focussing on a single aspect of the phenomenon for the duration of the meaning unit of text. Once the individual meaning units have been identified across all the interviews, the interviews are deconstructed and only the individual meaning units retained. This is thought of as literally taking a pair of scissors and cutting out the appropriate sections of text and putting side the irrelevant text. These meaning units are 'placed' in the pool of meaning that then contains all the possible ways of experiencing the phenomenon in question. The individuals interviewed have thus provided fragments of the ways of experiencing the phenomenon to this pool and the assumption is that this, at a collective level, would represent the variation in ways in which this phenomenon is experienced. The data is thus homogenised by removing unimportant differences such as

the terminology used during the interviews and the ‘integration and generalisation of important similarities’ (Dahlgren, 1997, p.24).

Once the pool of meaning is populated with ‘meaning units of experience’, Marton (1986) has described in detail a process for the next stage in the constitution of the categories of description:

The selected quotes make up the data pool which forms the basis for the next and crucial step in the analysis. The researcher's attention has now shifted from the individual subjects (i.e., from the interviews from which the quotes were abstracted) to the meaning embedded [in] the quotes themselves. The boundaries separating individuals are abandoned and interest is focused on the “pool of meanings” discovered in the data. Thus, each quote has two contexts in relation to which it has been interpreted: first, the interview from which it was taken, and second, the “pool of meanings” to which it belongs. The interpretation is an interactive procedure which reverberates between these two contexts. A step-by-step differentiation is made within the pool of meanings. As a result of the interpretive work, utterances are brought together into categories on the basis of their similarities. Categories are differentiated from one another in terms of their differences. In concrete terms, the process looks like this: quotes are sorted into piles, borderline cases are examined, and eventually the criterion attributes for each group are made explicit. In this way, the groups of quotes are arranged and rearranged, are narrowed into categories, and finally are defined in terms of core meanings, on the one hand, and borderline cases on the other. Each category is illustrated by quotes from the data. ... As the meanings of categories begin to form, those meanings determine which quotes should be included and which should be excluded from specific categories. The process is tedious, time-consuming, labor-intensive, and interactive. It entails the continual sorting and resorting of data. Definitions for categories are tested against the data, adjusted, retested, and adjusted again. There is, however, a decreasing rate of change, and eventually the whole system of meanings is stabilized. (p.43)

In Marton’s description, little detail is provided about how ‘utterances are brought together into categories on the basis of their similarities’ and how ‘categories are differentiated from one another in terms of their differences’. Few researchers make this process explicit probably because it is not simply a structured series of steps that can be easily described. The specifics of the process of analysis carried out for this study are dealt with in detail in the next chapter. The following discussion describes in general terms the process employed in this study for constituting the categories of description.

In my approach, from within the pool of meaning, core aspects that make up the ways of experiencing the phenomenon in question are grouped in terms of similar content and structure. The meaning units are read in the context of all those that have come before and

in the context of the interviews from where they have been derived. Each fragment informs and helps to delineate the others. At the same time, themes that run through the data are identified and used to structure the logical relationships both within and between the categories as they develop. The analysis alternates between the categories as they are being constituted, the meaning units, and the themes looking to substantiate, contradict or revise the relationships that are emerging.

Trigwell (2000, p.65) agrees with the sentiments of Marton's description earlier that the process of analysis is both complex and time-consuming. A phenomenographic analysis is not something that can be undertaken piecemeal, or in short bursts of activity. Researchers must immerse themselves in the data as it is important to be able to hold the meaning units in focus simultaneously to be able to work with the themes, structures and logical relationships as they emerge.

The categories of description constituted through this analysis make up the 'outcome space'. As described earlier, this outcome space is 'the complex of categories of description comprising distinct groupings of aspects of the phenomenon and the relationships between them' (Marton & Booth, 1997, p.125). The outcome space is thus a robustly constituted set of logically related categories comprising distinct groupings of aspects of the phenomenon. These categories of description are qualitatively different from each other and represent the variation in the way of experiencing the phenomenon. The structural themes give structure to the categories, both in terms of the internal structure, as well as the structural relationship between them. Thus, categories of description are differentiated from one another by the critical aspects of the way of experiencing a phenomenon that they each contain.

Specific examples of how the process of analysis was implemented in this thesis will be presented in Chapter 4.

3.4.4 Summary

This section has argued for the process used to develop the limited number of internally and logically related, qualitatively different, hierarchical categories of description that are the outcome of a phenomenographic analysis. I argued that the traditional Swedish method of dealing with interview transcripts by placing a collection of fragments from all the

interviews that refer to an experience of the phenomenon in question into a pool of meaning was an appropriate method for this study. The framework illustrating the process followed in this study for analysing the phenomenographic data obtained from the interview conversations, was presented. The rest of this chapter looks at the critical issue of validity, reliability, and generalisability of phenomenographic data.

3.5 The trustworthiness of phenomenographic research

How is it possible to know whether a study investigates what it sets out to investigate, or even whether the findings from a study allow for consistency in data interpretation and thus research findings? These questions are often dealt with by discussing a study's validity and reliability respectively. This section looks at these terms in the context of phenomenography as an interpretivist research approach and questions the call made by some researchers to report on phenomenographic studies in terms of these criteria, which in a strict sense emanated from a positivist research framework.

Lincoln and Guba (1985), in their seminal work *Naturalistic Inquiry*, argue that rigour can be appropriately reported on in interpretive studies. Their concern at the time was that interpretive studies were seen as 'undisciplined ... [with] "sloppy" research, [and researchers] engaging in "merely subjective" observations' (p.289). This book was written at a time when the positivist approach to research was dominant in the social sciences and the merits of interpretive research was judged based on characteristics that Lincoln and Guba felt were only appropriate to the former approach. The core of their argument was that it is not appropriate to argue for the positivist standards of validity, reliability and objectivity in measuring the value of interpretive research, but rather that the concept of the *trustworthiness* of the investigation should be employed. To argue for trustworthiness, they brought in the notion of 'credibility', 'transferability', and 'dependability' as equivalent to the traditional research notions of validity (internal and external) and reliability. As part of arguing for the 'trustworthiness of results' (or in a later refinement (Lincoln & Guba, 1986, p.78), the 'authenticity of results'), rather than a focus on validity and reliability of results as the appropriate measure of establishing rigour in research, it has been possible to judge the value of interpretive studies by a different set of appropriate criteria. The following sections expand on my view on how rigour is best ensured in a phenomenographic study.

3.5.1 Credibility and transferability

Validity in a study is the extent to which it is possible to show that a study measures what it sets out to measure. By drawing on the argument given by Lincoln and Guba (1985), it can be shown that there are other approaches that may be more appropriate as measures of this aspect of rigour in interpretive research. Cohen et al. (2000) agree with this position, and argue that it is important to discuss issues of validity in the *context* of the research perspective employed in a study. Thus, for interpretive research to be considered sound, it should not be a requirement to strive to meet the traditional criteria for validity, i.e. the need to ‘demonstrate concurrent, predictive, convergent, criterion-related, internal and external validity’ (Cohen et al., 2000, p.106). This notwithstanding, many phenomenographic studies have argued for ‘validity’ in their results in terms of the sorting of the descriptions into *already* constituted categories (cf. Johansson et al., 1985, p.251). This can be seen as a form of generating trustworthiness. Even so, there are still those who would argue for a more traditionally orientated approach to reporting validity in phenomenographic studies. One of the stronger proponents of this post-positivist type approach is Cope (2000). His attempt to introduce ‘rigour’ through application of the traditional approach to validity does not, however, adequately address the fact that a phenomenographic result is an interpretive (and thus by definition not objective) process describing individuals’ experience of a phenomenon and not of the phenomenon itself.

As mentioned above, Lincoln and Guba (1985) have replaced the traditional research notions of internal and external validity with ‘credibility’ and ‘transferability’ respectively. With reference to the latter notion of ‘transferability’, they maintain that ‘the naturalist cannot specify the external validity of an enquiry; he or she can provide only the thick description necessary to enable someone interested in making a transfer to reach a conclusion about whether transfer can be contemplated as a possibility’ (p.316).

Turning now to the notion of credibility, Booth (1992) argues that it is understandable for the research community to scrutinise the results and conclusions of an interpretive study with specific regard to their ‘credibility and trustworthiness’ (p.65). She highlights three approaches to ensuring that this measure of rigour occurs and although she frames these using the term ‘validity’, it is clear from the description of each that they bear little resemblance to the traditional notion of validity described earlier. The approaches she

highlights are termed ‘content-related’ (see also Cohen et al., 2000, p.109), ‘methodological’, and ‘communicative’ (see also Kvale, 1996, p.244) validity. Content-related validity concerns the researcher’s familiarity with the subject matter under investigation, methodological validity looks at how the goals of the study match its design and execution, and communicative validity involves the researcher’s ability to argue their interpretation of the data. In applying these constructs to the present argument I have chosen to use the term ‘credibility’ rather than ‘validity’ as in, for example, *content-related credibility*. I take this stance because of the associated legacy that terminology such as ‘validity’ brings to interpretive studies. I would argue that it is more appropriate to re-characterise the term ‘credibility’, as first proposed by Lincoln and Guba, instead of trying to take what is essentially a positivistic concept and manipulate it to work in an interpretive context. With reference to Booth’s use of ‘methodological validity’, she was referring, in the most part, to issues of method and not methodology as I defined the term earlier in this chapter. For this reason, I introduce the idea of *credibility of method* to encompass more accurately the sense of rigour in this context. These measures of credibility will form the bases of my argument for what is required to ensure rigour in phenomenographic research.

Content-related credibility

Content-related credibility relates to a researcher having a comprehensive grasp, or understanding, of topics related to the phenomenon under investigation. The research community could justifiably question the rigour of the results should a researcher not be completely familiar with the subject matter under investigation. Booth (1992) maintains that it is important that this knowledge of the subject matter in question be an *open* understanding as the ‘researcher has to be open for ways of understanding it [the subject matter] which differ from those generally accepted’ (p.66). I would argue that the need for an ‘open understanding’ of the topic of investigation is more important than being a leading expert in this topic because, in a phenomenographic analysis, the focus is on others’ ways of experiencing a phenomenon, which may turn out not to be related at all to the scientific (or other) ways of understanding it. It is critically important that during analysis, a researcher is able to ‘bracket’, or carefully examine and then suspend one’s own understanding of the topic so that the categories of description constituted from the data are not influenced by the researcher’s bias in understanding the phenomenon. Ashworth and Lucas (2000) argue that the act of bracketing allows a researcher to set aside, as far as is

possible, their own assumptions about a phenomenon ‘in order to register the student’s own point of view’ (p.297).

Credibility of method

Booth (1992) has argued that credibility of method (or what she terms methodological validity) ‘lies in the match between the goals of the study and its design and execution’ (p.66). To this end, issues relating to sample composition, the context in which the interview takes place, the structure and content of the interview, and the analysis of the data are centrally important.

In a phenomenographic study, it is crucial that the sample selected for the study be appropriate and relevant to the central research question under investigation. The result of a phenomenographic investigation is the variation in the ways a phenomenon is experienced and without careful consideration given to the selection of the sample, a justifiable critique from the research community could be the possibility that the full extent of the variation in ways of experiencing the phenomenon is not assured.

The second construct ensuring credibility of method lies in the context of the interview. It has been argued that the ‘mutual definition of the situation determines the value of the discourse’ (Booth, 1992, p.66). I argued earlier that context is a necessary element of a phenomenographic study that should be kept in mind during implementation of the research approach. By ensuring a shared experience of a phenomenon, there is a greater likelihood of ‘establishing a joint definition of what is being talked about’ in the interview situation (Säljö, 1996, p.23-24). This will directly influence the credibility of the results of the subsequent analysis.

I argued earlier in this chapter that in a phenomenographic interview, questions are not necessarily as structured as often found in other forms of interpretive studies and that the typical phenomenographic interview is of a semi-structured nature with only a few key questions predetermined. This introduces the importance of the third construct ensuring credibility of method and that is to ensure that the structure and content of the interviews are richly reported in a study so that the research community can determine the completeness of the data collected. During the interview conversation itself, the researcher must ensure that the possible power relationship that could exist between themselves and

the interviewee does not limit the 'open and deep discourse' (Booth, 1992, p.66) required to obtain rich, meaningful data from which credible categories of description can be constituted during analysis.

It is important to ensure credibility of method through the adoption of a particular attitude towards analysis. Ensuring rigour through analysis 'lies in the researcher's open and thorough attitude, eschewing preconceived ideas and being receptive for the meaning that interviews themselves reveal' (Booth, 1992, p.66). The actual process of phenomenographic analysis varies from researcher to researcher with the process employed in this study described earlier in the chapter. However, what is common to all approaches to analysis is that credibility of this aspect of a study rests on the 'search for meaning' in the data collected and during this process 'retaining a sense of the whole while pursuing the particular' (p.66).

Communicative credibility

Communicative credibility relates to the requirement of the researcher to be able to 'argue persuasively for the particular interpretation that they have proposed' (Åkerlind, 2005, p.330). It is also the ability to present the results and conclusions of a study to the research community in an open way that allows the study as a whole to be scrutinised. This allows the research community to recognise and judge for themselves the credibility and legitimacy of the researcher's interpretation of the results (Booth, 1992, p.67; Kvale, 1996, p.246-247). Unlike in a positivist-oriented study, here researchers do not argue for results as being the ultimate truth. In a phenomenographic study, the aim of a researcher is to be able to defend their interpretation of the data to the 'outside world'. This 'outside world' has a number of distinctive participative 'actors' that between them define an internal and an external aspect of communicative credibility (Booth, 1992, p.67).

External communicative credibility relates to other researchers with similar interests being able to recognise the legitimacy of the interpretation made of the data. There are a number of avenues for this to take place, both during the course of the analysis of a study as well as after a study is complete. These include conference presentations and seminars where interim constitutions of categories of description can be presented for discussion, as well peer-reviewed journal articles (Åkerlind, 2005, p.330). Internal communicative credibility relates to the participants of the study, and others indirectly involved in the study (Booth,

1992; Kvale, 1996). There is a reluctance in phenomenographic research to make use of internal communicative credibility even though Francis (1996) suggests that it is important to ensure the 'accuracy [of the interpretation] through the eyes of the individual concerned' (p.41). It is the focus on having an *individual* recognise the legitimacy of the constituted categories of description that is inherently problematic in internal communicative credibility. Earlier in this chapter, I described how individuals contribute fragments of an interview conversation to a 'pool of meaning' after which categories of description are constituted. Individuals should, as a matter of principle, not be able to recognise 'their' contribution to the outcome space. The categories of description do not capture their ways of experiencing the phenomenon, but rather the experience of the phenomenon by all those in the study. A further issue raised in this regard by Åkerlind (2005) is that one of the fundamental underlying assumptions of the phenomenographic approach is that an individual's experience of phenomenon is 'context sensitive' (p.331) and can change, even during the course of an interview, depending what aspect of the phenomenon is in focus at that particular moment. Thus, at the time the participants are asked about their interpretation of the final categories of description as constituted, there is no guarantee that they would still be experiencing the phenomenon in the way they were during the interview.

Summary

From the discussion above, it is apparent that the notion of credibility in a phenomenographic study is something that must be considered throughout the study. Contrary to the view of those arguing for the return of the traditional condition of validity, the idea of credibility is not something that is only left to those interrogating the research findings. Rather it is a way of designing the study that begins with the definition of the object of research and follows through each aspect of the study to its conclusion. Furthermore, it includes a tacit relationship with the community outside the study through an interaction around the research findings as they are constituted. The measures of credibility presented above ensure that the outcome of phenomenographic research can be taken seriously.

3.5.2 Dependability

The need for 'reliability' in an interpretive study has been questioned by some scholars (cf. Lincoln & Guba, 1985, p.316; Stenbacka, 2001, p.552). Lincoln & Guba claim that there can be no validity without reliability (see also Cohen et al., 2000, p.105) and thus, in the context of their terminology describing these constructs, no credibility without dependability. The consequence of this claim is that in a study, if credibility has been established, then the need to establish dependability to show that a study is trustworthy becomes unnecessary. However, they do acknowledge that in practice there is still the need to 'deal with dependability directly' (Lincoln & Guba, 1985, p.317).

Dependability (using the construct for 'reliability' proposed by Lincoln & Guba) in a phenomenographic study has been likened by Booth (1992) to a journey of exploration. She equates the planning of a study to the planning of an expedition and the execution of a study similar to 'following an outline chart while simultaneously ensuring the potentially interesting ways are followed and striking features are noted' (p.67). The results of the study are analogous to a description of the terrain in terms of what the explorer saw and experienced along the way. A different explorer may have the same goals for their expedition, but would most likely develop a different path to achieve these goals and would thus give a different description of what they saw and experienced along the way. However, should the second researcher be given the former's maps and charts, log-books, diaries, and itinerary, it is likely that the resultant description of the terrain covered during the exploration would be similar to that presented by the first explorer. Booth (1992) does add a rider to this expectation of similarity of description. She maintains that this does 'presuppose that both explorers (or researchers, now), have similarly thorough experiences of what it is to explore foreign lands (or research other people's conceptions)' (p.68). Similarly, in terms of a phenomenographic study, researchers should have a similar understanding of the phenomena focussed on as the object of study. It is clear from this analogy that dependability relates to 'consistency in data [interpretation]' and thus consistency in research findings (Åkerlind, 2005, p.331; Kvale, 1996, p.235) and should as far as possible be actively pursued in a phenomenographic study. Kvale (1996, p.236) identifies three areas in an interpretive study that can influence the dependability of research findings. The first area involves the interviewer during the data collection

exercise, the second is relevant during the transcription of the interviews and finally, during analysis, dependability issues are again raised.

Dependability as a function of the interview conversation

During data collection, the structure of the interview conversation and the issue of prompting the interviewee with leading questions is of critical importance (Francis, 1996, p.38; Kvale, 1996, p.157). The researcher must be conscious at all times of ensuring that the interviewees are expressing how *they* have experienced the phenomenon in question. Leading questions can influence the interviewee to attempt to 'see their experience through the eyes of the interviewer rather than through their own' (Francis, 1996, p.38). I argued earlier in this chapter how in a phenomenographic interview only a few key questions are predetermined. This places an extra burden on the researcher to ensure that non-leading questions are used during the interview conversation. Questioning strategies that develop based on what is brought into focus by the interviewee need to be carefully considered while the interview itself is still in progress. Francis (1996) argues that 'prompt trails' (p.39), based on a whole range of possible interviewee responses, could be set up before the time to help ensure that the interview is well grounded in the interviewee's experience of the phenomenon in question.

Dependability as a function of accuracy of transcription

I mentioned earlier in this chapter that one of the first decisions required of a researcher after an interview is complete is to decide how accurate a transcription is necessary. A decision of this nature is important because, as Kvale (1996, p.160) points out, the act of transcription is an 'interpretive process' in itself. My argument was that since a phenomenographic analysis does not have the same focus on linguistic elements as a method such as discourse analysis, it is not necessary to record every tonal inflection or pause in speech. What is important, however, is that the 'spoken word' is transcribed as accurately as possible.

Kvale (1996, p.163-164) suggests that to ensure dependability of transcripts, and to ensure that the 'spoken word' is transcribed as accurately as possible, two different transcribers should reach agreement on what was said to ensure that the decontextualised written word accurately captures what was said during the interview. This process would enable

intersubjective agreement to be reached on the transcripts resulting in the transcripts accurately capturing how a person has reflected over their experience of a phenomenon during the interview conversation.

Dependability as a function of analysis

Within the process of analysis of phenomenographic data, intersubjective agreement forms the basis for assuring dependability of results. Åkerlind (2005) has identified two possible types of intersubjective confirmation of categories of description in the context of analysis of phenomenographic data. One she labels the *dialogic reliability check*, where ‘agreement between researchers is reached through discussion and mutual critique of the data and of each researcher’s interpretive hypothesis’ (p.331). The second she labels the *coder reliability check*, where two or more researchers ‘independently code all or a sample of interview transcripts and compare categorisations’ (p.331). In keeping with the use of the construct ‘dependability’ in place of ‘reliability’, Åkerlind’s two types of intersubjective confirmation of categories of description are termed here a *dialogic dependability check* and a *coder dependability check*.

Bowden (2000a), Prosser (2000) and Trigwell (2000, p.29) are proponents of various forms of the *dialogic dependability check*. Bowden’s approach to analysis is to assign one member of his research team the responsibility of constituting draft categories of description, then having the other researchers re-read the transcripts, and independently make tentative allocations of each transcript to the categories. The allocations are compared and ‘where there were disagreements about categories of description or allocation of transcripts, they were resolved with reference to the transcripts as the only evidence of students’ understandings’ (p.52). Bowden claims that by making use of a group iterative approach to the analysis of phenomenographic data, new insights to the constitution of the categories of description can be achieved. He is also of the opinion that by carrying out a solitary analysis of the data, he would not have been able to constitute as accurate a set of categories of description as was possible by the group (p.59).

A strict implementation of the *coder dependability check* during the development of the categories of description (where researchers independently code the interview transcripts and compare categorisations) has been argued by Marton (1986) to be unreasonable to expect in phenomenography as ‘the original finding of the categories of description is a

form of discovery, and discoveries do not have to be replicable' (p.35 – see also Säljö, 1988, p.45). However, once the categories have been found, Marton (1986) argues that 'it must be possible to reach a high degree of intersubjective agreement concerning their presence or absence if other researchers are to be able to use them' (p.35). This idea of categories being recognised by others forms the basis for a practice widely practised in phenomenography (Cope, Horan, & Garner, 1997, p.12-13; Johansson et al., 1985, p.251; Marton, 1996, p.133; Säljö, 1988, p.45), often referred to by the traditionally positivist constructs of inter-rater reliability or interjudge reliability.

There are varying levels to which this latter check can be implemented. Some researchers (Cope, 2004; Johansson et al., 1985; Säljö, 1988) have argued for a statistic to be generated (note the positivist associations!) illustrating the agreement between how co-researchers have classified data in the categories of description identified by the original researcher. The appropriate level of agreement, after consultation between researchers, has been variously argued to be between 75% and 100% (Johansson et al., 1985, p.251) or between 80% and 90% (Säljö, 1988, p.45). Researchers (cf. Booth, 1992) have been critical of the use of intersubjective agreement of this kind, primarily because there is a difficulty in finding co-judges who are as well versed in the subject matter under investigation.

Sandberg (1997) has criticised the use of the *coder dependability check* on a number of fronts. Firstly, he argues that because a statement made by an individual could appear to a co-judge to encompass more than one conception, there is potential conflict as to where the statement should be located. In reality, it is possible that this statement (or more accurately, aspects of this statement) has helped constitute more than a single category of description. Another consideration is that a statement may not in itself be easily identified with a category of description, but it may have contributed a critical aspect that has helped constitute a particular category. He has argued that this 'integrated interpretation can be difficult for co-judges to see, since they do not have the same familiarity with the data as the original researcher' (p.206). Sandberg's (1997) second criticism relates to the extreme form of coder dependability where a particular percentage correlation is demanded between co-judges. He argues that searching for such correlation is not appropriate in a research approach that does not have an objectivist epistemology. He claims that a 'serious consequence of such theoretical and methodological inconsistency in the research process' (p.208) is that the scientific community is able to call into question the results of a

phenomenographic study. In order to overcome these concerns, he has argued for interpretive awareness to be the means whereby trustworthiness is ensured in phenomenographic studies. To 'maintain' this interpretive awareness means to 'acknowledge and explicitly deal with our subjectivity throughout the research process instead of overlooking it' (p.209).

Summary

I have argued in this section that *dependability* is a more appropriate construct to use for the positivistic term *reliability* and is an important part of a phenomenographic study. Ensuring the dependability of a study is important as it allows for consistency of data interpretation and thus consistency in the research findings of an investigation. To ensure dependability, care must be taken during the interview conversation, during transcription of the data, and most importantly, during constitution of the categories of description. During the process of finalising the categories of description, I argued that it is possible to make use of a dialogic dependability check that stops short of embracing the typical positivistic attributes of the widely used measure referred to as interjudge reliability.

3.5.3 Position taken for this thesis

Kvale (1996) has argued that validity, reliability and generalisability have reached the status of a 'scientific holy trinity' (p.229). I have argued that these traditional constructs cannot be appropriate for interpretive research such as phenomenography. I further argued that *trustworthiness* of research is a more useful approach to follow with Lincoln and Guba's (1985) credibility and dependability re-constituted to more accurately reflect the requirements to ensure rigour in the research process. I kept the importance of ensuring trustworthiness through credibility and dependability firmly in mind during every stage of this investigation. The measures taken to ensure the rigour in this process are presented in Chapter 4.

3.6 Concluding remarks

Phenomenography is not just a research approach to investigate the experience of phenomena. It should rather be seen as 'an approach - to identifying, formulating, and tackling certain sorts of research questions' (Marton & Booth, 1997, p.111). What I have

argued for above is precisely that. Phenomenography is a methodology that is more than just the theoretical underpinning of a method. It forms the central hub around which all aspects of an empirical study hinge. In Chapter 4, I describe the specific method used in the collection of the interview data and the process I went through in the analysis of this data by drawing on the methodological framework developed in this chapter.

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Chapter 4

Method

4.1 Introduction

Chapter 3 argued for phenomenography as an appropriate research approach for this thesis. Carr (in Clough & Nutbrown, 2002, p.vii) argues that ‘knowledge is ... valid only if its production conforms to the methods and procedures prescribed by [the] methodology [you have chosen]’ Following this line of reasoning, what is necessary is to ensure that the methods used in this study fulfil this requirement in the context of phenomenographic research. It is important to acknowledge that a method is not a pre-packaged black box that a researcher takes off a shelf to employ in a study. It is something that needs to be ‘painstakingly custom built’ (Clough & Nutbrown, 2002, p.27) with reference to appropriate methods. The methodological underpinnings of phenomenography dictate that the data collected be a person’s experience of a phenomenon as described by that person. This chapter describes the compound method developed to facilitate pupils being able to reflect on their conceptions of technology and on how they experienced interacting with technological artefacts.

The chapter begins by describing how photographs and a structured activity were used to ensure a shared and meaningful experience of the phenomena under investigation. It continues by discussing the basis for the ‘sample’ (or rather, study participants) selected and thereafter describes in detail the data collection strategy used in the investigation. A detailed discussion follows on how the data were collected through a series of semi-structured interviews. The chapter concludes with a section discussing how the trustworthiness of the results was established.

4.2 Creating a shared experience

A central requirement for credible results in a phenomenographic analysis is the assurance of a shared experience of the phenomenon in question amongst those taking part in the study. Säljö (1997) has pointed out that the most successful phenomenographic studies took place in situations with a meaningful context that the researcher and interviewees

could then explore together. Kvale (1996, p.124) has characterised this as an ‘interview conversation’. Säljö (1997) raises a concern about phenomenographic studies where interviewees have been asked ‘abstract questions’ (p.179) on almost any topic. In a similar vein, Booth (1992, p.66) argues that having a mutually shared definition of the situation helps to create the value of the discourse during the interviews.

In the case of my first research question, the aim was to investigate how pupils conceive technology and in my second, how pupils experience interacting with technological artefacts. To deal with these two different, yet complementary, experiences relating to technology, it was necessary to create two situations, each having their own specific contexts, which would ensure that the interview conversations were genuine shared topics of discourse.

The rest of this section looks at each of the research questions vis-à-vis creating a shared experience for pupils of the phenomena in question. In the case of the first research question, this was accomplished through the use of photographs taken by pupils of technology in their lives, and in the case of the second, it was through the use of a structured activity containing a number of technological artefacts. The two approaches were extensively piloted at different times during their development and these pilots are, where relevant, drawn on in the discussion that follows.

4.2.1 Interview 1: Constituting a shared context through the use of photographs

The first research question is about pupils’ conceptions of the nature of technology. My initial piloting approach to ‘bring to light’ (Marton & Booth, 1997, p.129) the ways in which pupils conceive of technology was unwittingly embedded in ‘abstract questions’ about this amorphous term ‘technology’. Then, reflecting on Säljö’s critique on abstract questions that I mentioned earlier in this section, I came to recognise that some parts of the questioning I was putting to pupils was indirectly introducing aspects of my own conception of technology. This resulted in pupils focussing on that aspect, or variations on that aspect, rather than on other experiences they may possibly have expressed under different circumstances.

In order not to influence the interview in this way, I started exploring a quite different approach; by using a photographic picture that was characteristic of many of the ways (as

described in Chapter 2) that technology could possibly be conceived. The goal was to explore, using such pictures, a means to help stimulate discussion around pupils' conceptions of technology from their perspectives. One such picture selected was of congestion caused by rush-hour traffic and was meant to help pupils focus on a variety of different aspects of technology during the course of the interview. The results were promising, but the conversation still grew from a discussion around a picture that did not evolve from the students perspectives; I had chosen it for use in the interview. Hence, from this use of a picture in an 'interview situation' grew the idea to have the pupils take photographs of what they considered as characteristic of technology in their own lives. I reasoned that this would shift the initiation of the conversation about their conception of technology from me to the pupils themselves to create the desired shared context with the pupils taking part in the study.

Anthropological beginnings

The use of photographs in research interviews is not a recent phenomenon. One of the earliest applications of photography to support the interview process was in the late 19th century when Franz Boas used 'photographs of masks and rituals' to aid his interviews of members of the Kwakiutl village (Heisley & Levy, 1991, p.258). A further illustration would be Bateson and Mead producing what is regarded as the classic 'visual' anthropological work (Harper, 1987, p.203) in their sociological study *Balinese Character: A Photographic Analysis* which to this day 'remains a model for photographic analysis' (Harper, 1988, p.58).

From the 1920s, it would appear that not much was published where photographs formed part of a research method. It has been suggested that this could be that there was a growing pressure from natural scientists about the suitability of photographs as data and the emergence of other quantitative methods (such as the statistical analysis of the results of a survey) that 'distanced the researcher from the subject' (Harper, 1988, p.58). It could also be that in the early years of photography, photographs were seen merely as 'reflections of "reality" ... [and] came to be seen as part of a purely representational paradigm' (Douglas, 1998b, p.6) and researchers struggled to overcome this biased perception.

During the 1970s the use of photographs as a research tool in the social sciences re-emerged as an accredited method of anchoring data in an interview situation. This

movement was primarily driven by John and Malcolm Collier (1986) who are widely acknowledged as principle refiners of the use of photo-interviews as a research method. The use of photographs in the process of gathering data during a research interview has more recently been the focus of renewed interest in sociological studies (cf. Cruickshank & Mason, 2003; Harrington & Lindy, 1999/2000; Harrington & Schibik, 2003; Hurworth, 2003; Zambon, 2004).

The photo-interview

In interviews that ask interviewees to give meaning to photographic images, photographs are used specifically 'to provide additional insight into the meaning ... inherent in the photographs' (Harrington & Schibik, 2003, p.28). Collier and Collier (1986, p.105) argue that 'photographs [invite] open expression while maintaining concrete and explicit reference points', while Dempsey and Tucker (1994) have argued that the nature of the data collected using photo-interviews 'yields richer data than that usually obtained from verbal interviewing procedures alone' (p.56).

A shift has taken place in how researchers use photographs in sociological interviews. It has been recognised that although it is useful to use photographs taken *by researchers* to illustrate objects, situations or other elements of interest, it has also been found to be extremely useful to have 'people ... photograph *their* environments ... and comment on the photographs' (Harper, 1988, p.65 – emphasis added). There has been a recognition of the need to 'build data from the point of view of ... subjects' (p.61) and where the interview is 'grounded in the perspective of the subject' (p.54). Harper (1988, p.64) refers to this the 'reflexive mode' of interviewing. Examples of studies being undertaken in this fashion include the work of Douglas (1997; 1998a; 1998b), Zambon (2004), and Harrington and Lindy (1999/2000).

These techniques, in particular those by the Collier brothers and Douglas Harper, were used in this study to further develop the idea of having pupils take their own photographs of 'technology in their lives'.

An interview about technology

The next step in developing the method for the ‘conceptions of technology’ aspect of the investigation was to introduce a reflexive ‘photo elicitation’ interview environment (Harper, 1988, p.65) where pupils would have taken the photographs used in the interview. However, the methods described earlier do not indicate any particular strategy for introducing the photographs into the interview conversation; or for that matter, how to *frame* the interview (Kvale, 1996, p. 127). I thus had to extend and develop the method into one that was appropriate for my context and that was congruent with the methodological underpinning of phenomenography as a research approach. Using photographs in this way was something new to phenomenography.

An important consideration was that by introducing photographs into the interview session, there would be a shift in the often typical power relationship between the interviewer and the interviewee as described by Kvale (1996, p.126). The interview situation would now centre on the pupils discussing their own photographs which would shift any feelings that they may have had that they were the subject of an ‘interrogation’ towards feeling that they were taking on the role of ‘expert [guide] leading the ... [interviewer] through the content of the pictures’ (Collier & Collier, 1986, p.106). This was a useful feature in the context of this investigation as the pupils were minors and thus possibly particularly susceptible to any perceived asymmetry in power in the interview situation.

A methodologically appropriate method?

The approach adopted to make use of photographs had to allow the discernment of the structure of pupils’ conceptions of technology against the background of the situations where they had experienced it. I would argue that using photographs as ‘triggers’ to focus awareness on a particular aspect of conceptions of technology was a useful approach and congruent with the methodology of phenomenography. When pupils took their own photographs of what they perceived to be ‘technology in their life’, they instinctively had a reason for selecting a particular photograph composed in a particular way. They may not have been able clearly to articulate what their reasons were, but the photographs provided a link back to this place and gave them an opportunity to bring back into focus why this selection took place. In phenomenographic terms, it is the ‘theme of ... awareness’ (Marton & Booth, 1997, p.98) that I was interested in here. By introducing a photograph,

within this thematic field, aspects (possibly closer to the margin – see Figure 8, page 43) would come to the fore and become central to their focus of awareness. This could also have been achieved using careful interviewing alone, but for my research question, I would argue that photographs were more useful given the kind of visual stimulus possibility just described.

However, introducing reflexive photo-elicitation to the interview method was no guarantee that pupils would explicitly take photographs that reflected the broad extent of the nature of technology. It was possible that pupils would simply take photographs of ‘things’ in the context of their everyday lives and not photographs involving ‘action’ of some nature. Now that would be acceptable if the extent of their conception of technology was just that: ‘things’. However, if this was not the case, it was important that the method not constrain their expression of the variation in ways they *did* conceive technology and gave scope for these aspects to be explored.

One way to explore this variation was to ask pupils ‘what they were thinking of technology’ when they took a particular photograph as they would instinctively have had a reason for selecting a particular composed photograph. They may not have been able to articulate clearly what their reasons for taking a particular photograph were, but as discussed earlier, the photographs were a link to their reasons and gave an opportunity for the pupils to bring back into focus why this selection took place. The pilot interviews indicated that the richest data did indeed come from asking pupils what they were thinking about technology when they took a particular photograph. It was possible that the interview conversation would be a simple discussion relating to the actual photograph taken, but I found that pupils presented a much broader discussion around a particular photograph.

A further way of exploring this variation (but not used as part of the final composite method) was to get pupils to set up dichotomous (or explicitly different) groupings of photographs and then encourage a pupil to verbalise how they experienced these ‘mutually exclusive’ groups. This forced a pupil to focus on similarities and contrasts amongst and between groups of photographs bringing to the fore aspects not necessarily simply related to the ‘thing’ photographed. This broadened the scope of the discussion. Clearly it was necessary for the pupil themselves to create these groups to keep the focus on their conceptions. Pilot interviews indicated that the process of initiating the development of

these groupings was central to its success. One extreme was to place two photographs in front of a pupil and then to ask them 'in the context of technology' to which of these two a third photograph most suitably belonged. On the face of it, having pupils interrogate the similarities and differences between two piles for the many possible photograph combinations should have provided a rich narrative to analyse. This turned out not to be the case as pupils tended to focus on specific aspects of a photograph in the first instance and then use this as the baseline for further comparisons. The pupils did not look at different aspects of the same photograph but rather remembered what they had previously used of that photograph in their descriptions.

A more useful approach; I then constituted the dichotomous arrangement by asking the pupil to take the complete set of photographs and sort them, 'in the context of technology', into an order that made sense to them. They were now required to consider various aspects of each photograph while searching for similarities and differences between photographs that they had taken. Interviews around photographs grouped using this technique showed that pupils then did focus on a broader set of issues in their analysis of the groupings. They no longer focussed on a single aspect or feature as took place in the 'two plus one' technique described earlier, and issues of process, function, impact on quality of life, and so on, started being brought into the discussion.

I need to point out that at no stage did I ask pupils upfront for their definition of technology. I believed that doing so too early in the interview process would confine a pupil's discussion in the context of that definition. However, once the pupils had discussed their photographs using the techniques described above, it was appropriate to ask this question. I would argue that the description the pupils then gave would be in the context of, and informed by, the discussions just completed about the photographs they had taken. Pilot interviews following this approach confirmed that the definition given of technology was informed by the discussion the pupils had had around their photographs.

Collectively, the techniques described above to frame the interview conversation showed themselves to enhance and inform the interview process and together shaped an appropriate method for use in obtaining data relating to the first research question, namely pupils' conceptions of technology.

4.2.2 Interview 2: Constituting a shared context for experiencing interacting with technological artefacts

The second research question in this thesis is about technological literacy and explores how pupils experience interacting with technological artefacts. Chapter 1 described how the assignments that made up the course *Introduction to Mechanical Engineering* provided the basis for the structured activity that I later took to schools to expose pupils to technology through a range of technological artefacts. In Chapter 2, the intrinsic qualities of technology, or rather the nature of technology, was described as being a typology of technology as objects, technology as an activity, technology as knowledge, and technology as volition. Additionally, to be considered technologically literate, a person must be in a position to understand the nature of technology, have a hands-on capability and capacity to interact with technology, and have the ability to think critically about technological development. It is thus reasonable to argue that developing a structured activity that draws on this framework would create the appropriate vehicle to facilitate this shared experience of interacting with technological artefacts to take place and thus also to provide a shared context in which to hold the interview conversation.

The key characteristics required for the structured activity

The following discussion describes the key characteristics that I found to be necessary to develop the structured activity that could enable this shared experience. These key characteristics, highlighted below, developed from three sources. The first of these sources was in the context of my prior experience with first-year university students in the course *Introduction to Mechanical Engineering*. The second source came through the interaction I had with pupils while ‘taking’ the activity described in Chapter 1 to schools. The final source was drawing on the definition of the nature of technology and what it means to be technologically literate as described in Chapter 2.

The first of the key characteristics was to ensure that the technological artefacts that made up the structured activity involved hands-on experiences of the technology being presented. Secondly, pupils should have been able to interact with the activity as a whole without necessarily requiring ongoing assistance. During the development of the original structured activity taken to schools, I had found that guiding and not directing the pupils was the most beneficial approach. Thirdly, the physical size of the technological artefacts

that made up the activity was important. The requirement here was that the technological artefacts should have been small enough for the pupils to interact with without feeling intimidated by their size. Anecdotal evidence suggested that while working in this environment, pupils would have the tendency to assume high levels of complexity when confronted with a perceived large piece of technical apparatus. A fourth characteristic was the provision of both audio and visual feedback. This acted as positive reinforcement of a pupil's success in achieving a particular result. The affirmation of a pupil's progress was seen during the original piloting of the activity as central to their development of increasing levels of confidence surrounding their interaction with technological artefacts. Finally, the integration of computers and electronics into the activity became an important entry point into the activity. The pupils responded well to the electronics component, specifically in the format where electronics were used to, in essence, control devices that could be considered part of the outside world.

In addition to these characteristics, the structured activity had to have the scope to be able to be viewed by pupils in terms of the diverse ways in which technology has been shown to be understood. In a broad sense, this means that the activity had to include the possibility for technology to be seen in the context of an object, an activity, as a form of knowledge, or as volition. Furthermore, given the specific requirements of the second research question, the structured activity had to allow pupils the possibility of showing that they had a hands-on capability and capacity to interact with technology as well as to give them the scope to show that they had an ability to think critically about the impact of technology on the world.

Given these characteristics for the development of the technological artefacts as well as the structured activity, the following sections discuss how these requirements were integrated into what became the structured activity for this aspect of the investigation.

The structured activity

This section describes the nature of the technological artefacts that made up the structured activity. The primary technological artefact in the activity was what I have called a 'multiboard' (shown in Figure 9). With this multiboard, pupils used a computer to control the operation of various devices including a light, a fan, a buzzer, a switch and a heater. The key here was that pupils could control several equivalents of every-day items by

having these items operate as they chose. However, one of the characteristics required of technological artefacts in the context of this investigation was that they not be perceived as being beyond understanding what was required, or possible. For many pupils, the multiboard fell into this category. With this perception in mind, an intermediate step was developed as a stepping-stone for pupils who had never interacted with anything of this nature before, thus enabling them to facilitate the building of their level of ability and confidence until they were ready to interact with the multiboard. This intermediate step consisted of two ‘simpler’ technological artefacts, both perceptually easier to understand (see Figure 10 and Figure 11). The programming required to make the simpler technological artefact operate was identical to the multiboard, but the perceived ‘complexity’ of the multiboard was dramatically reduced.

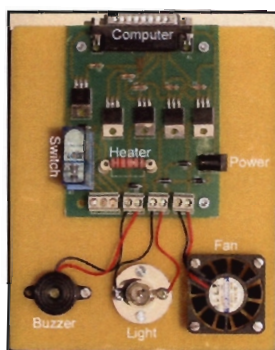


Figure 9 – The multiboard

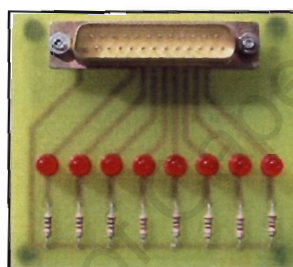


Figure 10 – The light emitting diode (LED) board

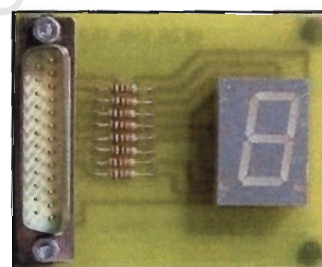


Figure 11 – The digital eight

The first of these simpler steps was to control a series of eight light-emitting diodes (LEDs) on an LED board (shown in Figure 10) by using a computer. The LED board was the ideal entry point to the activity as a first step to learning how to interact with the multiboard and consequently, control the ‘outside world’ using a computer. Its operation was straightforward. The binary equivalent of a decimal number sent via the computer to the LED board was represented directly on the LED display. For example, the binary equivalent of 171 is 10101011. Thus, a pupil ‘sending’ the decimal number 171 via the computer to the LED board would result in the first, third, fifth, seventh and eighth LEDs being illuminated.

Once pupils had grown comfortable in controlling the operation of LEDs through a computer-based conversion of decimal numbers, the LED board was replaced by the 7-segment common-cathode LED display (referred to hereafter as a ‘digital eight’) shown in

Figure 11. With the introduction of the digital eight, the 'same' eight LEDs from the LED board were 'repositioned' to form the segments of the digital display. This way of representing numbers was familiar to most pupils, as they would have recognised the layout from their alarm clocks, liquid crystal display (LCD) watches, and calculators. Using exactly the same commands as for the LED board, pupils were now able to make numbers (and some letters) appear instead of simply a string of lights. There were seven LEDs on the display and a 'dot' alongside (the eighth LED) to indicate orientation. This digital eight enabled the pupils to now actively select which LEDs to illuminate in order to make letters and numbers. This was an introduction to how they could use the computer as a tool to control how things in the outside world operate in a way meaningful to them. With very little additional effort, or understanding, pupils also now had the ability to make a series of characters appear by stringing a number of selected segments together. Once the pupils had familiarised themselves with the LED board and the digital eight, it was time for them to progress to interacting with the multiboard itself.

The multiboard was developed with recognition given to the key characteristics described earlier, together with the requirement to ensure a shared experience in relation to how pupils experienced interacting with technological artefacts. This was only possible if pupils were able to experience the characteristic attributes of the nature of technology and technological literacy through the multiboard as the primary vehicle of this experience. In the case of the nature of technology, the pupils could self-evidently experience the multiboard as a product of technology, either as a whole or as a number of different component parts making up the whole. Secondly, the pupils could experience the multiboard in terms of an activity. This was not necessarily in the sense of producing an artefact, although the constituent parts did need to be assembled before the multiboard could be used, but rather the multiboard's use to a particular end. Thirdly, inherent in both these previous attributes was the fact that the pupils could experience technology as the knowledge they had to assemble, or use, the multiboard. Finally, the multiboard allowed pupils the opportunity make a conscious decision about what it was that they wanted to control. This could have been the heater, the light, the buzzer, or any one of the other available devices. With respect to enabling aspects of technological literacy to be experienced, there was clearly the opportunity for pupils to experience a hands-on capability of interacting with the multiboard as well as to demonstrate that they had the

capacity to be able to do so. There was also scope to think critically about the impact on the external environment of the type of control that the pupils were able to demonstrate.

Over-and-above the reasons given above for developing *these* as the suite of technological artefacts used in the structured activity, another fundamental criterion was that they were all *accessible* as manifestations of technology in one sense or another. One of the technological artefacts used could arguably have been a ballpoint pen, for example. However, this would not have had the same level of accessibility to technology in a general sense, nor would it have had the characteristics of the nature of technology or of technological literacy that the multiboard could offer.

Controlling the activity

Central to this structured activity was having pupils use a computer to control the operation of firstly LEDs and finally the devices on the multiboard. To enable this, each of the boards used was connected via a cable to the parallel port (also known as the printer port) of a computer. The output from a parallel port of a computer is a combination of eight data bits, each either 0 volts or 5 volts.

The aim was not simply to have pupils use a Microsoft Windows software application to control the output to the parallel port (and ultimately the multiboard) by clicking a mouse on various icons on a screen. This would sidetrack them from the experience of interacting with the activity. Instead, a simple programming language was used to effect control, as this would show pupils that they too had the ability to write programmes that could control the computer – and thus by implication, control the LEDs or devices.

Modern software programming languages are by their nature difficult to learn to use. Even when a person has mastered the syntax, or structured set of commands, the user interface presents yet a further obstacle because a person still needs to learn where to find all the features and functions in the interface before they can actually start programming. This structured activity was not about developing expert programmers, so a programme was required that would allow pupils to immediately begin interacting with the technological artefacts. The central requirement for this to take place was to find a software programming language that was relatively simple to learn to use.

The programming language selected was Microsoft's QBasic. This DOS-based programme proved simple for the pupils to begin using immediately. It had no user interface that needed to be learnt and only one line of computer code was required to make any combination of the LEDs or devices operate. An example of a line of computer code that a pupil would use is: `OUT &H378, 109` (see Figure 12). This computer code can be interpreted as an *output* from the computer to *parallel port 378* and the *binary equivalent of 109* (ie, 01101101) must be sent to that port. When pupils connected the computer to the LED board, the result of this command would be to light up, from the right-hand side of Figure 10, the first, third, fourth, sixth, and seventh LEDs. When the digital eight replaced the LED board, for the same line of programming code, the number 3 would appear. When the digital eight was replaced by the multiboard, again using the same line of code, the fan, buzzer, and heater would operate.

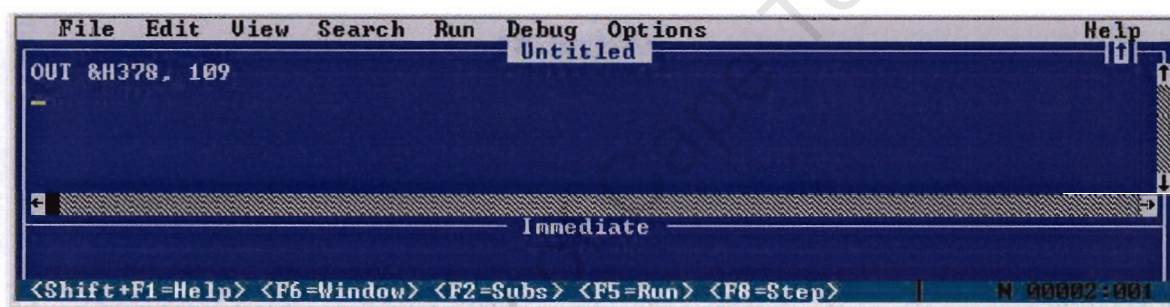


Figure 12 – Microsoft's QBasic showing a line of computer code

Microsoft's QBasic thus provided the ideal basis on which to integrate the control aspect into the structured activity as little focus needed to be placed on the mechanics of QBasic as a programming language. To increase flexibility, pupils were also shown how they could type a number of instances of the same line of code (with different decimal numbers) underneath each other for a series of operations to take place (see Figure 13). Finally, they were shown how using a `SLEEP` statement between lines could act as a pause before the next line executed.

Enabling the interaction

My prior experience showed that undirected exposure to technological artefacts such as these was not very successful. Pupils did not have a point of entry to the artefacts in the activity and consequently their interaction for the most part remained limited. However, those pupils who were guided into the interaction could swiftly progress to 'self-directed'

interaction. Consequently, I felt it was necessary to develop a structured path to lead pupils (both with strong and weak computing backgrounds) through the process of becoming familiar with the environment and finally to being able to interact with the multiboard with confidence.



Figure 13 – Illustration of multiple lines of computer code separated by ‘pause’ statements

To provide this entry point to the structured activity, a worksheet was developed (see Appendix A). This worksheet guided pupils through the process of being able to programme the computer code required to control the LEDs on the LED board, the LED segments on the digital eight and finally the various devices on the multiboard. The worksheet was very specific in its initial instructions in order to provide a scaffolded learning experience for pupils as they discovered how to have the control to turn LEDs on or off. However, even at this stage, pupils were encouraged to try their own ideas and combinations. The worksheet led the pupils from the LED board, via the digital eight into interacting with the multiboard. By this stage, the scaffold was complete and the pupils were left to experiment and try out different ideas with the multiboard. The worksheet was now essentially open-ended to give pupils flexibility in what they do with the devices on the multiboard.

The structured activity was thus a collection of the three aspects described in this section. First, there were the three technological artefacts. Secondly, there was the software programming language to control the operation of these artefacts. Finally, a worksheet facilitated an easy entry-point into interacting with the activity as a whole. The multiboard was clearly a central aspect of this structured activity. The format of the multiboard described above developed as the result of an iterative development over a number of years. The following discussion describes how this development took place.

The historical development of the multiboard

One of the technological artefacts I used in the teaching of both a third-year course, Computer Integrated Manufacturing and Robotics, and the course, Introduction to Mechanical Engineering, was a series of eight light emitting diodes (LEDs) that students controlled using a computer (see Figure 10). The activity associated with this LED board had also worked well with those pupils visiting the Department as discussed in Chapter 1. However, once the pupils had managed to switch the series of LEDs on in the order they chose, there was not much more that I could add to the activity. I had the idea to supplement the eight-LED board with a board where at least one of the LEDs was replaced with a device that pupils would come across in their every-day lives, such as a buzzer (alarm), a light, or a fan. This would enable the activity to be expanded to show pupils the relevance of what they were doing with respect to the outside world. The items selected to replace the LEDs were chosen specifically because of the feedback they provided; the buzzer made a loud sound, the light gave illumination, and the fan gave visual as well as tactile feedback.

The ideal situation would have been to simply be able to replace one of the LEDs with, for example, a fan. The pupils could see then that as simple as it was to switch an LED on and off with a computer, it was just as simple to do the same with a fan. However, replacing three LEDs with the three devices identified turned out not to be as easy as simply connecting the devices in the positions originally occupied by the LEDs. The devices each required 12 volts to operate and there was only 5 volts available from the output port of the computer. This was sufficient to illuminate an LED but nowhere near sufficient to power something like a fan. Figure 14 shows the additional circuitry introduced to provide enough power for the added components. In this figure, the modified LED board (cf. Figure 10) is shown on the left-hand side, the components on the right-hand side and the connecting circuitry on three circuit boards in the middle. The electronics were mounted on a large box (300x250x150 mm). Inside the box was the power-supply for the additional power required by the devices to operate. The circuit worked by using the 5 volts from the LED terminal to switch on a relay that in turn directed the power from the transformer in the box to a device. As a result, there was no direct connection between a replaced LED terminal and the component it was controlling.

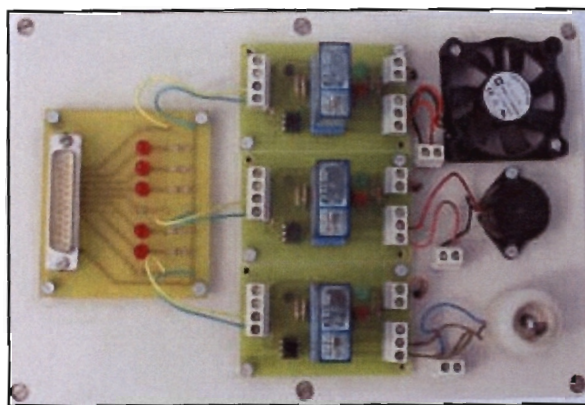


Figure 14 – The prototype multiboard

Pilot testing of this arrangement showed that some pupils became a little confused by the layout and intimidated by the perceived complexity of the box itself. They lost sight of the fact that as easy as it was to switch on or off an LED, so was it to control a more realistic device. Some did not easily grasp that the process was conceptually the same in each instance.

The redeveloped multiboard (shown in Figure 9) managed to address these concerns. It moved away from using a modified LED board and incorporated a new printed-circuit board (PCB) where the focus was only on the devices to be controlled and not on how the power got to the components or that conceptually, a device was simply replacing an LED. The PCB and the devices were mounted on a single piece of Perspex resulting in a significantly smaller package for pupils to work with. A heater and a relay switch were also added as additional devices to control. Further piloting of this new multiboard resulted in the resistor (which acted as the heater) specifications being changed. The resistance was made higher so that the 'heater' got hot more rapidly. For safety reasons, the resistance of the resistor was still chosen such that it would not get hot enough to burn the skin when touched.

4.2.3 Summary

This section has described how it was possible to constitute a shared and meaningful experience for pupils of the phenomena described in the research questions. In the case of the first research question, I argued that using photographs taken by pupils of technology in their lives was the ideal method to explore pupils' conceptions of technology. The important aspect of the introduction of these photographs into the interview conversation

was that they were taken by the pupils themselves to reflect their conceptions of technology. The use of a structured activity containing a number of technological artefacts formed the basis for situating the second research question. Here, a multiboard formed the core of the structured activity. In this activity, pupils used a computer to control a number of devices included on a multiboard. In order to give the multiboard relevance to a broader context, these devices were similar to the things that pupils could visualise wanting to control in the external environment. The consequence of this shared experience was to ensure that the interview conversation took place in the context of a genuine shared topic of discourse.

4.3 Selection of the study participants (the ‘sample’)

The outcome of a phenomenographic analysis is the variation in the ways a phenomenon is experienced. By implication, it is important to ensure that the participants selected are appropriate to enable this variation to be as comprehensive as possible. The most appropriate way of accomplishing this is to select a number of what a researcher considers ‘critical cases’ to ensure as much variation as possible. This is in effect an application of purposeful selection where representivity of a population is not the issue but rather where the focus is on ensuring maximum diversity within the study participants with respect to the phenomenon in question. Thus, selection of participants takes place through the insightful judgement of the researcher rather than using any kind of quantitative criteria. The result of this ‘critical case’ selection is that the cultural and gender profile of a population will not necessarily be statistically represented. However, I again emphasize that this is not at odds with the phenomenographic approach where the focus is on describing the key aspects of the variation of the experience of a phenomenon rather than focussing on the richness of individual experiences.

Working in the South African context

The context of my study is within contemporary South African society where strong socio-economic divisions exist. These divisions are reflected in perceptions, conceptions, and ways of understanding the world because of the vastly different environments in which pupils are growing up. Pupils with impoverished socio-economic backgrounds typically have very different access to opportunities compared to those from wealthier backgrounds

and as such have access to different types and levels of technologies. Thus, pupils in these different socio-economic environments could possibly interact with technology differently and even hold different ideas about what constitutes technology.

This investigation went through an extensive piloting stage where various aspects of the technological activity and photographic interview were trialled. In total, fifteen pilot interviews took place during the project's development. Thirteen of these related to refining the technological activity and two were specifically related to piloting the photographic interview approach. In selecting the participants for these pilots, I attempted to ensure a diverse mix of socio-economic backgrounds because of the particular context of my study as just outlined.

The technique used to focus on socio-economic groupings was to select schools serving specific communities in the greater Cape Town area. For the pilot stage, I used six schools ranging from a township school⁵ on the one end of the socio-economic spectrum to one of the most prestigious private schools on the other. The result of interviewing across this wide range of schools was a realisation that in the actual study I could ensure 'critical case' variation by focussing on pupils from three distinctly different local English-medium schools. The first of these schools was located in the heart of one of the elite suburbs in Cape Town. It was not a private school, but was exceptionally well resourced and serviced a number of nearby high-income residential neighbourhoods. The second was a school originally founded to educate the children of farm labourers who worked on vineyards in the Constantia winelands. This school now services an economically depressed suburb on the Cape Flats where pupils are driven to and from the school by bus every day. The third school was located in the heart of a local township where poverty is rife and unemployment levels high. The school itself was fairly well resourced, but the background of the pupils reflects the community in which the school is located.

⁵ In South Africa, during apartheid, racially segregated settlements called townships were created outside of urban centres for people of colour to be located. The schools in these townships were poorly resourced and did not provide an adequate level of schooling for the pupils who attended them. The legacy of this neglect and under-resourcing remains even though great strides are being made to improve the quality of education in what remain economically impoverished areas.

For completeness, I will, in Table 6, present the socio-economic profile of the pupils who took part in this study. This does not imply that *any importance* is placed on individuals in the context of the phenomenographic study based on the criteria presented earlier. Rather, it is as an illustration of the process gone through to ensure maximum variation in the results. The pupils were all in Grade 11, the second-last year of their twelve years of schooling, at the time of their interview.

Table 6 – Composition of the study participants with reference to socio-economic background

Gender	Economically advantaged	Economically depressed	Economically impoverished
Male	3	2	2
Female	3	3	2

A question closely related to the composition of the study participants is how many pupils should be included in the study. It may appear problematic that an attempt is made before the interview stage to predetermine the number of study participants, especially as theoretical saturation has often been used as a measure in qualitative studies of checking data completeness. This was extensively discussed in the previous chapter.

The initial approach I took to invite pupils to participate in this study was via the principals of the respective schools. The identification of particular pupils was as the result of an interaction between myself and either the principal or a senior teacher at the school. They were asked to identify a diverse group of pupils who were typical of their school, with no particular level of technical ability, to be invited to take part in the study. In each instance, after specific pupils had been identified, a meeting was arranged where I introduced myself to the pupils and asked if they were prepared to be part of the study. In keeping with typical qualitative research protocol, I did not give specific details of the study, but rather spoke in very general terms about what would be involved were they to participate.

In the pilot phase, I had interviewed ten of the pupils at their homes where consent was needed from their parents or legal guardians. This proved to be a difficult exercise fraught with logistical complexity. I often had to make at least two trips to each individual's home, often at night, and sometimes in potentially dangerous areas. I interviewed the remaining five pupils at their schools after their parents or legal guardians had given consent for this to take place. Interviewing pupils at their schools was significantly less problematic and

could often be scheduled sequentially in an afternoon. As a result, for the final data-collection phase of this investigation, I made a decision to interview the pupils at their respective schools. An added advantage of using schools as the venue for the activity surrounding the interviews was that the authority to give consent during school hours rests with the principal of a school. This consent was readily given in each case. Pupils were informed on a number of occasions, both before and during the activity and interview that there was no obligation to participate in the first place, or to continue to participate should they wish to stop. Only one pupil, who had initially indicated interest in taking part, decided later not to participate.

4.4 The data-collection strategy

In Chapter 3, I presented a number of principles related to the method and process of data collection. This section draws on these principles and describes the development of a comprehensive protocol to collect data from the participants in this investigation about both their conceptions of technology as well as how they interacted with technological artefacts.

The following is a brief overview of the strategy used to collect the data for this thesis. After a pupil had accepted the invitation to participate in the investigation, they were given a disposable camera to take a number of photographs of what they perceived to be ‘technology in their lives’ (see Appendix C). These photographs were processed and printed prior to each interview session that took place. Each session actually consisted of two interviews, separated by the structured activity, and took between 60 and 70 minutes in total to complete. The first interview focussed on the photographs the pupils had taken and directly addressed the first research question, namely how pupils conceive technology. Once this interview was complete, the pupils interacted with the structured activity. On completion of this activity, the pupils had their second interview. This second interview related to their experience of interacting with technological artefacts, the second research question, and used the just completed activity as the shared context for this discussion to take place. The remainder of this section discusses this data collection strategy in more detail.

4.4.1 Preliminary instructions to participants

Once the participants for the study from the three schools had been identified, I had a meeting with each of the groups where I introduced myself and told the pupils what would be expected of them should they choose to participate further. I also discussed what rights they had with respect to anonymity and being able to withdraw from the study at any time. The immediate need was to have them agree to take a number of photographs of 'technology in their lives' with a disposable camera. Appendix B shows the documentation that accompanied each camera requesting the pupil's participation. This documentation also included a series of instructions on how to take photographs. During the initial meeting with the pupils, I had a spare disposable camera with me and the pupils were all given the opportunity to take test photographs using the camera's built-in flash capability.

During the piloting of this aspect of the study, I found through experience that it was unlikely that pupils would take the time to fill the spool in the camera with the 27 possible photographs. The minimum number of photographs that I judged to fulfil the requirements of the interview appeared from the pilot interviews to be in the region of six. I therefore asked each pupil to take a minimum of eight photographs. As an incentive to actively go out and take photographs, I encouraged pupils to use the remaining 19 photographs by taking photographs of anything they chose. I offered to print these photographs for the pupils to keep after their interview. There were a number of pupils who had never had access to a camera before and they were particularly excited by this offer. This offer was only made *after* the pupils had agreed to participate in the study. The pupils had up to a week to take the photographs and were asked to return the cameras on the first Monday of the week after I had met with them. In most cases, the interviews took place later that week or early the following week.

4.4.2 The nature of the interview environment

The interviews all took place on school premises during school hours (except for one that took place on the first day of the September school vacation). I was careful to schedule the interview sessions to disrupt the pupils' schoolwork as little as possible. At times this involved meeting before the first teaching period had started, during the lunch period and the period directly thereafter (and thus missing a lesson), or after the final teaching period of the day.

All interviews took place individually and were recorded using a digital recording device. Early pilot sessions used a large analogue recording device that was particularly conspicuous and pupils were noticeably conscious of its presence throughout the interview. The digital recording device was about the size of a mobile telephone and was quickly ignored by the pupils during the interview. Before an interview session began, the right to withdraw at any time before or during the session was reiterated.

I took cans of soda and pastries with me to each of the interview sessions. This was not to act as 'payment' for a pupil's participation, but rather to create a more relaxed and informal atmosphere in which to hold the interviews. Chapter 3 described the potential for an asymmetric power situation to exist in an interview environment, especially where young children are involved. The refreshments I provided appeared to make a difference and allowed for a period before the 'official' session started where the beginnings of a relationship between the pupils and myself could be established.

Wherever possible, I made sure that a pupil being interviewed was physically positioned to create as non-threatening an environment as possible. This was achieved by not sitting directly across a table in a 'me versus you' style, but rather on adjacent sides of a table. This had an added benefit that while the photographs were being discussed, neither of us had to look at upside-down photographs. Between the two interview sessions, pupils interacted with the structured activity described earlier in this chapter. During this activity, I made sure that I was not a physical presence 'interfering' with a pupil's freedom to interact with the activity as they saw fit. I achieved this by asking the pupil if they minded me going to 'do some work' in another part of the room. I positioned myself off to a side but remained in their peripheral vision. They were thus conscious of where I was, while I appeared to get on with doing something that held my attention. From this vantage point, I had the opportunity of unobtrusively watching their progress and making field notes. I was, however, still close enough, and accessible enough, for the pupils to ask questions about actions or operations that needed some aspect of clarification.

4.4.3 A question of questions

I argued in Chapter 3 that the key to a phenomenographic interview is to facilitate a person to be able to reflect over their experience of a phenomenon. In the context of this thesis, it was important that the interview allowed conceptions of technology as well as experiences

of interacting with technological artefacts to be thematised where they may otherwise not have been. The previous sections have described how photographs and a structured activity were used to ensure this shared experience of these phenomena amongst the pupils. This section discusses the nature of the interview questions used to gather data relating to the pupils' experience of these phenomena.

The interviews in this study were semi-structured with the 'first' interview related to pupils' conceptions of technology and the 'second' to pupils' experience of interacting with technological artefacts. Although there were two interviews, they took place during the same session and, as described earlier, were only 'separated' by a pupil's interaction with the structured activity. The two-interview differentiation is only an analytical description as references to both topics were typically brought up across both interviews. This was possible because, as is typical in a phenomenographic interview, only a few key questions are predetermined. The majority of each interview was centred around following up and exploring different aspects of their experiences as they were brought up as thoroughly as possible. For this reason, the interview conversation could cross any artificial boundaries of an interview.

An important aspect in the development of the key questions for this study was recognising that the pupils were only in the region of 16 years old with many of them 2nd or 3rd language English speakers. As a result, the questions that follow in the next section may read as slightly simplistic, but the language used in the questions evolved through a number of pilot interviews.

Interview 1: Conceptions of technology

The following are considered the key questions for the semi-structured interview relating to conceptions of technology. As is typical in semi-structured interviews, the questions are not necessarily asked strictly in the order presented below. A transcript of an interview based on this protocol can be found in Appendix D.

1. *Thinking about technology, what were you thinking about when you took each of these photographs?*

This question encouraged pupils to vocalise what aspect of a photograph was important with respect to the instructions to take photographs of 'technology in their lives'. This proved to be the most useful question as it made pupils explicitly articulate various aspects relating to their conceptions of technology.

2. *How would you group these photographs together in different piles? Thinking about technology, can you describe this pile of photographs to me? What about technology groups them together? With regards to technology, what about this pile, and say, for example, this pile, makes them different? Now looking just at this group of photos, if you had to give it a description in terms of technology, what would it be?*

Typically, there would appear to be a random selection of photographs taken by the pupils. In the questions above, there would be no specific instruction as to how to group the photographs together, but the logical assumption was that the sorting took place with reference to the descriptions previously of what the photographs represented. This question brought focus to the themes the pupils may have subconsciously used to group the photographs in the way that they did. They were also made to articulate the differences between groupings of photographs.

3. *Let's put all the photos out now. Thinking about technology, which one of these photographs is the odd one out? What makes it different from the others? Is it still technology? What were you thinking when you took it? [The pile of photographs is now reduced by removing one photograph at a time (the odd one out) until there are no more photographs left that are considered by the pupils to be 'odd'] If there is no way to choose the odd one out of these remaining photographs, what then in terms of technology defines that they stay together? I'm going to pick up these few photos that are left that you indicate appear to be so similar and put two of them down in front of you. If I now show you this photograph that you removed earlier, and if you think about technology, which of the two photographs in front of you is this one most like?*

The nature of these questions was to open the possibility of obtaining greater differentiation and distinction between the different ways that pupils conceived technology.

4. *Was there anything about technology that you wanted to take a photograph of but couldn't? What does technology do for you in your life? Which photo would you put on a book cover about technology? Why would this be the best choice? Can you tell me what you think technology is – in your own words?*

This collection of questions focussed on having pupils articulate their conception of technology, first through a number of indirect questions and finally with a direct question.

Interview 2: Interacting with technological artefacts

The nature of the process used to explore pupils' conceptions of technology in the first interview resulted in there being a number of structured key questions around which the interview was constituted. The second semi-structured interview had far fewer follow-up questions pre-formulated. The questions presented below formed the entry point into a discussion about interaction with technological artefacts in general in the context of having just completed the structured activity. A transcript of an interview based on this protocol can be found in Appendix E.

1. *So, tell me about what you have just done? When you worked with the multiboard, did you think you would be able to do something like that?*

These questions aimed at probing how the pupils had experienced the interaction with the technological artefacts they had just completed. They explored the kind of interaction that had taken place by looking at the nature of their approach to the activity.

2. *If you had come across something like this that you hadn't worked with before, how would you work out how to use it? Can you tell me about the worksheet?*

The first question looks at the approach to interacting with the structured activity and other similar technological artefacts. Typically, a number of different avenues were opened up for further discussion by this question. Should the pupils not bring up the involvement of the worksheet in the activity, I brought it up towards the end of the discussion.

3. *What do you think the purpose of this activity was?*

I expected the response to this question to be to explore the activity in the context of a broader world view. Occasionally this question was not required as the topic was covered elsewhere during the interview.

4. *Where does the computer fit into the picture?*

Computers are the archetypical example given of ‘technology’ (see the discussion of the 2004 Gallup poll in Chapter 2). The aim of this question was to draw the pupil’s focus to the computer used in the activity. The question looks to see whether pupils experience the technological artefact as including the computer or whether the computer itself is perceived as outside of the boundary of the technological artefacts.

5. *How do you think your friends would have worked out how to use the multiboard?
What about if they had to work out how to use a video recorder?*

By asking a hypothetical question relating to how ‘a friend’ might approach the interaction with firstly the multiboard then a particular technological artefact (in this case a video-recorder), I was able to later bring the question to relate directly to the pupil about how they interacted with something like a video-recorder. By starting from an outside perspective, the direct question would appear less confrontational.

6. *How does what you have just done during this activity link to what you did earlier when we were talking about technology? Looking back on that book you have written about technology. Now that you have completed the activity, would this be a chapter in your book?*

These questions look to see if pupils recognise the bigger picture of what technology is (in the context of how they earlier described it) and how it relates to the integration of this interaction into a broader world view.

4.5 Approach to analysis

In the previous chapter, a detailed account of the traditional process involved in analysing phenomenographic data was presented. This section provides some practical details of the actual procedure I followed in the analysis of the data for this investigation.

4.5.1 Transcribing the interviews

The first step in the process of analysis was to produce transcripts that accurately captured how pupils described their experience of the phenomena during the interviews. I transcribed all the pilot interviews myself. This I did as soon as possible after each interview had taken place. Through this process, I was not only able to get a better feel for the data, but I could also refine my interview questions and techniques as I went along. I also developed an appreciation for the discourse and the nuances of the descriptions given in a language that was often not a participant's first language. Then, for the main study, I got professional help with the transcriptions. As I had transcribed all the pilot interviews, I felt that I had obtained a good sense of the linguistic elements and other nuances that I required the transcriber to capture. In our initial meeting, I outlined how I required her to interpret the instruction of producing a verbatim transcript. Once the transcriptions were completed, I then carefully went through each interview transcript listening to the recording to ensure that I had a good set of data – correcting the transcripts where necessary.

4.5.2 Analysis

The approach used for the analysis of the data was described in full in Section 3.4 *Phenomenographic data analysis*. The process I used for constituting the categories of description that make up the results of this thesis follows the approach presented in Section 3.4.3 *Constituting an outcome space*. In Section 3.4.3, I referred to 'structural themes' as providing structure to the categories of description without going into any specific detail on just what these 'structural themes' are or how they are constituted. In this section, I provide this detail.

The process of constituting 'structural themes' follows a format that Åkerlind (2003) developed for analysing phenomenographic data. In her format, she uses what she refers to as 'themes of expanding awareness' (p.89) to highlight the structural relationships between the different dimensions of variation. I drew heavily on her example, but placed slightly greater emphasis in my analysis on the structure of these themes and their relationship to the categories of description; hence the use of the phrase 'structural themes' to describe my focus. Åkerlind's format is comprehensively described as follows:

The initial search for dimensions of variation focused on identifying different aspects of the phenomenon that were referred to in some transcripts but not in others, in particular any themes of expanding awareness that occurred across transcripts and seemed to distinguish them. In this way, dimensions of variation that appeared critical in distinguishing between transcripts and between emerging categories of description started to be tentatively identified. At the same time, I looked to see whether these tentative dimensions of variation could be systematically grouped into themes that ran through *all* of the transcripts, or at least through all of the groupings of transcripts (the groupings represented tentative categories of description). The consistent occurrence of a theme through all transcripts or categories was used as one criterion for identifying variation that appeared critical to distinguishing qualitatively different ways of experiencing. This criterion was also seen as important in ensuring useful outcomes, in terms of providing insight into what would be required to facilitate the transition from one way of experiencing to another. In this way, themes of expanding awareness emerged, consisting of groupings of logically related dimensions of variation, in which each level of awareness within the theme comprised a new dimension of variation. These themes were constituted from a second order perspective, in the same way as the dimensions of variation of which they are comprised. In this way, the themes of expanding awareness could be regarded as also constituting dimensions of variation in awareness, but of a more complex nature than is usually referred to by that term. (Åkerlind, 2003, p.89-90 – emphasis in original)

The important issue here is that structural themes point to those key aspects that helped delineate the different categories. The constitution of structural themes gave structure to the categories, both in terms of the internal structure and the structural relationship between them. These themes emerged through an iterative process that involved reading and rereading the quotes from the transcripts, looking for structure and order as the themes were constituted and reconstituted. As was the case for Åkerlind (2003), the final ordering of the constitutive elements of the structure was ‘based on both logical and empirical evidence’ (p.91).

4.6 Ensuring the trustworthiness of results

In Chapter 3, the importance of having a credible and dependable research process was discussed in detail. This section highlights some of the more pertinent aspects of the process I adopted to ensure rigour in this thesis. The notion of credibility in a phenomenographic study is something that must be considered throughout an investigation and following Booth (1992), content-related credibility, credibility of method, and communicative credibility were for me central tenets in this regard. Ensuring the dependability of the work in this thesis was important as it allowed for consistency of data

interpretation and thus consistency in the research findings. I will discuss dependability as a function of the interview conversations and the accuracy of transcription.

Content-related credibility

Content-related credibility relates to a researcher having a comprehensive grasp or understanding of topics related to the phenomenon under investigation. In this regard, I am a registered professional mechanical engineer and as such have at least a reasonable understanding of the nature of technology and what it means to be technologically literate. Booth (1992) has argued that it is important that this understanding be an open understanding as the 'researcher has to be open for ways of understanding it [the subject matter] which differ from those generally accepted' (p.66). In my very early pilot interviews, I recognise that I did bring some preconceived notions of what technology was into the analysis of the data I collected. In developing the interview strategy, I learned to appreciate the need to 'bracket' my ideas so that the results were not influenced by my bias. Being fully conscious of the need to suspend my understanding of technology became a central feature of how I conducted the study from that point forward.

Credibility of method

Credibility of method 'lies in the match between the goals of the study and its design and execution' (Booth, 1992, p.66). I argue that credibility of this nature was ensured in this investigation through careful consideration being given to study participant composition, critical attention being given to the context in which the interview took place, by focussing on the structure and content of the interview, and finally through a careful analysis of the data. These aspects are now discussed in turn.

Through careful piloting and selection of pupils, I managed to ensure a final group of participants who would ensure maximum variation in the range of ways in which technology could be conceived as well as how interacting with technological artefacts could be experienced. I did not focus on ensuring a statistically representative group of study participants by race or gender, but rather purposefully selected pupils across socio-economic backgrounds as described earlier in this chapter. There is always the possibility that I did not capture the *full extent* of the range of ways that these phenomena *could be* experienced, but I am confident that I did constitute a set of categories of description that

fully describe the range of ways that this sample of pupils experience the phenomena. For this reason, it is even more important that the purposeful sampling be appropriate in relation to the object of research.

An important aspect of this investigation was to facilitate a shared experience by pupils of the phenomena to ensure that as far as possible a joint definition of what was being talked about in the interview situation could be achieved. In the case of pupils' conceptions of technology, this shared context was facilitated using photographs and in the case of pupils' experiences of interacting with technological artefacts, a structured activity was developed. Both of these techniques were extensively piloted and proved sound in providing a shared context on which to locate the interview conversation.

The nature of the phenomenographic interview is such that, typically, only a limited number of questions are predetermined. As the key questions that made up the basis for the interview conversation were presented earlier in this chapter, and the structure and content of the interviews are richly reported on in Chapter 5, it is possible for the research community to determine the completeness of the data collected. Moreover, representative transcripts of the interviews are presented in the appendices to allow an independent analysis to be made of the nature of the data collected. In the interview conversation, I also attempted to ensure that the possible power relationship that could have existed between the pupils and me was mitigated as far as possible. At the most basic level, I tried to constitute as relaxed an interview environment as possible, to the extent that I spent the first few minutes of a session sharing pastries and soda and establishing a rapport with the pupils. However, the most significant factor in this process was the use of photographs, taken *by* the pupils themselves, early in the interview conversation. As I suggested earlier in this chapter, the consequence of this was that the pupils did not feel as if they were being interrogated during the interview, but rather that they were taking the lead and guiding me through the content of the pictures in terms of their conceptions of technology.

Communicative credibility

Communicative credibility is the requirement for me to be able to argue persuasively for the interpretation of the data I have presented in this thesis. It relates directly to the ability to present the results and conclusions of this investigation to the research community in an open way that allows the thesis as a whole to be scrutinised. The primary way I did this

was through the discussion of my results with research colleagues and the presentation of the study as it developed at a number of fora including seminars, two local conferences and two international conferences. At these events, my research approach and my preliminary categories of description were subjected to rigorous scrutiny and debate. The discussion and feedback gathered from these events was integrated into the analysis as it was developing.

Dependability as a function of the interview conversation

The first step in ensuring dependability of the data interpretation was to be critically conscious at all times of ensuring that the pupils were expressing how *they* had conceived technology and experienced interacting with technological artefacts. The primary concern here was to ensure that the questions asked during the interview conversation were not leading and were able to facilitate a rich discursive dialogue to take place. This was particularly difficult in this investigation because the pupils were all adolescents who rarely elaborated on a simple answer without careful follow-up questioning. This is unlike adults who, through careful questioning, often display the confidence to talk at length in response to a question. Clearly, there is the potential here for leading questions to be introduced in the quest to draw the pupils into talking about their experiences of the phenomena. Extensive piloting and lengthy discussions over the resultant transcripts with my supervisors and fellow research colleagues ensured that the questions (presented earlier in this chapter) used in the interview conversation captured data that was in fact the experience of the phenomena through the eyes of the pupils. The data captured is thus well grounded in the pupils' conceptions of technology and experience of interacting with technological artefacts.

Dependability as a function of accuracy of transcription

To ensure dependability of transcripts it is important that the data collected during the interview conversation be transcribed as accurately as possible. I described in detail earlier in this chapter how I went about this.

4.7 Concluding remarks

This chapter has described the methods I employed in all aspects of this investigation to ensure that the data collected and analysis was robust and directly related to pupils reflecting on their conceptions of technology as well as how they experience interacting with technological artefacts. I developed a means whereby photographs and a structured activity could be used to ensure a shared and meaningful experience by pupils of the phenomena under investigation. Issues relating to how I selected my sample participants were addressed followed by the data collection strategy I used. I concluded the chapter by presenting some of the more important steps I took to ensure the trustworthiness of the results of this thesis. In Chapter 5, I present the results of the phenomenographic analysis of the data collected using the methods developed in this chapter.

Chapter 5

Results

5.1 Introduction

Chapter 4 developed the compound methods employed in this investigation to facilitate pupils' reflections on their conceptions of technology as well as how they experience interacting with technological artefacts – the research questions developed in Chapter 1. Chapter 5 presents the results of the two phenomenographic analyses of the data collected using these methods. The chapter begins by illustrating the outcome space for each set of results in tabular form. The full outcomes of each of the analyses are thereafter presented in detail.

The details included in the presentation of the results are as follows: In each case, the qualitatively different ways of experiencing the phenomenon are described by the presentation of a number of categories of description. In phenomenographic terms, these categories denote the referential (or meaning) aspect of the outcome space constituted by the results. Thereafter, the structural themes that run through, and help constitute the categories, are described. These themes define the structural relationship between the categories, and hence the structure of the outcome space, by elucidating the similarities and differences within and between the categories.

5.2 Summary of the two outcome spaces

Table 7 describes the outcome space for the ways pupils conceive technology and Table 8 the outcome space for how pupils experience interacting with technological artefacts. The tables each consist of four columns. In the first column are representative symbols, each denoting a qualitatively unique way of conceiving or experiencing the respective phenomenon; each symbol represents a category of description (COD). The meaning (or referential) aspect of each of these categories of description is shown in the second column. The third column contains a summary description of the focus of the category itself, while the final column draws on the structural themes developed in the analysis to describe the structure of each category of description. The rows in the table are

hierarchically related with each successive row showing an increasing complexity in the ways of conceiving or experiencing the respective phenomenon.

Table 7 – Outcome space of the ways pupils conceive technology

COD	Meaning	Focus	Structure
A	Technology is conceived of as an artefact	Technology is described in terms of being some physical, tactile thing. It is characterised as involving artefacts that have particular qualities or features.	Artefacts simply exist and people are absent from this conception of technology. The purpose of technology is taken for granted and is not focussed on and neither is the impact of technology focussed on. The character of technology relates to the properties and qualities of artefacts.
B	Technology is conceived of as the application of artefacts	The use of artefacts for a purpose is central and is the application of an artefact to have something happen. Artefacts are seen as 'active' as opposed to a passive focus on nature of qualities and characteristics of artefacts.	People are present, but in the form of the individual, the user of technology. Technology has a function and typically, an artefact is dependant on this function for its existence. The impact of technology is on an individual as a result of the utilisation of an artefact. The character of technology relates to the properties and qualities of artefacts.
C	Technology is conceived of as the process of artefact progression	Artefacts evolve (or progress) through a process; a series of actions, changes, or functions that bring about a result. There is no focus on how or by whom these artefacts evolve, simply that they do.	There is the realisation that technology can be done (though it is not defined by whom), but the focus is still on the individual as a user of technology. The improvement of the function of technology, typically through a process, is central. Even though the nature of an artefact may be changing, the utilisation of an artefact is important.
D	Technology is conceived of as using knowledge and skill to develop artefacts	The process of evolution or development of artefacts takes place by people using their knowledge and skills. These people have a plan and there is a purpose for what they are doing. There is an 'active' process of artefact change with a focus on an interrelationship between form and function and the process people used to get the artefact to its present condition.	The individual as simply a user of technology is no longer in focus, but rather that people are developers or evolvers of technology. There is the realisation that they (the pupils and others) are all 'technologists'. The idea of function is still fundamental to technology's purpose, but it is now the improvement of this function (via a plan) that is central. The impact of technology is the improved function and utilisation of an artefact.
E	Technology is conceived of as the solution to a problem	Technology is the solution to a problem faced by humans in their lives. Focus is no longer specifically on an artefact at all. The solution can be in the form of an artefact, but is not necessarily so.	Technologists do more than develop or evolve artefacts. They solve problems as the fundamental embodiment of technology. There is a shift from the idea of function to the purpose of technology being to solve a problem. There is a switch from the impact of technology relating to artefact utilisation and function to issues relating to quality of life. The impact of technology is directed to the notion of improving one's quality of life.

Table 8 – Outcome space of the way pupils experience interacting with technological artefacts

COD	Meaning	Focus	Structure
I	Interaction with a technological artefact is through direction	Interaction with a technological artefact is as the result of a directive by someone and is not something that happens spontaneously. There is reluctance to make a first move toward approaching an artefact. Pupils are on the outside looking in towards an artefact as a reified object.	Interaction with a technological artefact takes place in a formalised context where pupils are required to respond to the directions of an authority. There is no use of prior experience and there is no recognised purpose derived from this interaction other than making the artefact work within a specific framework as required by the authority figure. The interaction is characterised by their level of detachment from this interaction. Pupils experience no ownership in their interaction as it is something that they are directed to do for a particular reason. If they had a choice, they would not be interacting with it, as there is a fear of access. Specific directives from an authority figure are required for pupils to overcome their fear of the artefact.
II	Interaction with a technological artefact is through instruction	Fear of entry no longer inhibits interacting with a technological artefact and the interaction can be self-motivated. The primary focus is having instruction enable the use of the artefact.	Interaction is not formalised but takes place within a restricted context of specific actions. There is still no use of prior experience. However, it is recognised that it is possible to have the artefact perform a required function and there is recognition of a right of access to interact with the artefact. This interaction is instruction-mediated by some means and is only at the minimum level necessary to perform a specific function. Instruction of some kind is required to direct the activities.
III	Interaction with a technological artefact is through tinkering	Pupils self-initiate an interaction with a technological artefact by beginning to tinker with it. They have no need of instruction to enable them to begin this interaction. There is no sense of being intimidated by anything to do with an artefact.	Interaction takes place in the context of self-initiated free enquiry with prior experience being drawn from to inform the interaction with the technological artefact. Prior experience is used to self-initiate undirected interaction with an artefact. It is recognised that an artefact has a variety of functions and pupils set out to determine what they are and make the artefact operate. Pupils are aware of the potential of the artefact and experience full rights to access the artefact; however, there is not yet a sense of ownership of the interaction. The interaction is a physical, tactile action focussed around the artefact.
IV	Interaction with a technological artefact is through engaging	The method of interaction is something that is reflected upon and takes place through an engagement with a technological artefact. The barriers to entry into the space of an artefact are now absent and the pupils are creating their own contexts and frameworks within which to work.	Interaction takes place in the context of self-initiated free enquiry with prior experience being drawn from, and supplemented as required, to inform the interaction with a technological artefact. The purpose is to understand both how to use an artefact and the function of that artefact. It is a conscious process of investigation into all aspects of the artefact. Pupils experience full ownership in their interaction with the artefact and they interact completely with it within their own defined context. There is a cognitive and physical aspect to the interaction which provides for genuine engagement with the artefact.

5.3 Variation in how pupils conceive technology

This section presents the results of the empirical study that focuses on the first research question, pupils' conceptions of technology.

The outcome space constituted from the data consists of five qualitatively different categories of description. These categories form a logical hierarchy of increasing complexity (from A to E) in the way pupils conceive technology. The categories are described in full in the following section. Thereafter, the structural relationships between the categories of description are presented in terms of the structural themes that run through the categories.

5.3.1 Categories of description

In this section, the characteristics of each category are described in detail. The categories have been given names that reflect the meaning central to each category. Extracts from interview transcripts are used to illustrate aspects of each category. For each extract used, questions asked by the interviewer are shown in bold and the responses by the pupils are in regular font. In the responses, what I consider key phrases are italicised. As typical in a phenomenographic study, illustrative extracts cannot encapsulate the whole of a category, but rather can only illustrate critical aspects of a category.

Category A: Technology as an artefact (TAA)

In this category, technology is described in terms of being some physical, tactile thing. It is characterised as involving artefacts that have particular qualities or features. Examples of these would be bolts and screws in a security gate; cords, wires and plugs on appliances; artefacts being remote controlled; etc.

The focus on the qualities of an artefact as constituting technology is evident in the following extract. Here an artefact is conceived of as technology because of the fact that there are many wires and cords attached to it:

My overhead projector. It's the same thing. There were lots of cords and wires and it's especially, you can see all the wires, which made me think technology straight away when I saw it.

This idea of technology as an artefact is extended by the notion that technology is the sum of constituent parts. For example:

The door is technology.

What makes the door technology?

You need levers on the side, in order for it to stand, open and close and you need a handle on the door to close it and lock it.

This is further illustrated by the following extract where the removal of some of these constituent parts from the artefact results in an artefact that is no longer conceived of as technology:

So if you had to take out the motor, out of the washing machine and [take] out the wire and toss it on a scrap heap, will it still be technology?

... No, not technology, it will just be a box, just a box.

Linked to this idea of technology being conceived of as an artefact is a focus on technology being technology by virtue of the level of complexity it has. For example:

How would I describe it? Well, it's a bit complicated, firstly. It's *very technological*. It's exactly what I was talking about, what I said *complicated wires* and *things that you don't understand*, it looked like technology.

Category B: Technology as the application of artefacts (TEA)

While the emphasis of this category remains on artefacts, the central focus is on the *use* of those artefacts for a purpose. This *use* of technology is the 'consumption' of technology to *achieve* something or, put another way, the application of an artefact to have something happen. In a sense, artefacts are now seen as 'active' as opposed to the passive nature of Category A that was dominated by the qualities and characteristics of artefacts.

In this category, the fact that an artefact is used for a purpose is important. Technology has a function and typically, an artefact is dependant on this function for its existence. The following extract is in response to a question about why a door lock is technology. As in Category A, the character of technology relates to the properties and qualities of artefacts, but now there is an associated action:

The gears, the way it works for instance you turn the key it's just not turning the key you are putting levers together. You are making it move.

A further example of the use of artefacts as central to this category is seen in the following extract where the idea of the application of an artefact for the purpose of facilitating something else is presented:

A lot of these photographs are photographs of stuff which *needed technology to get to it*. ... [T]o get what we have and there must have been a huge amount of *technology used to make this* completely accurate map.

Another illustration of how this category centres on the use of artefacts is shown in the following two extracts. The artefacts are used for the purpose of doing something or achieving something. The extract also illustrates how, typical of this category, people are present, but in the form of the individual, the user of technology. For example:

[P]utting the actual music on the CD and like just putting the CD into a computer and just closing and then *copying music onto it*, to me *that's technology* because you put it into a computer and it copies music onto that disk.

[T]here's a lot of *technology used in TV production* like I've done TV production and I know like the stuff which is there, very expensive for one and like the most, it is the most smallest thing that is [inaudible] stuff, so it's like the products here, like you may see TV like this, but *you forget about the cameras, the lighting, the mikes that were used*.

Building on the idea of artefact use with a purpose, the idea of this being, in essence, the facilitation of an interrelationship between artefacts is illustrated below:

If the engine works and it makes the other parts of the motorbike work as well.

An artefact is not considered technology unless it is in operation (or use). This use results in an impact on the individual. This is clearly illustrated in the following two extracts:

If [the amplifier] was *just sitting there*, I think to me, *when it's actually switched on then that's technology*, because if it's something digital or something like that you switch it on, it says like power on or loading or something to that effect then that to me would be technology.

If the hi-fi is not plugged into the wall, is the hi-fi technology?

If it's not plugged into the electricity?

Ja, if there's no electricity and it's just sitting there with no electricity is it still technology?

Oooh, no, ja it is, cause *you can use the batteries*.

And if it's got no batteries in it.

It's being helped by the electricity cause it can't...

So if there's no batteries and no electricity and anything in that hi-fi...

Because *you can't hear anything*.

Ja, so if you can't hear anything is it still technology?

No.

Category C: Technology as the process of artefact progression (TAP)

The first two categories of technology had technology as an artefact and the use of that artefact as figural. The critical difference between Categories A and B on the one hand and C, D and E on the other is that in the latter, technology is something that occurs or happens. In Category C, artefacts evolve (or progress) through a process, where *process* is taken to mean a series of actions, changes, or functions that bring about a result (Ilson, 1987). This category is distinct from Category D in that in Category C, there is no focus on *how* or *by whom* these artefacts evolve, simply that they do.

A typical example of the critical aspects of this category is shown in the extract below. The focus is still clearly on an artefact, and the use of that artefact, but now there is an additional aspect that this artefact has progressed over time. Even though the nature of the artefact itself may be changing, focus is still on the use of the artefact. The extract below is in response to a discussion about the result of an artefact (in this case an oil-can spray) ceasing to be useful:

[F]or it to be where I think technology should be, it should have the *ability to progress and carry on* moving, so this, it's, if its *function is met*, other than just applying oil, that's fine, but if, if it was something that had the ability to move on, [and] it wasn't, then I think that's bad in terms of, that's not where I think technology should be, but here, it's okay, because it's *still performing its function* and *people still use it, even though it's old*.

Another key aspect of this category is illustrated in the following extract. This is the idea that the evolution of an artefact is to perform a function that has the consequence of helping *that* individual (rather than *an* individual) in their life. The following extract follows from a question about why the pupil took a photograph of a lamp as a photograph of 'technology in their lives':

Because, to me, it's something that it *started off very simple*, like just a light bulb and you switched the light bulb on but it is like something that has been put into like *something that has advanced over the ages* and you can carry it everywhere with you, it's something that *makes life easier for you* and for example there is a black out and you just switch this lamp on and there's like light.

The technological process as shown below is part of the progression of artefacts. It is just the fact that there *is* a process that exists that is focussed upon, not any more details on the nature of the process. For example:

With this photo I thought, running shoes, spikes, how much *the tech process, it had to go through* a lot *before it came out like this* so, I had to take a picture of it, because if you just look at it, it supports you full and it has spikes in front for more lift and stuff so it had to be something of technology.

Technology is not conceived of as only the progression of a single artefact, but also the progression of a system along with improvement of its function. In the extract below, this is evident in the discussion of the progression of a system of transport:

I think it's those things *they help make the car work* and *you use that in everyday*, and you just think it's technology and *they made it*, before *you used to use a horse and a cart* and now with a car you just put the thing in and you start and it will work.

Category D: Technology as using knowledge and skill to develop artefacts (TKS)

Both Category C and D have in the foreground an emphasis on the evolution or development of artefacts. In Category C, this process is undefined whereas in Category D it takes place by *people* using their knowledge and skills. These people have a *plan* and there is a *purpose* for what they are doing. Category C can be interpreted as a 'passive' and Category D as an 'active' process of artefact change where there is now focus on an interrelationship between form and function and the process people used to get the artefact to its present condition. The essence here is *design for purpose*.

In this category, the focus shifts from being related to the artefact itself (as it was in Categories A, B and C) to the process of developing an artefact. The following extract is in response to a question about why a photograph of a computer as technology was included:

[P]eople had to like test to see how it worked and like *went through a process* in order to like get to what they had over there, I think that *technology is basically a process*. You must have an *idea* and then *your planning and your research* and the *making of it* and then the evaluation.

However, it is more than simply the development or evolution of an artefact that is important, it is the fact that a person used knowledge and skill to do so. It is this 'human factor' in the development of the technological artefact that distinguishes this category from Category C. The individual as simply a user of technology is no longer in focus, but

rather that people are developers or evolvers of technology. There is the realisation that they (the pupils and others) are all ‘technologists’. The following extract further illustrates this point. In this extract, the use of the term ‘you’ is not personal but refers rather to people in a generic sense:

[I]t’s just that as time went by *things got a bit smaller* and that’s to do with like the *technological process of making things more, improving them*.

This technological process, what’s that?

It’s like, how can I say, it’s like, *this idea that you put into place*, say for example you have this *idea of making something and you put this idea onto paper and you like go through the steps of like making it*, like you have like your plan of how to do it, *and how the actual making takes place* and your evaluation of it, like *your results, your testing after*, whatever, that’s what I’m saying.

Another illustration of this point is:

The *television*, I thought that to me it’s technology because it’s *something scientific, like a plan that has been put into practice and they made it like that*, so, if they had a plan to like make a TV, they had a plan, like a *scientific plan and they made it in that way*, and it’s basically with electronics and a remote control so that’s why.

This process of development still has the improved function and utilisation of an artefact central to the conception of technology. In Categories A and B, the effect of technology was not considered. In Category C, the effect of technology was focussed on in the context of it being useful to the individual. In this category, the effect of technology is to make that individual’s life easier. For example:

My phone and my cell phone.

What were you thinking about technology when you took that [photograph]?

Well it’s got like *scientific knowledge to make it, someone sat around making* little circuit boards and stuff and connecting up all the networks up in South Africa *to make life easier*.

The idea of technology as being a process to develop an artefact that affects one’s life is further illustrated in the following extract:

Ja, and to go *through a process* I mean *the people couldn’t just come and start making the bin, like that they had to like think about how they were going to distribute it and how easy*, I mean if you start something like this, firstly, obviously they thought about a container with a lid and then they obviously like added the wheels like how can I say, an extra, *makes your life easy* instead of having to lift the thing up and walk outside.

Category E: Technology as the solution to a problem (TSP)

In Categories A to D, the artefact *per se* was progressively moving further away from being central to the conception of technology. In Category E, focus is not specifically on an artefact at all, but rather on technology being the solution to a problem faced by humans in their lives. This solution can be in the form of an artefact, but is not necessarily so.

Central to this category is the idea that it is no longer the development of an artefact and the use of this artefact to do something, but rather the recognition of a problem and the solution to that problem. For example:

Someone had a problem and so they made this solution to get from A to B, and they built a road, or wheel or a boat and these are just sort of modern advancements on the old ways.

This solution to a problem involves humans (technologists) using their knowledge and skill as shown in the quotation below:

People solving problems by making use of knowledge that they have about something which they intend to use to solve the problem.

Tell me more about it?

It's usually quite scientific, uses some sort of scientific background or knowledge to solve the problem.

This category is further illustrated in the following quotation where focus is on the design of the solution to a problem which directly impacts on quality of life:

'Ja', it helped, you know, before we had to use candles once again and then obviously, someone thought about this and they designed it and they made it and they helped solve a problem, which is what technology does, or they improve something, 'ja'.

5.3.2 Structural relationships between the categories of description

The categories of description constituted above represent the qualitatively different ways pupils conceive technology and the relationship between them determines the 'structure' of the experience (Marton & Booth, 1997, p.133). This structure is characterised by themes that run through the categories that serve to both qualitatively link and differentiate the categories. A full discussion on how these structural themes developed was presented in the previous chapter. The structural themes for this analysis are summarised in Table 9 and described below.

Table 9 – The relationship between the CODs and the structural themes

COD Structural themes	Technology is conceived of as				
	an artefact	the application of artefacts	the process of artefact change	using knowledge and skill to develop artefacts	the solution to a problem
Role of people	<i>people absent</i>	<i>individual user</i>	<i>individual user</i>	<i>developers</i>	<i>problem solvers</i>
Purpose of technology	<i>taken for granted</i>	<i>function</i>	<i>improvement of function</i>	<i>improvement of function</i>	<i>problem solving</i>
Impact of technology	<i>none</i>	<i>result of utilisation</i>	<i>result of utilisation</i>	<i>improved utilisation</i>	<i>quality of life</i>
Character of technology	<i>properties and qualities</i>	<i>properties and qualities</i>	<i>process</i>	<i>plan</i>	<i>idea</i>

The role of people

The role of people is a critical aspect delineating the categories. In Category A, people are absent from the pupils' focus. Artefacts simply exist. In Category B however, people are present, but in the form of the individual, the user of technology. Even though in Category C there is the realisation that technology can be *done* (though it is not defined by whom), the focus is still on the individual as a user of technology. In Category D, the individual as simply a user of technology is no longer in focus, but rather that people are developers or evolvers of technology. There is also the realisation that they (the pupils and others) are all 'technologists'. Finally, Category E shifts to where 'technologists' do more than develop or evolve artefacts: they solve problems as the fundamental embodiment of technology.

The purpose of technology

In Category A, the purpose of technology is taken for granted and not focussed on. In Category B, technology has a function and typically, an artefact is dependant on this function for its existence. Although Categories C and D still associate the idea of function with technology's purpose, it is now the improvement of this function that is central. With Category E, there is a shift from the idea of the purpose of technology being a function to being the solution to a problem.

The impact of technology

In Category A, the impact of technology is simply not focussed on. In Category B, the impact is on an individual as a result of the utilisation of an artefact. Category C also relates to artefact utilisation, irrespective of the fact that the nature of the artefact itself may be changing. In Category D, the impact is now the improved function and utilisation of an artefact to make an individual's life easier. Finally, with Category E, there is a switch from the impact of technology being related to artefact utilisation and function to issues relating to quality of life where the impact of technology is directed towards the notion of improving a person's quality of life.

The character of technology

In Categories A and B, the character of technology relates to the properties and qualities of artefacts. Category C has the character of technology as a process while in Category D, it is a plan. In Category E, the character of technology is an idea.

5.4 Variation in how pupils experience interacting with technological artefacts

This section presents the results of the empirical study that focussed on the second research question, pupils' experiences of interacting with technological artefacts.

The outcome space constituted from the data consists of four qualitatively different categories of description. These categories form a logical hierarchy of increasing complexity (from I to IV) in the way pupils experience interacting with technological artefacts. The categories are described in full in the following section. Thereafter, the structural relationships between the categories of description are presented.

5.4.1 Categories of description

The format of presentation of the categories of description of these results is similar to the first set of results shown earlier in this chapter. As before, in this section, the characteristics of each category are described in detail and the categories are given names that reflect the meaning central to each. The presentation of extracts follows the format

used previously. Once again, the illustrative extracts cannot encapsulate the whole of a category, but rather can only serve to illustrate critical aspects of a category.

Category I: Interaction with a technological artefact is through direction (ITD)

In this category, pupils experience interaction with a technological artefact as the result of a directive by someone. It is not something that happens spontaneously as there is a reluctance to making a first move toward approaching it. This category describes the experience as being on the outside looking in towards a technological artefact as a reified object; the artefact is placed on a 'pedestal' in an exalted, unapproachable position.

Pupils experience no ownership in their interaction with a technological artefact and this is characterised by their level of detachment from the interaction. The interaction is something that they are directed to do by an authority figure for a particular reason. If they had a choice they would not be interacting with it as there is a fear of initiating this interaction. They only want to do what they are told and nothing more and this is achieved by following directions exactly. The following extract illustrates this point. It was important not to 'mess up' by getting what was expected wrong. There is also the sense that having it 'go wrong' is not a recoverable incident and that one error leads to a catastrophe. In the following extract, the authority figure (in this case the interviewer) has 'directed' the adolescent to follow a tutorial:

Did you try anything different that wasn't in [the tutorial]?

No in case I messed up, oh no, thank you.

Tell me about messing it up, is that something you worry about when you work with technology?

Sometimes yes.

Why?

[B]ecause just now I mess up and the whole thing is broken again and then, no, it's fine, I don't want to mess it up cause if I press one thing and it's wrong and then the whole thing somer [just] goes wrong.

Pupils also need 'permission' from the authority figure to take even the first step towards a technological artefact. The following extract relates an experience with a computer. The first response to a question about how to approach a technological artefact is the stated need for 'permission' before it is even handled. The immediate assumption in response to the incident described was that they were in the wrong. That there was a computer virus

was also taken to be their fault. In this case, any interaction endangers the continued functionality of a technological artefact. Specific directives are thus required for pupils to overcome their reluctance to interact with an artefact:

[A]nd if you had to find one of these things in your classroom, or something like that, how would you go about finding out how to use this thing, or work it?

I'd probably ask someone before I touched it.

And why is that?

Because, I mean, it's got a heater and it's hot and, so I'm just, I wouldn't want to break it, because I promise you, I'm really, *I busted our computer the other day*. I didn't know what I, *I clicked something wrong* and there was a virus and that kind of thing, so I just wouldn't want to endanger whatever it was.

The description above illustrates how concern emerges about causing damage through incorrect interaction with an artefact. Typically, the interaction takes place in a formalised context where pupils are required to respond to the directions of an authority. There is no use of prior experience by the adolescent. The following extract illustrates how preference is given to observing rather than taking part in any interaction. The major concern expressed was that they could get what was required by the authority incorrect. This was greater than the desire to try doing it and acted as a significant barrier to entry to the activity:

We did it in grade nine, we did a circuit thing but, I didn't do it.

Why not?

Cause I didn't know how.

Okay, were you told you had to do it?

Yes, but I worked with somebody else so, they did all the stuff, *I just sat there and watched*.

There is a distinct concern about undirected interaction with an artefact as there is no recognised purpose derived from this interaction other than making the artefact work as required by the authority figure. The following extract illustrates that even when given free licence to explore an artefact as they saw fit, the fear of possibly making a mistake – not necessarily as severe as breaking or destroying it – created a considerable hurdle to interaction:

No, not really. Well, there were, [the worksheet] gave *things like now you can do this and do what you want with this*. I didn't explore too much.

And why is that?

Because I might do something wrong.

Category II: Interaction with a technological artefact is through instruction (ITI)

In this category, the reluctance to interact associated with Category I no longer prevents pupils interacting with technological artefacts. The interaction is now no longer driven by a directive but is self-motivated. The primary focus of this category is having instruction via some means enable the interaction with an artefact.

This category carries recognition of an instruction-mediated access to interact with an artefact. In the following extract, mediation is by instruction as provided by a manual of some kind. The use of the technological artefact is possible only after, in this case, the instruction book has been read. As in Category I, the 'interaction hurdle' is still clearly present. Not using the item correctly could result in the possibility of 'messing it up', but the instructions facilitate a mediated entry to the technological artefact:

Read the instruction booklet. Because, 'ja', I don't really like figuring things out myself. I'm sure I could actually mess it up and do something wrong.

Instruction of some kind is required to direct the activity of pupils. The instruction received need not be only in written format, but could be from a variety of sources including oral instruction from an adult. For example, the following extract illustrates how a father has previously given instruction on how to use various artefacts. These artefacts will continue to be used within the context of this instruction. The key here is that the artefacts are used within these parameters to facilitate entry:

Is there anything else you can think of that's like the cell phone that you don't need to work with?

A CD player.

Okay so you also happy to fiddle with that?

I'll fiddle on that.

Why is that?

Ummm, because I don't know, its just easy to use for me and there *is no funny buttons*. You press and then, maybe the hi-tech stuff that my Dad has, one of those big speakers and stuff like that, now I won't fiddle on his stuff. But I know how to use the amp and *he showed me how*, so, want to make the bass [inaudible] I'll fiddle on there; I know how to use it. That I will do *but I won't fiddle with anything else*.

Unlike Category I, this category carries a recognition that it is possible to have the technological artefact perform a required function. In addition, the interaction is no longer

formalised but takes place in a restricted context of specific actions and there is no reference to using prior experience.

In Category I, an artefact would only be used in terms of a directive. In this category, interaction will be personally initiated but this will be in the context of following instructions. Interaction will only be as much as is necessary to perform a specific function. The next extract illustrates the importance of instruction:

[I]f you had to get a new video recorder for example, how would you work out how to use that?

The book.

The book?

Yes, the *manual must* come with it.

Okay, you don't just want to go and fiddle?

No, I don't. I get into trouble for fiddling.

You get into trouble for fiddling?

Yes, if I mess it up.

Category III: Interaction with a technological artefact is through tinkering (ITT)

This category is characterised by a self-initiating interaction with a technological artefact by beginning to tinker with it. Unlike the previous categories, there is no need for instruction to enable this interaction. There is no sense of being intimidated by anything to do with the artefact.

The two extracts below illustrate the idea that self-initiated tinkering takes place. They recognise that an artefact has a variety of functions and set out to determine what they are and make the artefact operate. This tinkering starts in a constrained way and gradually expands to encompass the entire artefact. Although full rights to access the artefact are recognised, there is not an accompanying sense of ownership of the interaction. The description below also shows how Category III is qualitatively different from the previous categories with respect to the concern shown of getting something wrong while interacting with a technological artefact. There has been a shift to where getting something wrong is simply a consequence of tinkering. There is no judgement on the ability to get it right or wrong. Tinkering is personally motivated:

If you had to get a new cell phone, how would you know how to use that, [be]cause it comes with a nice thick set of instructions, do you read the instructions?

No, no, I like finding things, *finding out things on my own so I wouldn't read it.*

You aren't worried about something going wrong?

Well I would be, *I've already broken two cell phones*, blocked them, but ja, no *I'm not actually worried* about anything.

So when you come across some, some new technology, how do you work with it, what do you do with it?

Like slowly, but surely, like I start playing with it, like I sat playing around with it, until I can, I master it.

Playing around with it, what do you mean?

It depends what it is.

Do you play around with it in order, or do you just play around with it and see what happens?

No, I play around in order like, I don't do, whenever I mess around with something, I don't do like big stuff at once. I will do a small thing, then it's like okay, you can do that with that and switch it on, you can switch it off like that, you can do that and then like the next time, I will probably see what can happen if I put that thing on standby.

I see you were connecting the cable to the different devices there and you're quite happy just to pull it out and plug it in?

'Ja', because I've, I've worked with IDE cables on PCs.

Okay, so you're happy with that? You're not worried about breaking it?

No, like I said, it's like you can't, you can't be perfect. At some stage, you will break something, so you might as well.

A characteristic of this category is the drawing on a prior experience to assist in the interaction with technology. The extract below shows how prior experience has been drawn on as the starting point for tinkering. The polarity of batteries is understood and is used as the first step to tinkering and the consequences of this tinkering are 'dealt with later':

Well, usually, you know, with, I'll look, if it's this kind of thing, then I'm really worried, this is like some *big kind of hectic circuit*, but if it's batteries and stuff, you know, *you just know positive to negative and negative to positive* and how sort of and *just kind of fiddle around* and, until I get it right.

So where does the, where does the fiddling around stop and then the worrying about what you're going to do to it, begin?

Well, you know, that, that *usually starts in the beginning. I kind of worry then, but I seem to deal with the consequences later.* Well, when it doesn't go on, like after, I'm pretty sure that it's right what I've been doing, then I start to worry.

A further illustration of taking prior experience and applying it to the current technological artefact is shown in the extract below:

[H]ow would you work with something that you hadn't come across before, that was based on this sort of [idea]?

Well, I would, I try and *remember what I did before* and then I know that one of them was the, you know, the cable that was connecting them and I'm trying to figure out what the number of that cable was, but basically, *it would have to be a trial and error thing.*

It is recognised that additional information is available if required. However, this is not sought as it is the tinkering with the technological artefact that is central to their activity. This is where pupils are now aware of the potential of the technological artefact. The interaction is a physical, tactile action focussed around the artefact. The extract below illustrates this aspect of Category III:

If you had, take your amp[lifier] for example, if you had to go and buy a new amp[lifier], how would you work out how it works?

Umm, the thing is this sort of technology and it's kind of got to the point where *it's got almost a universal language*, like the power button is quite obvious and *from there onwards it's just, it sort of follows a pattern* like everything that I've known in my life.

Okay what about the manual that comes with it?

I might look at it if I get stuck somewhere.

So as a rule, manuals are something that you look at when you get stuck?

Ja, as sort of a last resort I normally just go straight ahead.

Category IV: Interaction with a technological artefact is through engaging (ITE)

This category differs from the previous three in that the method of interaction is now something that is reflected upon and takes place through an engagement with the artefact. The kind of barriers to entry into the space of the technological artefact as typified by Categories I and II continue to be absent and the pupils are creating their own contexts and frameworks within which to work.

In this category, there is no indication that technological artefacts are something to be wary of. The objective of interacting with an artefact is to *understand* its use and thus a cognitive aspect has been added to the physical action associated with the previous category. This type of interaction provides for real engagement with the technological artefact. As in Category III, interaction takes place in the context of self-initiated free

enquiry. However, prior experience is drawn from and *supplemented as required* to inform the interaction. A variety of methods of doing this are available. In the extract below, it is a backwards and forwards process of engaging that is taking place. The manual referred to in the extract is not necessarily saying *how* to do something, but rather that a feature is available. Typical of this category is that if there is no additional information available then pupils will simply find out for themselves through a process of investigation:

So if you had to get a video recorder for example with a manual, how would you work out how to use a video recorder?

You would read the manual.

You read the manual, is that the first step?

You would read the manual and *you would look at the thing at the same time so as you read the manual they tell you something and you'll see okay it is there and try it out or if you didn't have the manual, you just as we say, 'pieter' [potter], until you find out.*

In the extract below, it is clearly shown that this interaction is not just about tinkering but rather engaging. Information is obtained about the artefact from a selection of sources and it is assessed as a whole to help determine what and how to do what needs to be done. Having this information as a framework is their choice. They are in control and this interaction is a personal experience. The purpose here is to understand both the function of, and how to use, an artefact. It is a conscious process of investigation into all aspects of the technological artefact:

When you get a new radio control car, do you take it apart straight away?

Not really, *I first like see how it works*, what, why did I buy it first of all, cause it can move and do stuff so *then I will find out, think, how would they, for instance how would they make a steering column* or how would they make the back wheels with front wheels move, how is that my couple of batteries in the back of the remote or in the car would give it enough or sufficient energy to go to do whatever it is supposed to and how long can it last.

Okay and how do you go about interacting with the car, how do you go about working with the car?

Working with the car, as in opening it?

Ja, if you want to know more about it, if you wanted to work with it, if you want to use it...

First of all I would see what I could do *without me opening it first, and then when I open it I will take it apart slowly so that I would remember how to put it back together* and then of course I then I will look where does the energy come from, where does the power come from and then how is it regulated in the car and how does it get spread or distributed to wherever it must go.

The extract below shows a further illustration of this method of engagement. Here, pupils experience ownership of the understanding of how it operates in their interaction with an artefact. They are interacting completely within their own defined context and there is a clear sense of achievement:

If you had to buy something that you consider technology, let's pick something [from one of your photographs] off the table here, if you had to get a new telephone, for example, how would you learn how to use the new fancy telephone?

I'd like, you will work around it, like play around with it and I know like I've messed up a lot of things, play around with them.

And you don't mind doing that?

No. *Because it's like the way you learn about it, because okay, manuals do help, but they're really boring, the way they're written, they are not interesting, they are not 'vibey', so it's like you're reading through this boring book. So it's like the best way to learn is practical.*

Okay and, and how does it feel when you actually get it right?

You're so *proud of yourself*, because then you like...

But what about if you need to read the manual then?

Okay, there are times to read it, but then at least when you read it, you're ready to know some of the stuff. It's unlike when you come and then they talk about stuff, it's like basic stuff that you don't know, 'cause you've only read through, it's like knowing theory is, some of it is theory, some of the practical stuff is better stuff than some of the theory.

5.4.2 Structural relationships between the categories of description

The relationship within and between the categories of description above determines the 'structure' of the experience of interacting with technological artefacts. As in the first analysis, this structure is characterised by themes that serve to both qualitatively link and differentiate the categories. The structural themes that were constituted in this analysis are described below and summarised in Table 10.

The context of the interaction

The context in which this interaction takes place is an important aspect differentiating the categories. In Category I, interaction takes place in a formalised context where pupils are required to respond to the directions of an authority. It is clear that there is no use of prior experience by pupils. In Category II, although there is no use made of prior experience, the interaction is no longer formalised but takes place in a restricted context of specific actions. By Category III, interaction takes place in the context of self-initiated free enquiry.

Prior experience is drawn from to inform the interaction with a technological artefact. As in Category III, interaction in Category IV still takes place in the context of self-initiated free enquiry. However, prior experience is also supplemented, as required, to inform the interaction with a technological artefact.

The purpose of the interaction

In Category I, there is no purpose derived from an interaction with a technological artefact other than making the artefact work within a specific framework as required by some authority figure through the completion of an instruction. This changes fairly significantly in Category II where pupils recognise that it is possible to have the artefact perform a required function. In Category III, pupils now recognise that an artefact has a variety of functions and they set out to determine what these are and make the artefact operate in some way. In the final category (IV), the purpose of the interaction becomes to understand how a technological artefact functions and its use in general.

Ownership of the interaction

In Category I, pupils experience no ownership in their interaction with technology. The interaction is something that they are directed to do for a particular reason. If they had a choice, they would not be interacting with it at all as there is a definite fear of accessing the technological artefact. Category II introduces the recognition in pupils of a right of access to interact with an artefact. This interaction is typically instruction-mediated by some means. By Category III, pupils experience full rights to access the artefact. However, there is not yet a sense of ownership of the interaction. Finally, in Category IV, pupils experience full ownership in their interaction with an artefact. They interact with the technological artefact in the manner which they choose to define.

The interface with the interaction

At the interface with a technological activity, Category I is characterised by the pupils' level of detachment from their interaction with the activity. By Category II, pupils are interacting with technological artefacts, albeit at a superficial level. Interaction is only at the minimum level necessary to perform a specific function. In Category III, pupils are now aware of the potential of the technological artefact. The interaction is a physical,

tactile action focussed around the technological artefact. Category IV is similar to Category III with the addition now of a cognitive aspect to the physical action. This type of interaction provides for genuine engagement with a technological artefact.

The process of interaction

In Category I, the process of interaction requires specific directives from an authority figure for pupils to overcome their fear of the technological artefact. In Category II, fear of interaction is no longer apparent, but instruction of some kind is required to direct the pupils' interaction. In Category III, prior experience is used to self-initiate undirected interaction with a technological artefact. Category IV is similar to Category III with the addition that interaction with the technological artefact takes place through conscious process of investigation into all aspects of the artefact.

Table 10 – The relationship between the CODs and the structural themes

COD Structural themes	Interaction with a technological artefact is through			
	Direction	Instruction	Tinkering	Engaging
Context	<i>Formalised</i>	<i>Restricted</i>	<i>Self-initiated</i>	<i>Self-initiated</i>
Purpose	<i>Complete an instruction</i>	<i>Perform a function</i>	<i>Determine functions</i>	<i>Understand functions</i>
Ownership	<i>None</i>	<i>Mediated access</i>	<i>Right of access</i>	<i>Full ownership</i>
Interface	<i>Detached</i>	<i>Superficial</i>	<i>Physical</i>	<i>Physical and cognitive</i>
Process	<i>Following directive</i>	<i>Directed</i>	<i>Through prior experience</i>	<i>Conscious investigation</i>

Chapter 6

An example illustrating the usefulness of the results

6.1 Introduction

The outcome of a phenomenographic analysis is a set of internally and logically related, qualitatively different, hierarchical categories of description. The results of the phenomenographic analyses undertaken to answer the research questions developed in Chapter 1 were presented in the previous chapter. Any further research work done using these categories of description falls outside of a phenomenographic study, although it is both perfectly reasonable and methodologically appropriate to use the categories of description in other studies.

The current chapter takes leave of the stated research objectives of this thesis and is a speculative illustration of how my categories of description can be utilized to underpin other studies that could further investigate issues relating to pupils' understanding of the nature of technology and their levels of technological literacy. As such, this chapter should not be seen as a core part of the knowledge contribution of the thesis, but rather as an exemplar pointing towards one of the *possible* future directions for research based on the results in this thesis.

The chapter describes the preliminary work undertaken on a questionnaire that could possibly be used to classify individuals in terms of their *conceptions of technology* as well how they *interact with technological artefacts* with the aim of determining their *technological profile*. The work presented in the chapter is not meant to be viewed as contributing a new research question. Rather, the Technological Profile Inventory (as the questionnaire is called) used to facilitate this classification process has been developed to the stage where it can now be exposed to rigorous, large-scale testing to confirm, amongst others, inter-item correlation.

The first stage in the development of the Technological Profile Inventory (or TPI) involved determining a number of questions, based on the previously constituted categories of description, which could be used in the classification process. Complementary to this process was the development of the structure of the TPI itself and here two alternatives

were considered. Once the structure of the two alternative questionnaires had been finalised, a selection of pupils from the original group of study participants was used to test its validity and reliability. The pilot study involved checking whether the TPIs gave results that matched those based on a reclassification of the original interviews in terms of the categories of description.

6.2 The nature of the questionnaire

The starting point in the development of the TPI was the categories of description described in the previous chapter. These are summarised below for ease of reference and alongside each category of description is a three-letter acronym to allow a shorthand style of referencing to be used throughout the remainder of this chapter.

A. Conceptions of technology

1. Technology as an artefact (TAA).
2. Technology as the application of artefacts (TEA).
3. Technology as the process of artefact progression (TAP).
4. Technology as using knowledge and skill to develop artefacts (TKS).
5. Technology as the solution to a problem (TSP).

B. Interaction with technological artefacts

1. Interaction with a technological artefact is through direction (ITD).
2. Interaction with a technological artefact is through instruction (ITI).
3. Interaction with a technological artefact is through tinkering (ITT).
4. Interaction with a technological artefact is through engaging (ITE).

The underlying principle behind the TPI is to ask pupils a series of questions and to analyse their responses to these questions to be able to determine their Technological Profile. The assumption is that pupils would identify with statements related to one or more of the categories of description and once these had been identified, claims could be made about pupils' Technological Profiles. The rest of this section discusses the development of the constitutive questions used in the questionnaire as well as the logical structure of the questionnaire.

6.2.1 Developing questions for use in the questionnaire

In order to be able to classify pupils relative to the categories of description, and hence be able to describe their Technological Profile, it was necessary to develop a number of statements clearly attributable to each category. In order to develop these statements, the original interviews were *reanalysed* and sections of an interview related to a specific category were ‘assigned’ to that category. This resulted in a number of clearly defined statements pertaining to each category.

These statements were examined closely, which resulted in a number of questions being developed which were representative of each category. The structure of the resultant TPI defined how many statements from each of the categories were required. This will be discussed in the section to follow. The 41 resultant questions are shown in Table 11 and Table 12; the 25 in Table 11 are questions related to pupils’ conceptions of technology and the 16 in Table 12 are questions related to pupils’ experiences of interacting with technological artefacts. As an example of how the essence of a section from an interview was used in the development of a statement, consider the following extract that was classified as belonging to the category ‘Technology as an artefact (TAA)’:

Well, it’s a bit complicated, firstly. It’s *very technological*. It’s exactly what I was talking about, what I said *complicated wires and things that you don’t understand*, it looked like technology.

In the category ‘A: Technology as an artefact (TAA)’ in Table 11, the fourth statement (highlighted in *italic* font) clearly shows its link to this extract. The critical feature of these resulting statements is that they originate from the pupils’ comments and are thus in a style that they would relate to.

Table 11 – Questions related to pupils’ conceptions of technology

A. Technology as an artefact (TAA)
Having wires coming out of things makes them technology. Because a door has a handle and hinges and can be locked, is it technology? A washing machine on a rubbish dump with no motor or wires is not technology. It is just a thing. <i>Things with complicated wires and parts that you don’t understand are technology.</i> Technology is all about computers and other electronic and electrical things like that.
B. Technology as the application of artefacts (TEA)
A door lock becomes technology when a key is turned in it and the levers move to lock it otherwise it is just a lock. A map is technology because satellites were used to give the information needed to make it. A CD is technology when you put the CD into a computer and then copy music onto it. An amplifier or CD player becomes technology when it is switched on. A television is technology when you can watch a movie on it using a signal from the air.

C. Technology as the process of artefact progression (TAP)

Technology is when a product progresses and develops over time.
Technology is something that has advanced over time and that makes life easier for you.
The process that goes into making (for example) a running shoe makes the shoe technology.
Technology is the process of progressing from something like the horse-and-cart to a motorcar.
Technology is the changing or development of a product to help you in your life.

D. Technology as using knowledge and skill to develop artefacts (TKS)

Technology is the planning and research of something and then the making of it.
Technology is using knowledge and skill to develop some product.
Something is technology because a person had a plan that was put into practice by making it.
Technology is about using scientific knowledge to make something that makes life easier.
Technology is using knowledge to evolve and develop to a product.

E. Technology as the solution to a problem (TSP)

Technology is about solving a problem.
Technology is making use of knowledge people have about something and using this to solve a problem.
Technology is an idea that has been put into place by someone to make life easier for everybody.
Technology is coming up with an idea to solve a problem (such as how people can cook things without a stove).
Technology is a person making something to solve a problem and improve quality of life.

Table 12 – Questions related to pupils' experiences of interacting with technological artefacts

I. Interaction with a technological artefact is through direction (ITD)

I always ask permission before I use some new technological thing in case I break it.
I would rather watch someone work with a complicated technological thing instead of trying to do it myself.
I always seem to do something wrong when I try to use technological things.
I would rather get someone else to work a technological thing. I might get it wrong or mess it up.

II. Interaction with a technological artefact is through instruction (ITI)

If someone first shows me how to do something with a technological thing then I can use it.
With a manual, I would be able to find out how to do what I want with this technological thing.
When using technological things, instructions tell me exactly what to do – and then I can do it.
I can usually use technological things when I follow instructions.

III. Interaction with a technological artefact is through tinkering (ITT)

When I see a new technological *thing*, the first thing I want to do is play around with it to see what it can do.
I would rather play around with a technological thing than waste time reading instructions about how to do it.
I like opening up technological things to see what's inside.
It is fun figuring out how technological things work without being given instructions to follow.

IV. Interaction with a technological artefact is through engaging (ITE)

I like to understand a technological thing by playing with it as well as by reading more about it.
With a new technological thing, I read the manual a bit and play with it a bit – whichever helps me most.
Finding out how a technological thing works is easiest by reading the manual and playing around at the same time.
Instructions are boring, but they can help you find new features on the technological thing and understand it better.

6.2.2 Developing the structure of the questionnaire

In developing the structure of the TPI, two different approaches were considered:

A. The discrete option (DO) Technological Profile Inventory approach

In the first approach, one statement from each of the above categories was used to make up a question (see Figure 15).

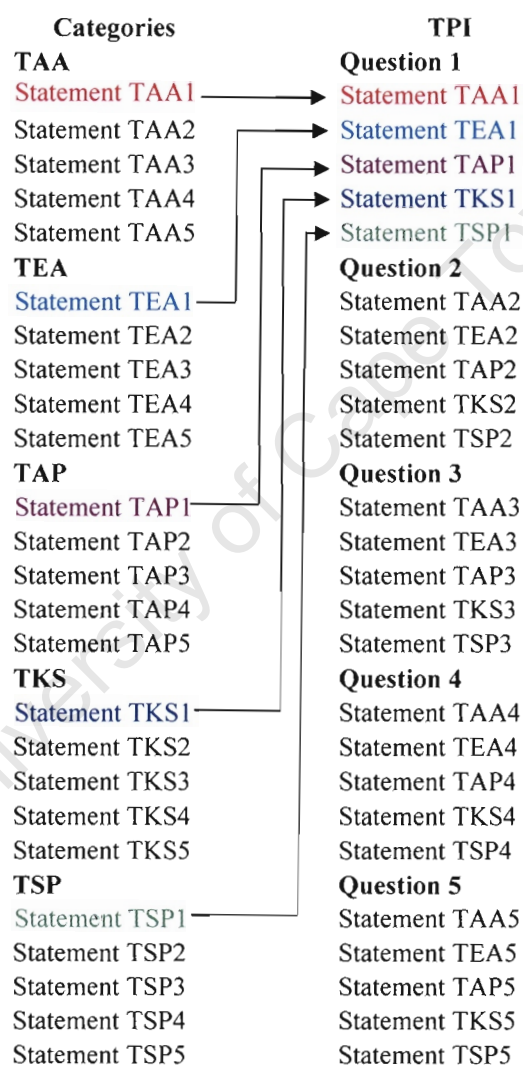


Figure 15 – Determination of the number of statements required per category

The idea was to have pupils select, *from within this question*, the statement they most agree with (this is the discrete option or DO approach). For example, in the ‘conceptions’ categories, there are five qualitatively different ways of conceiving of this phenomenon. Thus, five statements are required for each category resulting in five questions, each made up of one statement from each category. In order to have sufficient statements to

investigate both instrument types, five statements for each of the ‘conception’ categories and four statements for each of the ‘interaction’ categories were developed – the 41 statements shown in Table 11 and Table 12. The resultant discrete option (DO) TPI is shown in Appendix F.

Within each question, the five statements were randomised. To illustrate this, consider the group of statements presented as a question (and shown in Table 13) from the resultant discrete option (DO) TPI. The acronym alongside each statement identifies the category the statement comes from. The acronyms do not appear on the final questionnaire. Here I need to point out that the order of the statements is not the hierarchical order of the original phenomenographic categories of description.

The nine question sets appeared in random order on the TPI and not as five ‘conception’ questions followed by four ‘interaction’ questions. Preliminary piloting showed that the latter layout allowed for the recognition of patterns of statement types and resulted in pupils instinctively looking for particular statement types as they completed the questionnaire. Interspersing ‘conception’ questions with ‘interaction’ questions appeared to satisfactorily address this issue.

Table 13 – Illustration of the randomisation of statements within a question

Question 2	
<i>TSP</i>	Technology is a person making something to solve a problem and improve quality of life.
<i>TKS</i>	Technology is using knowledge to evolve and develop to a product.
<i>TEA</i>	A television is technology when you can watch a movie on it using signal from the air.
<i>TAA</i>	Technology is all about computers and other electronic and electrical things like that.
<i>TAP</i>	Technology is the changing or development of a product to help you in your life.

B. The Likert type (LT) Technological Profile Inventory approach

The second approach used a traditional Likert type scale (or LT) approach. In this approach, statements from Table 11 and Table 12 were randomly presented on a questionnaire. Pupils were given the option of selecting, on a scale, their level of agreement with each of the statements. An averaging approach was used to determine a pupil’s association with each category, and hence their Technological Profile. The Likert type (LT) TPI was thus developed by taking the 41 statements in Table 11 and Table 12 and randomising them. A six-option Likert scale was used alongside each statement with

the instruction to indicate the level of agreement with each. The Likert type (LT) TPI is shown in Appendix G.

6.3 Validity and reliability of the Technological Profile Inventory (TPI)

The best format for the TPI was established by giving a group of the pupils that had taken part in the original study both versions of the TPI to complete. In the case of the discrete option (DO) version, the pupils were also interviewed about why they had chosen specific statements over others. Before this process could take place, it was necessary to select an appropriate group of pupils from the original group interviewed to complete the two versions of the TPI. This was achieved by going back to the data from the original participants of the study who had, *after the phenomenographic analysis was complete*, been classified according to the categories of description using a factor analysis approach. Pupils who could, amongst them, be expected to give a spread of responses across the categories, were selected.

In order to make this selection of pupils, histograms were developed (see Figure 16) that illustrate how many times a pupil was placed in each category (shown on the y-axis) based on a factor analysis of their earlier interview (reasons for selecting these particular pupils will be discussed later). Each histogram shows both pupils' contributions to the 'conceptions' categories as well as their contributions to the 'interaction' categories. The key to the acronyms used on the x-axis can be found at the beginning of this chapter.

In analysing the histograms of all the pupils who took part in the original study, it was clear that a pupil did not necessarily 'fall' into only one category. Rather, the results tended to cluster in regions. It would be of concern, however, if a pupil's histogram was severely bi-modal. For example, in the conceptions histogram, if a pupil appeared to be located in the most simplistic conception of technology (TAA) *and* located in the most complex conception on technology (TSP) – with nothing in between – then the value of the categories of description developed as part of the phenomenographic analysis could possibly be questioned. The histograms shown in Figure 16 are typical of the results obtained and no bi-modal results were found in any of the fifteen pupils included in the original study. The histogram of each pupil was analysed and four pupils selected to take part in the validation of the TPI. By selecting the four pupils shown in Figure 16 it was possible to cover responses across all of the categories.

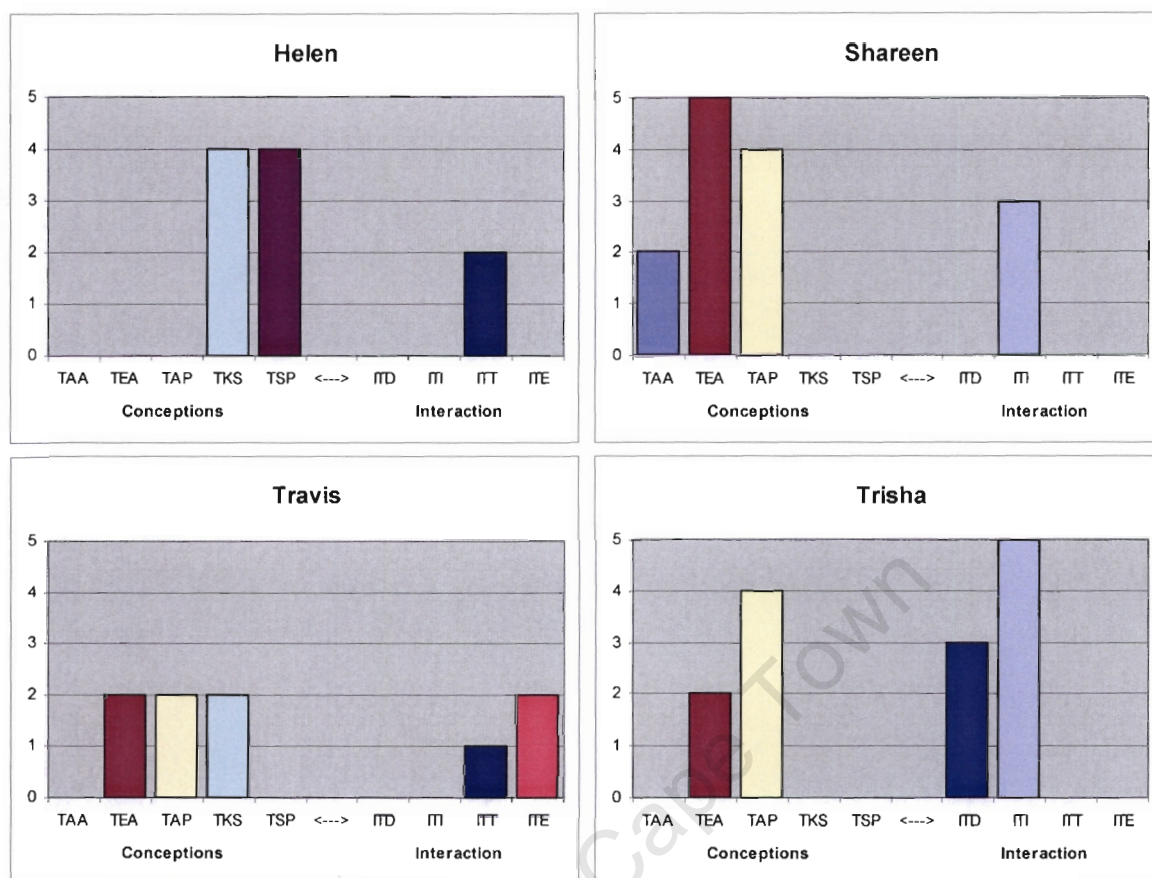


Figure 16 – Histograms showing the number of times a pupil is placed in a category

6.3.1 Piloting the discrete option Technological Profile Inventory (DO TPI)

The pupils selected via the process described above first completed the DO TPI. The completion of this TPI and the subsequent interviews took place with one pupil at a time. The instructions given to pupils for this version of the TPI were as follows:

This questionnaire has been designed to explore people's ideas about technology. There are nine sets of questions below. For each question, please read through each of the statements about technology and **indicate with a cross (x) the ONE statement** that you most agree with. If you agree with MORE than one statement, please make a cross (x) next to the one that you MOST agree with. Do not spend too long thinking about your answer. Your first thought about which one to choose is probably correct for you.

The completed DO TPIs were collected from the pupils and analysed by comparing them to the expected responses as indicated in Figure 16. The data obtained from Trisha is reproduced in Table 14 as an illustration of the types of responses given. Her responses to

the nine questions from the DO TPI are shown in Table 14. The statements in each question have been re-ordered by increasing complexity as per the original hierarchical phenomenographic categories of description for ease of comparison. The first column (ACTUAL) indicates Trisha's *actual* response to the TPI. The second column (PRIMARY) shows the *expected* response from Trisha based on her histogram in Figure 16. The choice of which category in the histogram to choose as PRIMARY is dictated by greatest contribution of original quotes from an interview to a category. In a case where there were two categories with an equal number of quotes included, the more complex conception (or way of interacting) was chosen as PRIMARY. The other categories that contained data were designated SECONDARY and appear in the third column of Table 14.

Table 14 – Response by Trisha to the DO TPI including expected responses

		Actual	Primary	Secondary			Actual	Primary	Secondary
Question 1					Question 5				
a	ITD	X		X	a	TAA			
b	ITI		X		b	TEA			X
c	ITT				c	TAP	X	X	
d	ITE				d	TKS			
Question 2					e	TSP			
a	TAA				Question 6				
b	TEA			X	a	ITD			X
c	TAP	X	X		b	ITI	X	X	
d	TKS				c	ITT			
e	TSP				d	ITE			
Question 3					Question 7				
a	TAA				a	TAA			
b	TEA			X	b	TEA			X
c	TAP	X	X		c	TAP		X	
d	TKS				d	TKS			
e	TSP				e	TSP	X		
Question 4					Question 8				
a	ITD	X		X	a	TAA			
b	ITI		X		b	TEA			X
c	ITT				c	TAP	X	X	
d	ITE				d	TKS			
					e	TSP			
					Question 9				
					a	ITD			X
					b	ITI	X	X	
					c	ITT			
					d	ITE			

A comparison was made between the *actual* and *expected* responses. In Table 14, the hatching indicates the relationship between the actual response and the expected response.

Only question seven showed significant variation between the actual and expected responses. Each pupil was interviewed about their ‘unexpected’ responses to determine what aspects of those particular statements in the TPI led to these responses. Consequently, eight statements were modified. The changes were primarily related to sentence structure, and to a lesser degree, content, to more accurately express the categories as the pupils perceived them from the statements.

The result of Trisha’s response to the discrete option (DO) TPI pilot is summarised in the histogram shown in Figure 17. With regard to her *conception of technology*, it is quite clear that TAP is the best represented category. Her *interaction with technological artefacts* responses are equally weighted between ITD and ITI. In this case, the more advanced (or complex) category would be the one attributable to her.

Thus, for this individual, her technological profile would be that she conceives of technology as the process of artefact progression and that she interacts with technological artefacts through instruction.

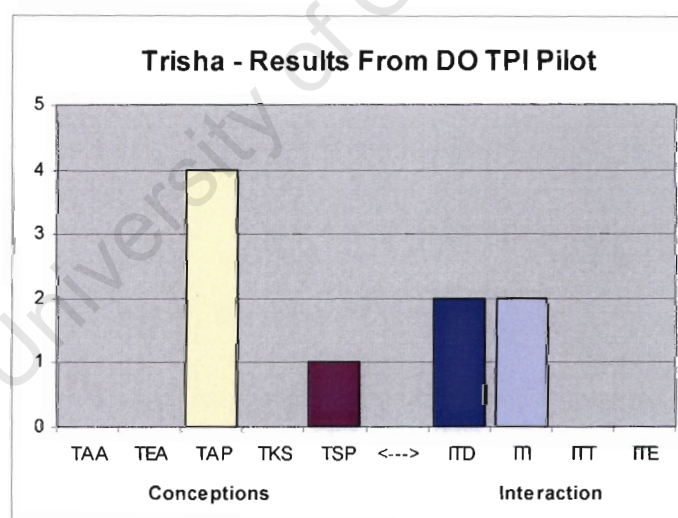


Figure 17 – Histogram of the results of Trisha completing the DO TPI pilot

For completeness, the results of the other participants in this validation exercise are shown in Table 15. The figures in brackets in the DO TPI column indicate the number of times that that particular category was selected. The results show that there is a fairly good correlation in both the ‘conceptions’ categories and the ‘interaction’ categories.

Table 15 – Summary of relationship between DO TPI responses and interview data

<i>Trisha</i>	Interview	DO TPI
TAA		
TEA	Secondary	
TAP	Primary	Primary (4)
TKS		
TSP		Secondary (1)
=====		
ITD	Secondary	Secondary (2)
ITI	Primary	Primary (2)
ITT		
ITE		

<i>Travis</i>	Interview	DO TPI
TAA		
TEA	Secondary	
TAP	Secondary	Primary (3)
TKS	Primary	Secondary (1)
TSP		Secondary (1)
=====		
ITD		
ITI		
ITT	Secondary	Secondary (1)
ITE	Primary	Primary (3)

<i>Shareen</i>	Interview	DO TPI
TAA	Secondary	Secondary (1)
TEA	Primary	Secondary (1)
TAP	Secondary	Primary (2)
TKS		
TSP		Secondary (1)
=====		
ITD		Secondary (1)
ITI	Primary	Primary (2)
ITT		
ITE		Secondary (1)

<i>Helen</i>	Interview	DO TPI
TAA		
TEA		
TAP		
TKS	Secondary	Secondary (2)
TSP	Primary	Primary (3)
=====		
ITD		
ITI		
ITT	Primary	
ITE		Primary (4)

6.3.2 Piloting the Likert type Technological Profile Inventory (LT TPI)

After the discrete option (DO) version of the TPI had been completed, the Likert type (LT) version of the TPI was given to pupils to complete. The instructions provided in this case were as follows:

This questionnaire has been designed to explore people's ideas about technology. There are 41 statements below. Please read through each statement about technology and **indicate how much you agree with the statement by circling a number between 1 and 6**. Circle the number 1 if you **really don't** agree with the statement and 6 if you **really do** agree with the statement. The closer the number is that you choose to six, the more you agree with the statement. Do not spend too long thinking about your answer. Your first thought is probably correct for you.

Trisha's response to the Likert type (LT) TPI illustrates the results obtained and is shown in Table 16. In this table, the response to each of the five statements (St 1 – St 5) in each

category is recorded on a scale of one to six. A separate column gives the average of the responses in each category. As discussed in the previous section, the expected responses to each category were determined from the original interview process. These appear in Table 16 as the column on the furthest right. Here I need to point out that the ‘interaction’ categories only have four statements, as there are only four categories (see the earlier discussion).

Table 16 – Trisha's results from the LT TPI

	St 1	St 2	St 3	St 4	St 5	Average	Expected
TAA	3	3	1	4	3	2.8	Secondary Primary
TEA	3	4	4	3	3	3.4	
TAP	6	6	4	6	6	5.6	
TKS	3	4	4	3	6	4	
TSP	4	5	6	4	6	5	
====						====	====
ITD	6	6	2	6		5	Secondary
ITI	6	3	4	3		4	Primary
ITT	1	1	1	1		1	
ITE	2	1	4	4		2.75	

There is a good correlation for Trisha between the expected and the average Likert scale responses in the ‘conceptions’ categories. In the ‘interaction’ categories, the Likert approach clearly indicates that ITD and ITI are the dominant ways of interacting with technological artefacts. The process of selecting which category to consider PRIMARY was based on the original interview data and is by its nature subjective since the number of contributing quotes to each category was counted and interpreted in absolute terms. It could be argued that one cannot strictly make a distinction between which is PRIMARY or SECONDARY based on a limited number of quotes. However, what is clear from both the Likert scale data and the original interview data is that the two least advanced categories (ITD and ITI) correspond to the Likert scale data and the expected responses based on the interview.

6.3.3 Selection of the appropriate form of the TPI for further development

The results of piloting the two versions of the TPI were presented earlier. This section looks at the composite results and argues for the selection of one version of the TPI to develop further. Table 17 shows how all the results presented to date from the two TPI versions relate to the expected interview responses. The numbers in brackets refer to the quantitative results presented earlier in this section.

Comparing the results for the discrete option TPI and the Likert type TPI, they correlated as expected for three out of the four pupils in the ‘conception’ categories with the fourth correlated through the SECONDARY option. For the ‘interaction’ categories, two pupils correlated as expected and two correlated via the SECONDARY option. The correlation between each TPI and the expected responses with respect to the interviews are not shown in Table 17 because they were presented earlier.

Table 17 – Composite results from both versions of the TPI

<i>Trisha</i>	Interview	Discrete	Likert
TAA			
TEA	Secondary		
TAP	Primary	Prim (4)	Prim (5.6)
TKS			
TSP		Sec (1)	Sec (5)
=====			
ITD	Secondary	Sec (2)	Prim (5)
ITI	Primary	Prim (2)	Sec (4)
ITT			
ITE			

<i>Travis</i>	Interview	Discrete	Likert
TAA			
TEA	Secondary		
TAP	Secondary	Prim (3)	Sec (4)
TKS	Primary	Sec (1)	Sec (4)
TSP		Sec (1)	Prim (4.8)
=====			
ITD			
ITI			
ITT	Sec	Sec (1)	Sec (4.5)
ITE	Primary	Prim (3)	Prim (5)

<i>Shareen</i>	Interview	Discrete	Likert
TAA	Secondary	Sec (1)	
TEA	Primary	Sec (1)	
TAP	Secondary	Prim (2)	Prim (5.6)
TKS			
TSP		Sec (1)	Sec (4.6)
=====			
ITD		Sec (1)	
ITI	Primary	Prim (2)	Prim (6)
ITT			
ITE		Sec (1)	Sec (5.5)

<i>Helen</i>	Interview	Discrete	Likert
TAA			
TEA			
TAP			
TKS	Secondary	Sec (2)	Sec (5.8)
TSP	Primary	Prim (3)	Prim (6)
=====			
ITD			
ITI			Prim (5.8)
ITT	Primary		
ITE		Prim (4)	Sec (5.5)

The results of this illustration indicate that both versions of the TPI give useful results. However, one form of the TPI needs to be selected over the other for the focus of further development. Even though the DO and the LT TPIs both have a similar correlation with the expected responses, the DO TPI would be more practical to implement on a wider scale as individuals would only have to make nine option choices versus the 41 required by the LT TPI. To test this claim, a selection of 65 pupils completed the DO TPI and a different group of 67 pupils completed the LT TPI. The LT TPI was generally poorly completed in that 36% were returned incomplete. Some of the returned questionnaires had the Likert scale clearly completed in a regular pattern indicating no attempt to match a particular

response to a particular statement. On the other hand, only 11% of the DO TPIs were returned incomplete indicating a clear preference for this format of the questionnaire amongst pupils.

6.4 Concluding remarks

This chapter was a speculative illustration of how the categories of description developed in this thesis could be utilized to develop a Technological Profile Inventory for the quantification of pupils' understanding of the nature of technology and their levels of technological literacy. The results obtained during the process of validation show a good relationship between classifying pupils based on the categories of description after an interview and the data obtained directly from the TPI.

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Chapter 7

Discussion and concluding remarks

7.1 Introduction

In Chapter 1, I presented my research questions, which focussed on understanding pupils' experiences of technology in the context of technological literacy, namely:

1. How do pupils conceive technology?
2. How do pupils experience interacting with technological artefacts?

In Chapter 3, I argued that phenomenography was an appropriate research approach to answer questions of this nature, while in Chapter 4, I developed a compound method that facilitated the collection of data of pupils' experiences of these phenomena. Chapter 5 presented the results of the phenomenographic analysis of this data. In Chapter 6, I gave a speculative illustration of how the categories of description that resulted from this analysis could be used in further studies that investigate questions focussed on pupils' understanding of the nature of technology and their levels of technological literacy. The current chapter relates the results presented in Chapter 5 to the relevant literature discussed in Chapter 2, and elaborates on the relevance of the findings in terms of the criteria outlined in Chapter 1, namely the ability to inform teaching practice, the approach to recruiting students, as well as the ability to contribute to a research perspective. Furthermore, the contribution this thesis makes to phenomenography as a research approach is highlighted. The chapter concludes by presenting possibilities for further research followed by selected concluding remarks.

7.2 The categories of description

This section discusses the categories of description presented in Chapter 5 in the context of the literature discussed in Chapter 2, as well as other relevant literature.

7.2.1 The nature of technology

The first research question investigated pupils' conceptions of technology within the context of the nature of technology. The categories of description constituted through the phenomenographic analysis were:

1. Technology as an artefact (TAA).
2. Technology as the application of artefacts (TEA).
3. Technology as the process of artefact progression (TAP).
4. Technology as using knowledge and skill to develop artefacts (TKS).
5. Technology as the solution to a problem (TSP).

The categories of description that make up this outcome space can be recognized in terms of the various ways that technology was shown to be understood in Chapter 2. When considering these categories of description, there is a logical split, or grouping, that manifests itself. On the one hand, there are those categories that characterise technology as being 'product' centred (TAA and TEA), while on the other, there are those that characterise technology as being 'process' centred (TKS and TSP). The difference between these two groupings is clearly articulated by a distinction made by the Technology Association of South Africa (2003a) who argue that the product of technology is not technology. Thus, technology for this association is a process that may result in an artefact, but the process is considered technology, not the resultant artefact. This is a 'process-centred' view of technology.

Stables and Kimbell (2001), Benenson (2001) and Rennie (2001) describe how the alternative position, the understanding of technology in terms of a 'product', often develops from a young age. The Gallup poll discussed in Chapter 2 confirms that for many adults, the dominant view of technology remains that of 'computers'. This view of technology perpetuates the misconception that *technology* and *information technology* are synonymous; examples of this misconception appear almost daily in the popular press. An unintended effect of this misconception regarding computers' relationship to technology is the teaching and learning perception that 'technology' is difficult to master, expensive to obtain and beyond the comprehension of the average person (Benenson, 2001, p.731).

In the framework describing the nature of technology presented in Chapter 2 (repeated here for convenience as Figure 18), one of the constructs employed characterises the nature of technology in terms of *technological artefacts* and from the discussion in Chapter 5, the singular focus by pupils on technological artefacts was shown to be a limited understanding of technology (TAA). However, conceiving of technology as the *application* of artefacts (TEA), illustrates how, in the framework for describing the nature of technology presented in Chapter 2 and shown in Figure 18, aspects of *society* and *nature* are brought together to provide for a slightly more advanced understanding of the nature of technology. Focus, however, is still on the *product-centred* view of technology and an artefact is still of central importance in the conception of technology.

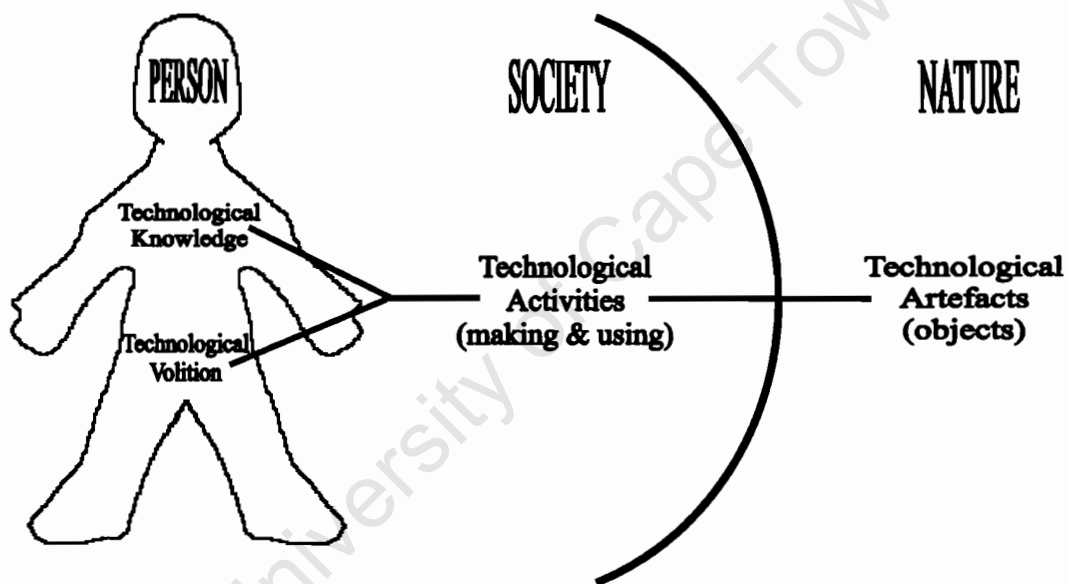


Figure 18 – Schematic representation of the domains describing the nature of technology (after Mitcham, 1978, p.234, 1994, p.160)

It is within the domain of *society* (as illustrated in Figure 18) that the boundary is manifested between the *product-centred* and the *process-centred* view of the nature of technology. The construct *technological activities* has two constituent parts. The first part (the *using*) formed aspects of the discussion earlier around the conception of technology as an artefact and is the *product-centred* view. The second of these constituent parts is the notion of *making* as representative of a technological activity. The distinction was made earlier between *making* and *using* and this distinction forms a natural dividing line between the first two categories of description (TAA and TEA), which are clearly *product-focussed*, and the three more complex conceptions of technology (TAP, TKS, and TSP), which are *process-focussed*.

The third conception of technology describes technology as being conceived of as the *process* of artefact progression (TAP). This category of description can be seen as the point of division between *product* and *process* understandings of the conception of technology, containing aspects of both. In the context of the domains shown in Figure 18, TAP has aspects of both *making* and *using* artefacts, but the focus is still on artefacts *per se* and not the people who would typically be behind the process of making. Rose et al. (2004) provide further support from the Gallup poll in 2004 for the idea that this category of description sits midway between the product- and process-centred views when they argue that ‘there is a general belief that new technologies are often developed to improve upon previous technologies’ (p.4).

It is only in the conception of technology as the use of knowledge and skill to develop artefacts (TKS) that focus moves from artefacts themselves to the intellectual capacity behind the production of the artefacts. This is manifested in a relationship between the domains of *person* (and the construct of *technological knowledge*), and *society* (the *technological activity* of *making*) as shown in Figure 18. An interrelationship develops here between form and function with a focus on the processes people use to get an artefact to its present state. Until fairly recently, the type of *technological knowledge* that constituted this understanding of the nature of technology was the knowledge and the techniques handed down by a master practitioner through an apprenticeship process (Takanaka, 2001). More recently, books and formal education have complemented this process.

The most complex way of conceiving technology is as the solution to a problem (TSP). In terms of the framework describing the nature of technology presented in Chapter 2, technological volition, the will (or choice) to use technology to an end, underscores the essence of what it means to ‘solve a problem’ in the context of technology. The nature of technology here is no longer focussed on an artefact, the use of an artefact, or indeed any process related to an artefact. It is a person’s internal volition to make an impact on others by solving problems related typically to issues of quality of life. Further evidence of the credibility of this most complex category of description can be found in the definition given by the South African government (Department of Education, 2002) on the meaning of technology. They argue that technology is:

The use of knowledge, skills and resources to meet people's needs and wants by developing practical solutions to problems, taking social and environmental factors into consideration. (p.4)

In the Saskatchewan Education study discussed in Chapter 2, one of the four dimensions investigated was 'understanding, describing and adapting technology'. This dimension has aspects similar in nature to my first research question that investigated how pupils conceive technology. The 'assessment criteria' illustrated in Table 3, which are essentially different levels that pupils are expected to have of understanding this dimension share some limited similarity with the structure of the categories of description developed in Chapter 5. A number of the elements of the Saskatchewan levels are also recognisable in the categories of description. These include the idea of technology as being a product, technology as being a process, the fact that a product could be improved, the operation and features of a technological product, to name a few. However, an element that is notably absent from the Saskatchewan levels is the relationship that the nature of technology has with the solution to problems in the world. This aspect comes out strongly in the categories of description constituted in response to this particular research question.

It has been shown in the discussion that the categories of description constituted through the phenomenographic analysis share significant attributes with the framework describing the nature of technology presented in Chapter 2. Even though the framework was presented with no particular structure, the hierarchical nature of the categories of description, and their close relationship with the constructs within the framework, allows a logical structure to be recognised within the constitutive elements of the framework itself.

7.2.2 Technological literacy

The second research question investigated pupils' experience of interacting with technological artefacts. The categories of description constituted through the phenomenographic analysis were:

1. Interaction with a technological artefact is through direction (ITD).
2. Interaction with a technological artefact is through instruction (ITI).
3. Interaction with a technological artefact is through tinkering (ITT).
4. Interaction with a technological artefact is through engaging (ITE).

In Chapter 2, I argued that to be considered technologically literate, a person must be in a position to understand the nature of technology, have a hands-on capability and capacity to interact with technological artefacts, and have an ability to think critically about technological development. The second research question relates directly to this notion of the requirement for a hands-on capability and capacity to interact with technology – a dimension of technological literacy.

For pupils to have the *capacity* to interact with something implies that there is a sense of power to perform their interaction. This relationship between pupils, power, and the interaction is evident in the hierarchical nature of these categories of description. In the first two categories (ITD and ITI), pupils may have the capability to interact with the technological artefact, but they do not have the capacity to do so. They require an outside intervention, either through the instruction of an authority figure, or through a series of directions. The power experienced by the pupils to interact in each case was thus provided via a proxy.

The shift between the first two categories of description (ITD and ITI) and second two (ITT and ITE) typifies the distinction that defines those pupils who fully embrace technology and those who do not. However, it is not to say that a pupil who interacts with a technological artefact through *instruction* should be considered technologically illiterate. There is no ‘line drawn in the sand’ that divides technological literacy from illiteracy and the two should be considered as part of a continuum. Having a capability, but lack of capacity, to interact with technology in the category ITI simply indicates a transitional space between the two. Having said that, I would argue that to interact with a technological artefact through direction (ITD), situates a pupil toward the side of the continuum that could be considered to indicate a limited level of technological literacy. Given that I defined technological literacy in Chapter 2 in terms of a number of attributes, more would be required to be known about an individual to be able to make a substantive claim about their level of technological literacy.

At the other end of the technological literacy continuum are pupils who would fall into the categories ITT and ITE. Here, unlike the categories ITD and ITI, pupils have both a capability and a capacity to interact with technological artefacts as evidenced by their self-initiation of an interaction and their desire to understand both the form and function of any

technological artefact. Interaction here is more than simply carrying out a set of instructions.

In the Saskatchewan Education study, another of the four dimensions investigated was ‘using technology, including computers’. This dimension is similar to my second research question. The ‘assessment criteria’ illustrated in Table 5, which, as discussed earlier, are essentially different levels that pupils are expected to have of understanding this dimension, have only limited correlation with the categories of description that address my research question. The main focus in each of the levels of the Saskatchewan study is on the use, or not, of instructions in being able to utilize a technological artefact, as well as the impact of the application of this technology. In the categories of description constituted in this thesis, ‘instructions’ in their general sense form only one aspect of the categories.

7.3 Informing teaching practice

An important result of my investigation is the confirmation of the assumption that there are a number of different ways that pupils interact with technological artefacts. Chapter 1 described an intervention I developed over a number of years to expose pupils to technology. At the time, I based the development of this structured series of activities that made up the intervention on my experience together with anecdotal evidence I had gathered over time. What I had not appreciated at the time was how inaccessible the technological artefacts that made up the structured activity may have appeared to some of the pupils. The less advanced ways of interacting (through direction or instruction) requires the facilitator of the interaction to ensure that a well-defined and supportive environment be provided to guide these pupils into what is, for them, often a potentially intimidating experience. The goal, in this case, should be to develop the confidence of these pupils in their interaction and take them to the point where they feel confident to initiate interaction with the artefacts, even if initially only in a limited way. Consequently, my results show how important it is that in any structured activity, aspects are included that can promote the development and nurturing of what is hoped would be a growing confidence in interacting with a technological artefact. In a similar vein, those who interact with technological artefacts in an advanced way (through tinkering or engaging) may feel constrained by a detailed, carefully structured, nurturing environment that is so important in the less advanced ways of interacting. In contrast, pupils who tinker or engage with technological

artefacts are shown through the structural aspects of the categories developed in Chapter 5 to thrive on investigation and exploration. The approach to facilitating this tinkering or engaging would require a different outlook. The challenge is thus to develop a structured activity that explicitly recognises that there are various approaches pupils could take in their interaction and makes provision for these.

Having *pupils* interact with technological artefacts is not the limit of the extent of the ability to inform teaching practice. Students in their junior years at a university (or similar tertiary educational institution) often participate in courses of the nature I described in Chapter 1. An important aspect of these courses is the hands-on components that are typically aimed at giving students a physical sense of engineering (or some other technical degree programme).

The reality we face as educators, particularly in a context such as South Africa, is that current students who enrol in engineering degree programmes bear scant resemblance to those who may have entered engineering degree programmes in previous generations. Children who grew up before an era of computers and television often came with ‘hands-on’ hobbies such as building Meccano models, crystal radios, model aeroplanes and boats, or keeping an old car in running order. They would have experienced building tree-houses, dismantling and reassembling toys (and often other items in their homes) and through this kind of activity would be stimulated to follow a technical career. It is my experience that students entering higher education today have had little or no exposure to these classical ‘technological’ stimuli and very few have indulged in any form of technical hobby outside of computing. A recent study (Reed & Case, 2003) has shown how of the ten factors influencing pupils to follow careers in mechanical engineering, half of them had no bearing on anything to do with knowledge or understanding of what engineering actually entails. These factors include: studying engineering because their school subjects allowed them to do so, the availability of bursaries, how much they would potentially earn as a professional engineer, and most concerning, engineering being the least objectionable option from a range of possible choices of study.

Students entering tertiary education under these conditions will be likely to display a range of ways of interacting with technological artefacts. As such, it is important when developing course material to open up a ‘space for interaction’ that allows students who

may only interact through direction (or instruction) to progress to being in a position to interact through an engagement with technological artefacts.

7.4 Technology education at schools

Debates around the nature of technology and how technological knowledge is gained have been synthesised and published by a variety of organisations as policy documents. These documents describe the importance of understanding what technology is and why it is deemed necessary to be technologically literate. Examples of these are National Academy of Science's *Technically speaking: Why all Americans need to know more about technology* (Pearson et al., 2002), the International Technology Education Association's *Technology for all Americans: A rationale and structure for the study of technology* (TAAP & ITEA, 1996), and most recently, the National Academy of Engineering's *Technically: approaches to assessing technological literacy* (Garmire et al., 2006). Technology educators, researchers and practitioners have all contributed to this process and these documents reflect to a large extent, from their perspective, the current thinking about issues relating to technological literacy.

7.4.1 Technology as a school subject

There has been a corresponding move in many countries to explicitly include technology as a subject at school level. The South African government (Department of Education, 1997) planned to introduce technology education into schools by 2005 as part of what was known as Curriculum 2005 which was to be the phased introduction of outcomes-based education. In 2000, the 'Chisholm report' (Department of Education, 2000) recommended that technology as a subject no longer form part of the final grades of schooling, Grades 10 to 12, the Further Education and Training (FET) level. This move was strongly criticised, particularly by the Technology Association of South Africa (2003b), given the importance the South African government had placed on technology as a subject during the development of Curriculum 2005. Resources and levels of teacher training were some of the reasons provided as to why technology as a subject was no longer going to be offered at this level, but only from Grades R to 9, the General Education and Training (GET) level (Department of Education, 2000).

The curricula for senior-secondary schools in South Africa are again going through a comprehensive redevelopment, partially as a result of the critical response to the curricula that developed from the Curriculum 2005 project. However, the one thing that has not changed is that technology as a separate subject remains notably absent. The argument given is that subjects such as Mathematics, Physical Science, and others will all include aspects of what would typically have been covered in a separate technology subject. Now, given that the Department of Education (2002) defines technology as ‘the use of knowledge, skills and resources to meet people’s needs and wants by developing practical solutions to problems, taking social and environmental factors into consideration’ (p.4), it is hard to imagine how it is going to be possible to accomplish this in a piecemeal fashion. This becomes even more of an issue when it is recognised that not all pupils will take the same subjects and will thus conceivably miss out on aspects of this apparently integrated approach.

I would argue that it is through the introduction of a defined technology education curriculum that the different conceptions of technology held by pupils can be addressed by helping those that conceive of technology in less advanced way (as simply an artefact, or the application of artefacts) to recognise that technology is about solving problems. This cannot, I believe, be accomplished through the segmented introduction of aspects of technology into existing subjects. Many other education systems across the world continue to have the subject technology taught up to Grade 12. I find it hard to believe that South Africa’s approach to technology education can be considered ‘best practice’.

7.4.2 Technology as an applied science

A further unintended consequence of no longer including technology as a separate subject but rather integrating aspects of it into other subjects is that this may strengthen the view held by some that technology is simply applied science. The idea that ‘technological fruits fall from scientific trees’ (Gardner, 1997, p.14) indicates one of the ways that this distorted understanding of technology as applied science has been described. In Mitcham’s (1980) typology of the nature of technology discussed in Chapter 2, he describes ‘substantive theories’ (p.314) (an aspect of the construct ‘technological knowledge’) as constituting what are known as the engineering sciences. He argues that these are the real-life application (most often by engineers) of scientific theories – technology as applied science.

In contrast to this position, there is also the view that technology is the driving force behind the advancement of science. Throughout history, there have been instances where engineers or artisans have developed technological artefacts that have had no direct input from scientists. In fact, Gardner (1997) maintains that ‘practical experience with artefacts ... [is often a] precursor to scientific conceptualisation about them’ (p.15). A classic example of this would be in the early 20th century when a master craftsman would use the experience and knowledge handed down by their mentor to refine the performance of a ship’s propeller or a water-wheel. The scientific theory of how and why a particular shape or design worked so well came later. In this case, the technologist drove the development of the scientific theory.

7.5 Stimulating a future in technology

The recruitment of talented pupils to study mechanical engineering is of particular interest to me given my position as a Programme Convenor in the Department of Mechanical Engineering as well as my direct interaction with the first-year students in the Department. This section looks at how the results obtained in this study can, in the first instance, make it possible to develop pupils from being ‘technologically phobic’ to at least being interested in learning more about technology. Secondly, it shows how it will be possible to encourage pupils who may have an interest in technology to consider a technological career path where they may otherwise not have. Finally, it will be shown how the results obtained can make it possible to profile potential students applying to study engineering at a tertiary educational institution to help ensure that only the most appropriate applicants are accepted.

7.5.1 Empowering those who shy away from technology

From the outset, the structured activity that I took to schools to expose pupils to technology using technological artefacts was specifically developed to include aspects (see Chapter 1) to make the pupils’ interaction fun and well as empowering. The importance of the fun aspect is self-evident, but the results of this thesis show how important the *empowering* aspect actually is. At the most fundamental level, my aim was to let a diverse group of pupils have fun with technological artefacts. The results from this investigation have shown that pupils who interact with technological artefacts through direction or instruction (ITD and ITI, the least advanced categories of description) are unlikely to benefit

positively from the activity unless specific steps have been taken to deal with the anxiety that they experience about technological artefacts in general.

The most complex manifestation of this anxiety will be amongst those pupils who only interact with technological artefacts through direction – someone explicitly telling a pupil that they are required to complete some action or operation. In this context, it is important that a non-threatening, supportive environment be ensured. Once a pupil has had success in doing something both constructive and enjoyable within this environment, the goal would be to continue to get them to be able to experience their interaction in new and more complex ways. Although it may be unrealistic to expect a pupil to move from interacting with technological artefacts through direction (ITD) to engaging with these same artefacts (ITE) in the space of a single structured activity, what is possible is to work at removing the ‘barrier to entry’ to these technological artefacts which I described in Chapter 5. The result of this shift in pupils’ experiences of interacting with technological artefacts will be to open up the ‘space for interaction’ that I discussed earlier. How could this be achieved? In Chapter 1, I gave the example of a pupil who had not wanted to take part in the structured activity because she did not feel that it held any interest for her. After having carefully taken her through an experience of interacting with the activity, her response was that she found it extremely fascinating and that she ‘enjoyed every minute of it’. I would argue that her ‘space for interaction’ with technological artefacts was opened up through this activity by carefully structuring the activity to allow those who interact through direction (as she appeared to do) to move to more complex ways of interacting. It is possible that in future she will be less apprehensive about interacting with technological artefacts and she may possibly even have moved beyond her ‘fear of access’ that would most likely have characterised her way of interaction before the structured activity. On one level, having pupils move beyond their anxiety of, and their ‘fear of access’ to, technological artefacts is the central result of any structured activity. The direct result of this change in the way of experiencing interacting with technological artefacts will be for them to at least be interested in learning more about technology.

7.5.2 Careers in technology

For those pupils who have already moved beyond the ‘fear of access’ characterised by the interaction described above, a structured activity for interacting with technological

artefacts, developed with cognisance given to the categories of description constituted in Chapter 5, has another important benefit. It can help to stimulate a greater interest in technology in general, with the ultimate manifestation of this being that pupils follow a career in technology. For these pupils, a structured activity is more than simply about giving them an opportunity to tinker (ITT) or engage (ITE) with technological artefacts. It is also about allowing them the space and opportunity to be able to conceive technology in more advanced ways.

A logical assumption would be that pupils who interact with technology in more complex ways (ITT or ITE) do not, as a rule, conceive of technology in advanced ways such as technology being the solution to a problem (TSP). In fact, it would appear that some do not see technology as anything more than artefacts. The outcome space of the ways pupils have of conceiving of technology shows that understanding technology in this way is a limited way of doing so. The strength of the results constituted in Chapter 5 is that they provide an informed basis to develop a structured activity that can take pupils, who may interact with technological artefacts in advanced ways, and open up opportunities of experiencing technology in more complex ways. I would argue these pupils are those who would be considered by the lay populace as being technologically literate given that they have the capability and capacity to interact with technological artefacts. However, earlier in this chapter, and in Chapter 2, I argued how this is only a limited understanding of technological literacy. Another requirement for technological literacy is to understand the nature of technology. In the context of the categories of description constituted for the ways pupils have of conceiving technology, this means that a structured activity needs to have as one of its aims, the goal of enabling pupils to be able to conceive of technology ultimately as the solution to a problem.

Having a structured activity which not only allows pupils to interact with technological artefacts in advanced ways (something these particular pupils may already do), but also underpins the opportunity of enabling these pupils to conceive of technology in more advanced ways, will help them to develop a complex understanding of technology in general. I argue that this complex understanding will ensure that when it comes to having to make up their minds about future career opportunities, technology is something that will not only appeal to them, but that they will have a deep understanding and appreciation of.

7.5.3 Student profiling

In South Africa, as is much the case across the world, greater success rates for students enrolled in tertiary educational institutions are being encouraged, and even demanded, by governments. Nowhere is this more apparent than in the engineering disciplines where engineers are arguably seen as the drivers of economic development and are recognised as key players in an economy. Recently, the South African government launched AsgiSA, the *Accelerated and shared growth initiative for South Africa* (South African Government, 2006). AsgiSA argues that for both public infrastructure and private investment programmes in South Africa, ‘the single greatest impediment [for growth] is [a] shortage of skills’ (p.9). These include professional skills such as engineers as well as others such as skilled artisans. Thus, the challenge is to find ways to be able to graduate larger numbers of engineers, particularly from the population groups not currently well represented in engineering, to help address this issue. One simplistic approach may be simply to increase the intake into tertiary educational institutions which is an approach that has significant quality and resource implications. Given that up to a third of students entering these institutions never graduate, increasing the intake is arguably not an educationally sound approach. A better option would be to improve the ‘throughput rate’ of the current student cohort. This could be achieved by significantly improving the learning experience of engineering students (cf. Case, in press; Fraser, Linder, Allison, Coombes, & Case, in press) and by improving the way students are selected.

The Technological Profile Inventory (TPI) developed in Chapter 6 is an illustration of how it may be possible to gather data about an applicant and then use this information to help inform the decision taken about whether to admit that person into a particular academic programme. Reference to the development of the TPI will show how it classifies a pupil in terms of two sets of categories – showing how they may have a particular approach to technology in a particular context. I would argue that to be technologically literate, and thus be most suited for entering an engineering degree programme, it is necessary to be located in the two most complex of each of the categories of description (see Figure 19). This means that, on the one hand, a pupil will conceive of technology as using knowledge and skills to develop artefacts (TKS) or, preferably, as the solution to a problem (TSP). On the other hand, that same pupil will interact with a technological artefact through tinkering (ITT) or through an engagement with it (ITE).

	<i>TAA</i>	<i>TEA</i>	<i>TAP</i>	<i>TKS</i>	<i>TSP</i>
<i>ITD</i>					
<i>ITI</i>					
<i>ITT</i>				CORE	
<i>ITE</i>					

Figure 19 – Relationship between the categories of description in the TPI

There is no argument being made that should a pupil not be located within the area marked ‘core’ in Figure 19 that they will not succeed in an engineering degree programme. Indeed, they may well be expected to have different approaches to technology in different contexts. However, the other categories focus on technology being constituted by artefacts as well as on the need for mediation (through direction or instruction) before an interaction with technological artefacts can take place. I would argue that as a result, pupils falling outside of the ‘core’ might possibly be less suitable candidates when compared with those falling within the core. This could have the potential to act as an additional admissions criterion that needs to be met before acceptance into an engineering degree programme. Further work would need to be done in this area to ensure that the context that is being used as the basis for gathering this data is appropriate for the decisions it is being required to inform.

An alternative use of the information gathered through this process of categorisation could be to inform a department about the technological orientations of their first-year students. This could then help to inform the design of learning experiences that are well matched to these students’ levels of technological engagement.

7.6 Contributing to a research approach

In Chapter 2, I discussed a number of empirical studies that have investigated pupils’ understanding of the nature of technology and their levels of technological literacy. It is clear from the discussion of the approaches taken and the results obtained from these studies that an alternative approach is required. One of the fundamental contributions my thesis makes to this body of knowledge is the use of interpretive research to reconstitute the grounding upon which such studies could be based.

It is apparent in Chapter 2 that there is not much data available relating to pupils’ levels of technological literacy. The Saskatchewan study, discussed in Section 2.3.2, is a typical example of a qualitative study undertaken on pupils’ levels of technological literacy. I would argue that this thesis presents a much broader model that defines technological

literacy in a particular way and with both sets of categories of description available, each referring to a major issues related to what it means to be technologically literate, it will now be possible to get a measure of levels of technological literacy more easily.

The results of this thesis are not only applicable to pupils, but also to students entering tertiary educational institutions. With technology being one of the most powerful forces shaping society, there is scope to make a significant contribution to quantifying the levels of technological literacy in both pupils and students – the society destined to be shaped by technology.

7.7 Methodological additions to the phenomenographic approach

The theoretical underpinnings of the phenomenographic approach have been discussed at length in Chapter 3. In that chapter, I argued that although the approach developed from strongly empirical roots, traditional phenomenographic research (as distinct from work in variation learning theory) has developed a well-established methodology. My thesis has added to the methodology of phenomenography in its approach to gathering phenomenographically appropriate data (through the use of photographs), as well as by continuing to develop the approach to analysis initiated by Åkerlind as themes of expanding awareness, reconstituted for this thesis as ‘structural themes’.

7.7.1 Photographs

The key to good phenomenographic results is to collect data that has individuals reflecting over their experience of a particular phenomenon in a spontaneously meaningful way. The challenge of having pupils reflect over their experience of technology proved itself an area that needed careful consideration during the development of the method used for data collection. Using the typical semi-structured interview approach to data collection was problematic as the interview tended to end up being embedded in abstract questions since the term ‘technology’ itself is such an amorphous concept.

In response to these difficulties, I drew from the anthropological work of Collier and Collier (1986) and Harper (1988) where the use of photographs as part of the interview process was developed as an accepted research method. The key to the success of this method in a phenomenographic context was the introduction of a *reflexive photo-*

elicitation interview that involved pupils taking their own photographs of their experience of what is a particularly difficult subject matter to define.

The result of this approach to collecting data about the experiences of a phenomenon proved to be very successful. The data was rich and it ensured that, amongst those who took part in the interview process, there was a shared experience of what had up until then proved a difficult concept to address adequately whilst using a traditional interview approach.

7.7.2 Structural themes

The structural themes used in the constitution of the categories of description were developed from the conceptual work done by Åkerlind (2003) in developing what she calls ‘themes of expanding awareness’ (p.89). This is an extension of the less clearly structured traditional approach to constituting the structural relationships between different dimensions of variation in the experience of a phenomenon. I argue that building on Åkerlind’s work goes some way towards helping to make phenomenographic analysis more accessible. The constitution of the categories of description are in essence a researcher’s invention and developing the approach of using structural themes as part of the constitutive process adds a logical element to the process of analysis.

7.8 Possibilities for further research

The results presented in this thesis have opened up a number of possible avenues for further research. These are presented in turn below.

7.8.1 Interpretive relational possibilities

In their book *Understanding learning and teaching*, Prosser and Trigwell (1999) show how it is possible to develop a relational view of cognate phenomena. As an example, Figure 20, drawn from Trigwell, Prosser, and Waterhouse (1999, p.60), illustrates the relational dynamics of teaching and learning. A useful addition to the results presented in this thesis would be to look for relational possibilities between conceptions of technology and interacting with technological artefacts by following a similar approach.

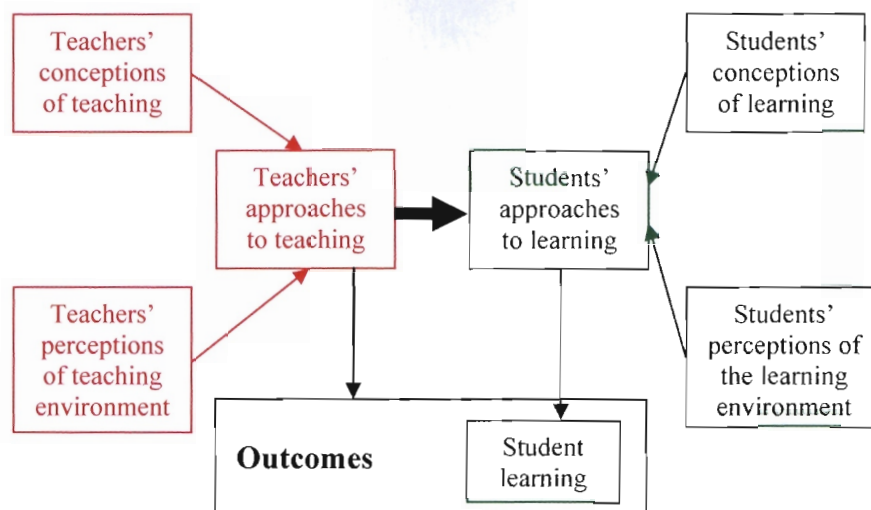


Figure 20 – Relational dynamics of teaching and learning (after Trigwell et al., 1999, p.60)

7.8.2 Determination of a person's Technological Profile

The Technological Profile Inventory (TPI) was developed (in Chapter 6) as a speculative illustration of how my categories of description could be utilized to underpin other studies that further investigate issues relating to pupils' understanding of the nature of technology and their levels of technological literacy. To be useful as a research tool, the TPI still needs to be exposed to rigorous, large-scale testing to confirm, amongst others, inter-item correlation. Once statistical measures such as Cronbach's alpha have been used to check for reliability and consistency of the items for measuring a single category of description, baseline data will be required to be able to benchmark what a particular Technological Profile means.

The process for implementing this benchmarking could be to administer the TPI to first-year and final-year students across different academic departments. For example, selecting groups of students from mechanical engineering, ballet, fine art, chemistry, accounting, and English literature could conceivably give a reasonable indication of what typical technological profiles exist and how they are distributed amongst particular groups. Once benchmarking has been completed, claims could be made about the type of Technological Profile that would be most appropriate for studying a particular technologically-based degree programme, such as mechanical engineering.

7.8.3 International consideration of the research questions

This research was conducted in an environment that ensured good variation in the ways the phenomena in question could be experienced. Similar research would be useful in a different environment, possibly one considered an integral part of the first-world economy. It is possible that this study did not identify all the possible ways of experiencing the phenomena. By broadening the study through an international collaborative project, it is possible that other critical aspects could become evident.

7.9 Concluding remarks

In conclusion, there are a number of important aspects of this thesis that I would like to highlight.

This thesis contributes to a broader understanding of how pupils experience technology. In responding to the key research questions of this thesis, namely, how pupils conceive technology, and how they experience interacting with technological artefacts, I have developed two sets of categories of description that describe the range of ways that pupils experience technology – from their perspective. The analytic outcomes stand as significant contributions to a research field where traditionally, researchers approach these questions in terms of ‘authoritative’ definitions of the nature of technology and technological literacy as developed by experts in the field – from the perspective of the ‘expert’ researchers in this field.

In this thesis, I developed a model that shows the importance of both *capability* and *capacity* in consideration of what it is to be technologically literate. The model also highlights the importance of an understanding of the nature of technology. The hierarchical relationship between the categories of description lend themselves to the possibility of using these attributes to develop a way of being able to characterise *individuals’* technological profiles.

The results I obtained were also used to show how it might be possible to impact on the technological literacy levels of pupils through the development of a series of structured technological activities. A consequence of this thesis will be that the development of such activities need no longer be merely experience-based, but can now draw on a broader understanding of the ways that pupils experience interacting with artefacts of this nature. In

this spirit, I have discussed how technological activities may be developed in a way that could possibly also stimulate pupils to follow careers in technological fields, or at least have pupils want to know more about technology.

The methodological basis of the traditional phenomenographic approach has been extended by the use of photographs to involve individuals in spontaneous and meaningful reflection on their experience. The rich data collected in this way shows that there would be significant value in researchers adopting the use of photographs in other phenomenographic studies. Similarly, it has been shown that the use of *structural themes* contributes towards strengthening the outcome of the analytical process used in the constitution of the categories of description.

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Chapter 8

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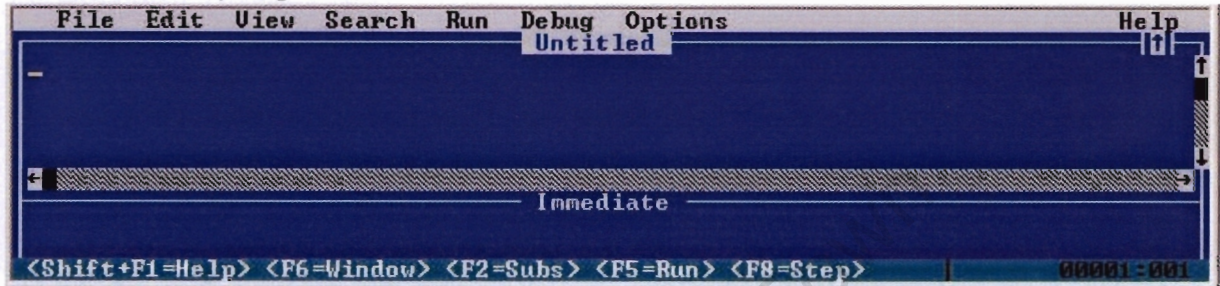
Appendix A

Worksheet for the structured activity

1. Introduction

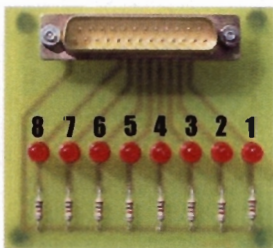
The screen shown below should be open on the computer. This is the programme we will be using to talk to the things we are going to connect to the computer.

Microsoft's QBasic opening screen



This tutorial will show you how to switch lights, a buzzer, a heater and a fan on and off with the computer. *Let's start simple by just switching some lights on and off.*

2. Working with the lights



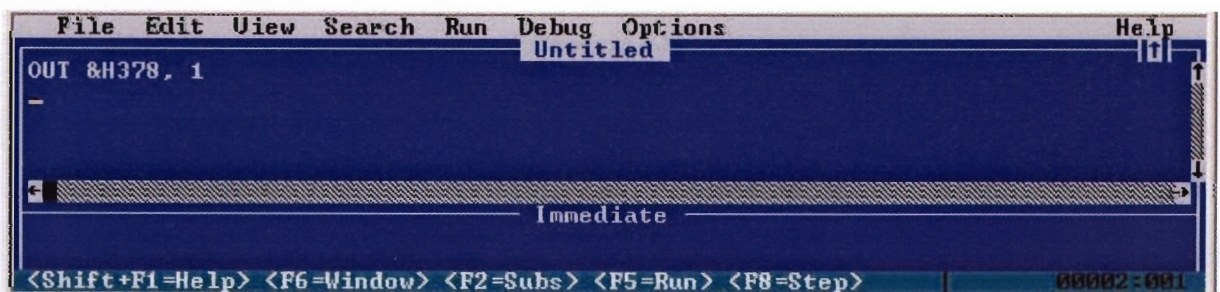
Eight lights connected to the computer

On your table in front of you, you will have a board that looks like the one shown in the picture. We are now going to use the computer to switch these lights on and off. Do you need help connecting this to the computer? If so, ask, or try plugging it in yourself...

a. Switching the first light (light number 1) on

For us to **turn the first light on**, we need to tell the computer that this is what we want to do. To do this we use a special computer language (called BASIC). Type into the computer what is shown in the picture below. (The line is: **OUT &H378, 1**)

After typing in the line of text, press enter.



First line of BASIC code: OUT &H378, 1

b. What does this line mean?

- The “**OUT**” stands for output – in other words, we want to send information OUT of the computer to the lights.
- The “**&H378**” tells the computer what plug on the back of the computer we are using to connect to the lights.
- The “**1**” tells the computer which light to turn on.

c. Running the programme that you have written

You need to tell the computer that you want to run the line you have just typed. Use your mouse to click on the word “**RUN**” on the toolbar and then choose “**START**” as shown below. *You have just used a computer to switch something on in the outside world!!*



Choosing RUN / START to run the programme you have written

Press any key to go back to the screen that you started with.

d. Switching on different lights

To turn on different lights, change the number in the line you typed in earlier to **ANY number between 0 and 255**.

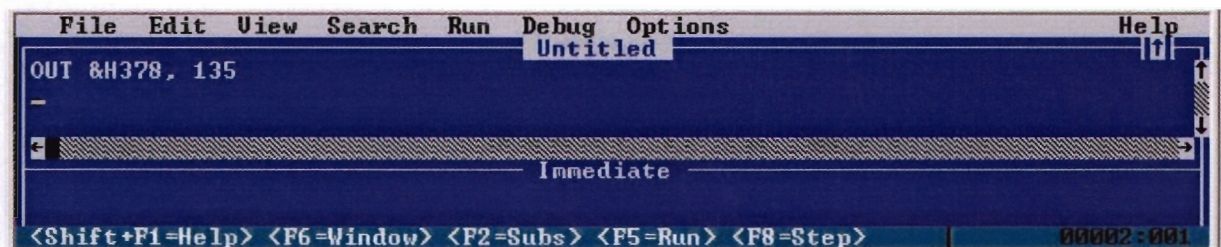
“0” switches ALL of the lights OFF.

“1” switches the FIRST light ON.

“255” switches ALL of the lights ON.

Any other number switches SOME of the lights ON.

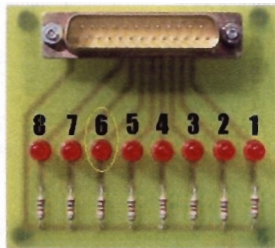
An example of a switching some lights on is shown in the picture below. Once you have changed the number “1” to **ANYTHING THAT YOU WANT TO TRY – it can be any number between 0 and 255**, run the programme again and watch the new lights go on.



Switching on random LED lights

e. How do you switch on the lights you want?

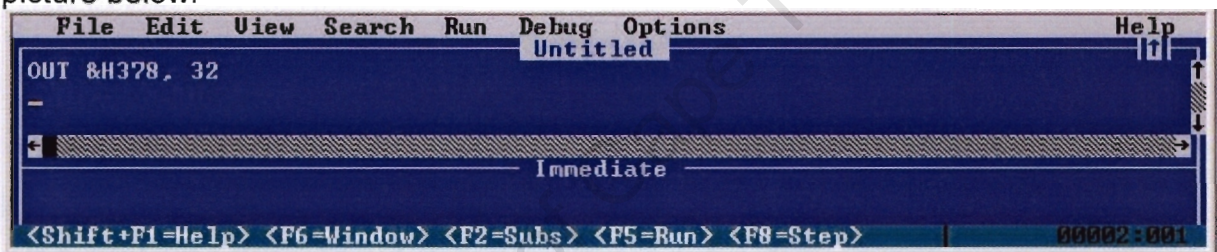
To switch on only the lights you want, you need to know the “number” of each light. The table below has a list of light numbers and values to switch them on.



LIGHT NUMBERS							
8	7	6	5	4	3	2	1
VALUE USED TO SWITCH THE LIGHT ON							
128	64	32	16	8	4	2	1

Table 1 – List of Light numbers and associated values to switch them on

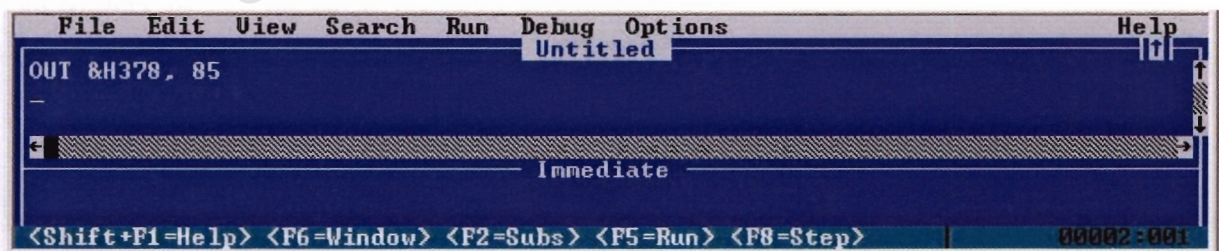
Let's say we want to switch on light number 6. Instead of using “1” which turned on light 1 in your original program, **use the number shown under light 6 that is “32”**. Change your program to have “32” instead of “135” and run it. This is shown in the picture below.



Turning on LED light number 6

f. Switching on more than one light

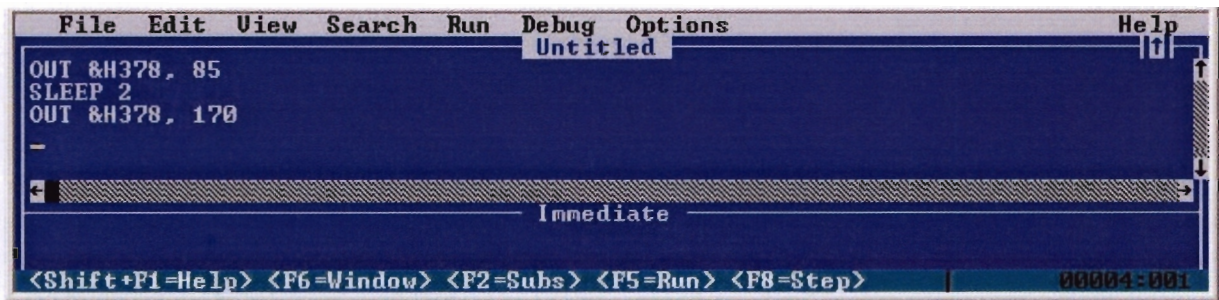
If you want to switch on more than one light, all you need to do is choose which ones you want to switch on and then **add the values of each light number together**. In other words, if you want to switch on lights 1, 3, 5 and 7, add the numbers $1+4+16+64=85$ and put “85” in your programme (like in the picture below). *Run your programme and see how this works.*



Switching on LED lights 1, 3, 5 and 7

g. Switching lights on and off

We can add more lines to our programme to make different lights come on at different times. The computer runs one line that you have written at a time. **Let's make some lights go on and then after 2 seconds, switch some others on.** Type the following two lines **under** the one you have already done (as shown in the picture below). Once you have typed them in, run your program and see what happens – **now run it again.**



Alternating flashing lights

The "SLEEP" command that you typed tells the computer to stop for 2 seconds before doing the next line.

"SLEEP 2" makes the computer stop for 2 seconds. If you want to change how long the computer stops for, you only need to change the number "2" to the length of time you want... "SLEEP 1" makes the computer stop for 1 second.

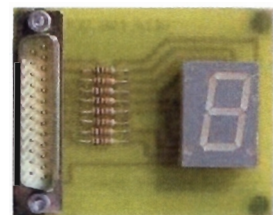
You can add more and more lines as you did above to make a whole series of lights go on and off. **If you want to**, you can try adding more lines like shown in the picture at the top of the next page.



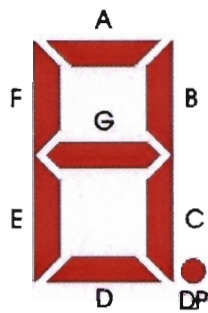
Code to step the lights sequentially

3. Using the 8 light number block

Do you need help connecting this next device to the computer? If so, just ask, or try to connect it yourself... **Go on, you can try it. You can't break it... Just ask if you get stuck.**



This number block works the same way as the row of 8 lights did, but now you can make **numbers** and **letters** go on and off. **Don't change your programme from before, just run it again and see what happens...**



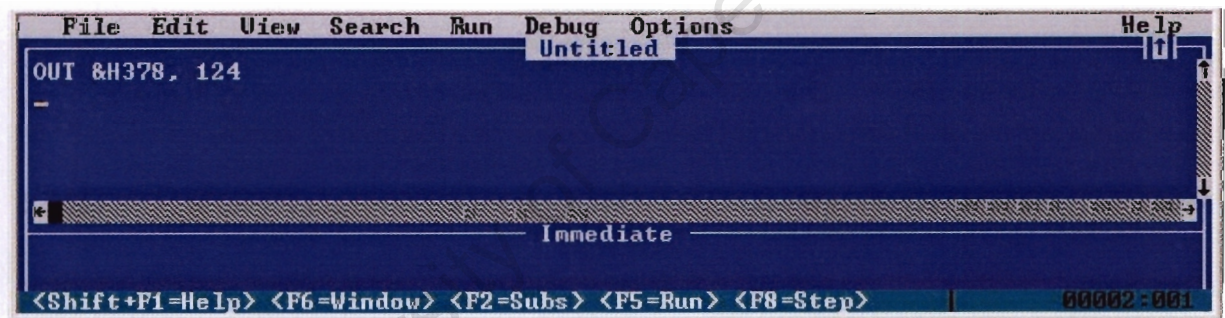
THE LIGHT LETTER SECTIONS							
•	G	F	E	D	C	B	A
VALUE USED TO SWITCH THE SECTION ON							
128	64	32	16	8	4	2	1

Table 2 – List of LED segment letters and associated values to switch them on

a. Showing different numbers

Remember to delete all the lines that you have already typed in before you type in any new lines. To have a number **8** show, we need to turn on C, D, E, F and G. Does this make sense to you?

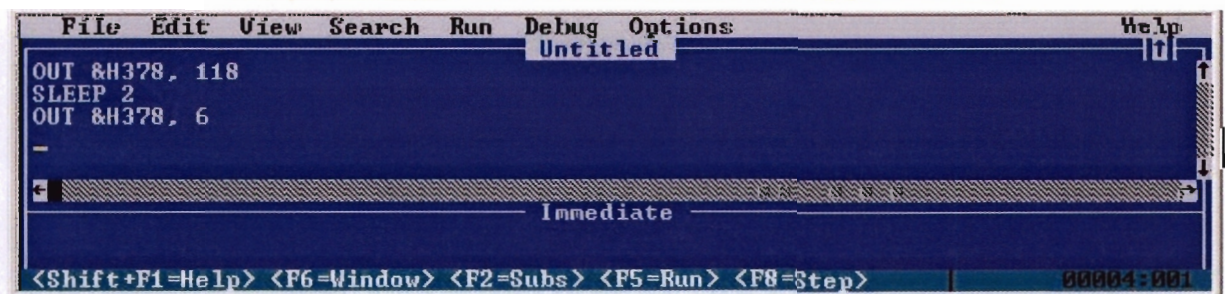
To do this you do exactly like you did before with the row of 8 lights. Look at the table above and add together the values shown for those letters C, D, E, F and G, ie. $4+8+16+32+64=124$. Type in the line shown in the picture below (by now you should be start to know what to do and what to type in without looking at the picture).



b. You can also make letters

By choosing different sections, you can also make letters. We are now going to make the letter **H** show and two seconds later turn on the letter **I** to spell "HI". To make the "H", we use sections B, C, E, F and G which from the table above tell us to use $2+4+16+32+64=118$. The letter "I" is just B and C, ie. $4+2=6$.

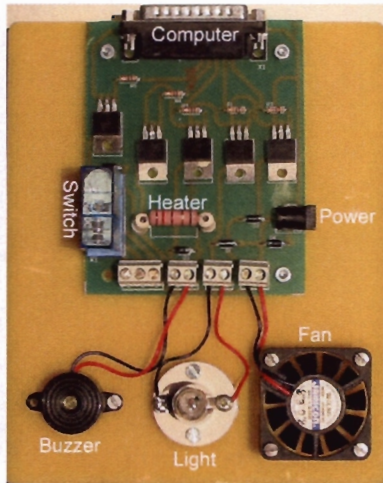
Try your own letters and numbers now, if you want to.



LED sections flashing the word HI

4. Moving from lights to a multiboard

When you are ready, you can plug in the multiboard shown in the picture. Do you need help connecting this device to the computer? If so, just ask, or try to connect it yourself... **Go on, you can try it. You can't break it... Just ask if you get stuck.**



Multiboard showing the layout of the devices

This multiboard has five things connected to it. There is a fan, a buzzer, a light, a switch and a heater. **You can switch these things on and off just the same way you switched the lights on and off.**

The fan can be thought of as light 1, the light as light 2, the buzzer as light 3, the heater as light 4, and the switch as light 5.

You can now use Table 1 to find the numbers to use to turn each thing on or off.

HINT: to make the heater really hot, leave it on for at least 15 seconds, ie, "SLEEP 15"

a. Switching a device on and then off again

If you want to turn the light on and then 3 seconds later switch it off, look at Table 1 and see that the value to use is 2. The programme shown below uses a "0" at the start and at the end of the code. **This is done to turn everything off at the start and then again at the end. At the end of your program, it is a good idea to always turn all the devices off. They will stay on automatically until you actually turn them off, ie. always end with OUT &H378, 0**

```
File Edit View Search Run Debug Options Help
Untitled
OUT &H378, 0
SLEEP 1
OUT &H378, 2
SLEEP 3
OUT &H378, 0
-
Immediate
<Shift+F1=Help> <F6=Window> <F2=Subs> <F5=Run> <F8=Step> 000006:001
```

IF YOU WANT TO, you can now try anything you like with any of the devices you have worked with. When you have had enough trying out things, just tell me and we can carry on...

Appendix B

Instructions to pupils for taking photographs

Thank you for being involved with my PhD research on what technology means and how people interact with technology.

The first part of the project is for you to take some photographs for me of *technology in your life*. What I would like you to do is to take photographs of whatever “technology” means to you.

You can take a photograph of ANYTHING as long as it is about technology in your life.

**Please take at least eight (8) photographs with the camera.
You can take up to 24 if you want to.**

I look forward to seeing your photographs. If you want a copy of the photos you take, just let me know and I'll print a set for you as well. If you decide after you have taken the photographs for any reason that you don't want to give the camera back to me, that will be OK.

When I have developed your photographs, I will come and see you for about one hour. During this time, I'll give you the chance to work with some technology related devices and a computer. We'll also chat about the photos you took as well as how you worked with the devices.

Thanks for doing this for me.
Brandon

How to use the Kodak camera



- Move the button (shown on the picture of the camera by “A”) in the direction shown by the arrow until the button stops moving.
- Push and hold down the word “Flash” (shown by “B”) while you count to 10.
- Look through the window (shown by “C”) at whatever you want to take a photograph of.

- D. Press the button on the top of the camera (shown by “D”) quite hard when you want to take the photograph. You will hear a click when the photograph has been taken.
- E. Try not to block the flash of the camera (shown by “E”) with your fingers when you take the photograph.

University of Cape Town

Appendix C

Photographs taken by pupils

This appendix illustrates the photographs taken by Thabo based on the instructions described in Appendix B. Alongside each photograph is an extract from his interview where he describes what he was ‘thinking about technology’ when he took each photograph. As these photographs were taken by a ‘novice photographer’, they are not necessarily of high image quality. In the context of the interview, it was not important whether the photographs were in focus or not, or indeed whether they were even artistically framed.

Notes on transcription conventions and abbreviations:

- The text in bold is the interviewer.
- ... Trailing off at the end of a sentence.
- () Interjection by the other person.
- [] Explanatory text.



It's like, clothes, to make clothes, it's different to the way its done now, like the material stuff. ... Technology includes like the fibre that's used in it, the different types of material and like the effort that went into it, it's not done in the same, in the same way as it was done in the past. **(Tell me about that 'effort'?)** The 'effort', to my knowledge, I think it's like sewing-machines and it goes like to factories, like a factory line kind of system, provide different people to different tasks and the machinery which each person uses is different and it was designed by probably some intelligent guy.



I thought most of like design takes place on PCs and it's like, it's entertainment and it's also like these things, scientific research. **(So you say Design takes place in PCs. Is the design the technology, or is the PC the technology?)** I'd say the PC itself was designed, so it is technology which, it's like it facilitates technology. Technology for technology.



That, that you use paper, like paper production, that's what I've thought about. And, 'Ja' and how these images were manipulated somehow with the program on the PC software which to me is technology. (**Okay, so the software is also technology?**) 'Ja', 'cause it's like it facilitates the correction of something else.



It's the public phone and like, this is like communication, like the government is spending lots of money on communication, telecommunications. ... I was thinking of the stuff that goes around, it's like you've got the satellite, which transfers all those, you've got like the, like Telkom Operators.



That's the electricity 'thing-a-me-jig' [dispenser]... Well, electricity itself, it's like, it facilitates so many other stuff like that, as you know, so it ... (**What do you mean by facilitate?**) 'Facilitate', it allows other stuff to take place.



Actually, I thought of it as technology, because of the cars there, it's like transport, human transport, its changed a lot and something that's progressive, so it definitely has to be technology and like all the stuff that goes around it, like the traffic lights, you can see them in the background, like you wonder how they should control them and, because I think in American movies, not in America, actually movies, actually control like centres, which are very up to, like very fast.



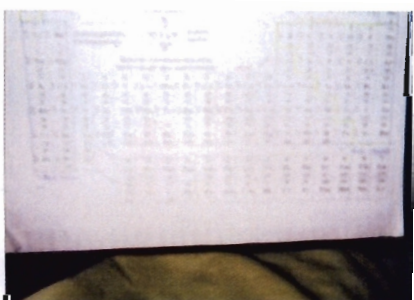
It's like, I thought about it as, in the olden days like how people used to get water and like already like they still, they still take a lot of scientific research to know what kind of elements you could use in order to create the taps itself and then the water, I just thought of, it's like, the basis of human life.



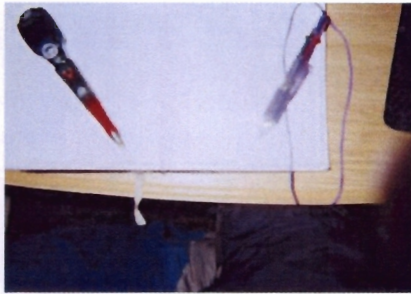
It's like, okay, this is a construction site and it was just like, it's like the basis of how, as you can see, it's like, this will probably result in something like that, you see. **(So the ground will be converted into, into a house, so what technology were you thinking about when you, when you took that?)** Construction, building. ... The building is knowledge and then it's like you use technology in order to bring your knowledge to life.



Well, it's like, it's part of entertainment and a lot like this, and there's a lot of technology used in TV production like I've done TV production and I know like the stuff which is there, very expensive for one and like the most, it is the most smallest thing that is [inaudible] stuff, so it's like the products here, like you may see TV like this, but you forget about the cameras, the lighting, the mikes that were used on.



'Ja', it is [a periodic table] actually. This, okay, it's, okay, all this stuff [pointing to the photographs], it's probably originated, it originated somewhere here. ... It's like the basis of technology, the foundation. **(Okay, what, those, those elements?)** 'Ja', 'cause like, every, if you take this, for instance, the metals [points to the telephone photograph] It's metals, if you take water, it's hydrogen and oxygen, you take, I don't know what paper is. That I don't know.



That is, okay, a lot of stuff has been documented, those are pens you can see. ... It's, okay, this is fact is a much more fancy pens, like, so it's like already itself, it's amazing how it was done, like you wonder how, how you were able to fit such a, a game on such a small thing [computer game on the top of a pen] and then it's like throughout times it's always been documented and documentation came through the pen. It facilitated something. **(Okay, tell me some more about this facilitating?)** It's like when you produce something, you need like stuff to produce a thing, like a raw material and then to me technology is like the raw material from which you create something and whatever your product, it probably facilitates something else as well...



A time-keeping machine. It's a sort of a watch. You know how small watches are these days and you wonder how it works, it's like, to me it is technology, because the person designed it probably had to go through a lot. **(So if it was a big watch, would it still be technology?)** It would still be, but it won't be as fancy as this, because I think what's happening with technology, it's like the smaller, the smaller it is, the much more fancy it becomes and the more liked it is.

Appendix D

Sample interview transcript: Part 1

This interview took place on 21 June 2005 with Trisha. Only the first part of the interview session is shown below. An exemplar of the second part of the interview (which takes place after a pupil has interacted with the structured activity) can be found in Appendix E where Shareen's transcript is presented.

Notes on transcription conventions and abbreviations:

- The text in bold is the interviewer.
- ... Trailing off at the end of a sentence
- () Interjection by the other person
- [] Explanatory text

What we got here are some photo's you took. What I want to do is, I'm going to just put a photo down and then, just thinking about technology, you were thinking about technology when you took the photograph, just tell me what you're thinking of. So if we put that one first, what is that?

That's a CD player, portable CD player. I took that picture because I mean technology help make that, before you couldn't get that CD player, you just put a small round thing in there and you press play and it will work.

So what was the technology then?

Sound technology. I was just thinking of engineering kind of things, things you make with engineering and you can use everyday kind of thing.

Okay you must remember there is no right or wrong answer here at all I don't know a right answer. All I'm interested is knowing what you had to say about it, it's really, really very open, so that you can't say the wrong thing at all, and what was that?

Computer

What were you thinking about technology?

You use a computer, which is technology, for your assignments your things, like for, you need it to run a business also, you can have all information on there.

You said the computer is technology, why is the computer technology, what makes it technology?

I don't know it's like, you just, you can use it for everything. For me it's very good technology, the person that came up with it is brilliant, because you wouldn't be able to cope without it.

You said the "person that came up with it". Is that also part of technology?

Ja, I think so.

Why?

He made it and he helped other, the computer helps other people with other technology, you can use the computer to make other technology, I just feel like that.

Okay, over there, and what's that?

A car

Yes, okay what were you thinking about technology with that?

I tried to show underneath the car but

Okay, well we can pretend that you took that photograph.

The engine and the workings of the car, technology for me, ummm,

Why is that?

You, I don't know, the way you work on the car and stuff, you need, like some parts technology, you need, that means for the whole car to work and engineering, you need mechanics.

What about the engineering

Hydraulics and pneumatics.

What makes all of those technology?

Ummm, we doing technology in grade nine so I remembered...

It's not about what you can remember of the class, it's what you think.

I think it's ummm, those things they help make the car work and you use that in everyday, and you just think it's technology and they made it, before you used to use a horse and a cart and now with a car you just put the thing in and you start and it will work.

Was the horse and cart not technology, is the car technology?

I think, no, no, the horse and the cart was also technology but I took it the car because the horse and cart, more, the car is a newer technology than before.

Okay and that? [Referring to the next photograph]

I tried to get the boat but the, it didn't, I think it make together like from the computer you got the laptop, so it was like newer technology so it get advanced to a laptop where you can carry it around with you.

Okay are they both technology?

Yes, they are technology.

What makes one a different technology or are they a same technology?

I think they different in ways but more or less they are the same. They do the same things but that's not with a printer but more or less they do the same thing.

Okay and that over there, what's that, what were you thinking about technology for that?

Art and just creation of different things, cars, and that's like an art work thing, graffiti.

Okay, so what is it about art that's technology?

Architecture and things, you draw things, make things, that kind of a thing, I think architecture for me was also part of technology, okay, this isn't advanced but it's similar to, I wasn't able to take [building ... inaudible] but I thought it was technology for me.

So if you had to say, if you had to give me one sentence about why this is technology, what would that sentence be?

Umm, architecture is technology because it's, I don't know, how can I say ...

It's no pressure...

I would say, ummm, difficult one.

We'll come to it, we'll come back to it, we'll talk about it in a different context, and that one over there, what's that?

Cell phone.

Why are they technology, what's technology in that photo?

The way the cell phone range and advances so quickly and you know you get new things, with the first cell phone you could just make calls, receive calls, SMSs, the next cell phone you get the more advanced technology like, I don't know use all this different kind of things that make it work and the colour screens, things like that, games, polyphonic ring tones, you can put video's on there.

So what about that is technology?

I think the way it is manufactured and the way it's made into a small little thing like that.

Okay, so is a big cell phone less technology than a small cell phone?

No. It's just that is, how can I say, the bigger one, you didn't have the effects of the smaller one with all the different kinds of things on it.

Okay, but they all still technology?

Yes, all technology.

Okay, and what about that one?

That one's a old camera, I took of before's technology (I didn't know how to look inside the camera) that is before and this is now, it just shows how technology has changed over the years and things. That one you didn't use batteries, you needed a spool, just snap away, and you used it differently. With today's camera, you just put it, the digital camera put it like this and you can take a picture, you can zoom, and you can un-zoom, change the colour.

But they are both technology?

Yes the both technology.

Is there anything else in that photo which is technology?

The cars and the CDs, ja, I think everything in that picture is technology itself, the woodwork and things.

Oh okay, the woodwork of the chairs, what about that is technology?

The way you make it, where you get the wood from the trees and things. How you change the texture and shape and the feel of the wood to make the chair.

Okay so is the chair technology or is then the process of getting the wood and the...

When they process the thing, more the process is the technology than the chair.

And so the chair is not really technology?

No.

Okay, and the CDs?

Before you got the LPs, the big ones.

You got a photograph here of those, okay, let's just talk about that photograph now, which is the CDs and the LPs.

CD and the LP, you can see the LP is much bigger they must have done something amazing because you get the small things now and that for me is technology because like with today's world and stuff, you, you don't get, okay, you don't see people using LPs anymore it's now more CDs and MP3 players and things like that.

Okay, you said somebody must have done something clever to get from the big one to the small one. Is that technology?

Ja, for me that's technology.

Tell me more about that.

Ummm, how they changed that big thing, and how they got the music onto this small plastic thing, that's so amazing for me, they just made it smaller and more convenient for other people to use.

If it wasn't convenient, would it still be technology?

Ja, yes, it would, I think we would still be using LPs today if they hadn't come up with CDs, we would still be using LPs.

Okay, and you've got here a?

Oh the TV, the DVD and the video machine.

What were you thinking about technology when you saw that?

The technology, like the way the TV works inside, the wires and things like that.

Okay what makes that technology?

Ummm, I would say, the working of the TV, how they get it to work and the look of it, how they get it to look like that, technology to make those things to come up with those ideas and things like that.

Okay so is that all technology?

Yes, that is all technology.

And then, this last one over here, what's that?

That's a LP player. Record player and that's the CD obviously

Record player and the CD together, so what were you thinking about technology when you took that photo?

A CD player you just take the CD and you put it in and you press play, this you move around to you no where...

But that, that's more how it works, so what about technology, were you thinking

Let me see [Pause].

Why did you take that photograph, I mean is there technology in there?

Yes there is, there is technology in there, the way it, I don't know, the way it affects our lives, our daily lives like, it might not be easier, it must be easy for you but it is for somebody else to use but it affects our daily lives with the way it works everybody else how they ummm, if they like that kind of technology or not and then they prefer the CD player or the record player.

Okay. What I'm going to do is put all these photos out in front of you and ask you to group them together in, thinking about technology, make them into groups about things that are the same about technology for you.

Okay [Pause].

Let's have a look. Let's take this one first, which is the record player and the CD player and the record and CDs. What about technology links those together, what is the technologies that link them?

Ummm, music, and also how you get to play the music, which way and the advances is like now you get the portable radio and the LP.

So is the fact, is the fact that it's advanced, is that technology?

Yes.

Okay, so if it doesn't advance is it no longer technology, if it's something that just stays the same for years and years and years?

No, I don't think so. Even if it stays the same from years ago it doesn't mean it's not technology and because, ummm, this is like, like you get this kind of CD player now, you didn't get those before but and whatever you use to make music that few years ago is also technology, but it's just you know earlier stage and this is now latest stage of technology.

Okay, ummm, so what defines, what defines that as technology then, what, what is the technology there?

I'd say, umm, let me think now, ummm...

If you can't think of something, not a problem...

Ummm, no.

Okay, let's have a look at what you got here, you got cars and an old camera and yes. Thinking about those three photographs what links those together?

I took the cars and then, because of the architecture of that, the artwork and [inaudible] the woodwork.

Okay so it's the artwork and the woodwork, what about technology is that?

The artwork could be umm, people like have different perceptions of art, some I think this is like graffiti and junk and others might think its actually good art. That for me is technology because I don't know, it just defines different aspects of the art. Some people like ummm, you get different kinds of technology obviously...

Okay now what is a different type that you get?

Like your mechanics and, ummm, what's that word now, engineering that kind of thing, you also get the basic technology, like easy things to use and easy things to make.

Like what?

Like also making food and that kind of things, that's also technology, the basic food groups, carbohydrates and proteins.

What about those are technology?

It helps your body and it helps your body to run smoothly and to go everyday things that for me is technology and the car, engineering and mechanics, things like that, that also helps you to carry on with your daily lives and it affects you, it affects you.

Is that important, the fact that it helps you with your daily life?

Yes, it does, it is important, and without technology these days, you, okay, you not be messed up but it will be actually, it will be weird without it, because I mean, TV is technology, you, you, I won't see myself without a TV or my cell phone, kind of thing. Also the woodwork, where you going to sit on a chair.

All right let's have a look at this group, which are computers and cell phones and TV?

Mmm, electronics. I'd say electronics, computer, laptop they basically do the same thing.

So what is the technology, which links them together?

Ummm, the not engineering, not software, I don't know you, they just do the same things so I thought okay, they, I took the picture because it's, this is like the basic thing that you use in your homes that's more for a business kind thing and ummm, the technology would be, I don't know, it's not software ummm, like a, can't get it, ummm, just the wires and the things like that, this one will use a lot of technology

What the computers, the big computers?

Big computer you use a lot of things like the wires and the things that make up the screen and the modem and the thing, what do you call it?

The box

The box, and this thing is like a small, flat thing.

The laptop, oh ja.

Ja, it can do a lot more than this computer, maybe this computer but it's much smaller and I think you will prefer the laptops to the big computers at home.

So what makes, so what makes the laptop technology?

Ummm, I don't know, just the working of a laptop though, the insides, the how it's made, the way it's made. To help you with your daily life, with your business and things like that, it helps you.

Okay, now what I'm going to do is just lay these photo's out that you took and ask you which is the odd one out?

None

None there must be one that doesn't fit? If you thinking about technology which one is the least like technology?

The least of technology, I'd say the artwork.

The artwork, why is that?

Because when I start taking pictures, I thought technology was only about electronics and things like this but I found out while doing this that it's not only about that, it's about the art, the architecture, the way things are made not just this kind of things, but food and a building and the way you build it and everything has to go in, according in a process in order for you to get it the way it is now, so I think it's where the art, I think for me.

Okay, so it's the art one. What's the next one, it's quite difficult I know, what would you think is the next one, thinking about technology, that's different from the other?

The camera and just the woodwork.

Is the woodwork the same as the camera, different?

Different.

Ja okay, so why is that one, why is that one different?

Ummm the cameras must be easier, ummm, it's much older and people don't use them today and it's a very, very old camera. It just shows how much technology has advanced and the woodwork I think it stays the same and you use woodwork to make the desks and things like that, it's not different from anything else, making anything else with wood.

And just one last one, which one would you say now is the least like the others thinking about technology?

The TV.

The TV, why would the TV be the least like technology thinking about the technology and others?

Thinking about now, ummm, the TV I think it has been around for quite a while and for ummm, first they didn't have TV's but now they doing it, it's made almost the same and there is nothing different about, like from that TV and another TV or a smaller TV or a bigger TV, I think there hasn't been any change in technology lately, [inaudible] it works the same.

So it's still technology?

It's still technology.

But because it hasn't changed what does that make the technology?

I don't know, ummm, it will be, how can I say, ummm, it's just, it hasn't changed so much from like, people usually change over a period of time and our advances it becomes boring for some people. The TV, it has changed over the years but now it's getting to the stage where I don't think a TV can change anymore.

Okay, so the technology has run out?

Ja, I think so, I don't think they can find anything else to do with the TV.

Was there anything that you wanted to take a photograph of that couldn't you couldn't find to take a photograph of?

Yes a building, a construction, it was so dark. So I was going to take a picture of a thatched roof of a building.

Why is that, what about technology is that?

To make the house you need all this ingredients and stuff, you need the cement, you need the sand, thatched roof, you need the stuff.

Is the sand technology? The cement technology?

I think its technology what's used to create the thing but ummm, I don't know, I just think its technology because you're making something, you using other things to make new things, which is a new technology.

Okay let's just pretend for a moment that you're writing a book on technology and you need a picture for the cover of your book, which photograph here would be the best photograph to use for your picture of your book on technology?

The cellphones.

Cellphones. Why would that be the best picture of technology for you?

To show it's changing, how it's changing, how it's changing and how technology actually to make your life better and it's, ja, I think the cell phone would show, you know, that's the old generation that's the newest, the latest cell phone and it just show how much technology has changed over the years.

Okay, okay, ummm, as a final question then before we move on, in your own words then, what is technology?

Technology is, I think it's life, it's, without it there is ummm, I think there is nothing, because you can't run your everyday life without technology these days because everything is made up of technology, it's fascinating, ummm, you need your oven, electric, electricity, that's all technology, the way it is made to help you and your life.

Okay what we're going to do, is just go over to this, you can sit on that chair over there now. This is a little multiboard and on the multi board you got a fan, a little light, a little buzzer, got some prestik on it to make it not too loud, there's a little heater over here, that heats up, a little switch over here and what you're going to do is, is you're going to work through that tutorial and that little worksheet and it will show you how you can go and work with these things, using the computer to control it. But before we start there, how would you describe this multiboard, what does it look like it could be?

A circuit and a lamp, a light circuit and a circuit board.

And how would you, if you had to come across something like this, how would you find out how to use it?

There would have to be instructions, else I wouldn't know how.

Okay, great, there's the worksheet for you to go through, just work through at your leisure and then when you finished we can carry on talking.

Appendix E

Sample interview transcript: Part 2

This interview took place on 22 June 2005 with Shareen. The transcript below is the second part of an interview session and takes place after a pupil has interacted with the structured activity. The exemplar of the first part of the interview session relating to photographs taken by the pupils can be found in Appendix D.

Notes on transcription conventions and abbreviations:

- The text in bold is the interviewer.
- ... Trailing off at the end of a sentence
- () Interjection by the other person
- [] Explanatory text

Why shooe?

No, I was holding my breath just in case I break something.

Why are you so worried about breaking something? Is that how you feel with all technology type stuff that you work with?

Yes, especially with a computer, yes.

What other sorts of things make you feel like that?

Maybe the computers, the DVD machine and so on, the radio sometimes.

And cell phones?

Yes, small ones.

The little ones. So if you had to get a, let's just say a cell, a radio another radio, a fancy radio, how would you work out how to use it?

I will just press buttons until I find out, what's happening.

Okay you not worried you're not breaking it?

No.

No okay, but what about computers then?

With the computer I will need somebody to help me or the book, the instructions will tell me what to do. Okay I received a cell phone a few months ago and I actually read the manual before I started using it because it's the small one.

Why is a small one different to a big one?

Because the big one I actually knew where to press and what to do and a different type of cell phone as well.

Do you always need the manual or do you sometimes not use the manual?

No sometimes not.

Is there any particular way when you know not to use the manual?

No.

Okay, what was it you think that you were doing up there?

Using a computer to switch on lights and heater.

Have you ever done anything like that before?

No, never.

Did you think you'd be able to do that?

I didn't know that I would be able to.

And how was it?

It was actually very nice.

You think there should be something like this in your school's curriculum?

Ja?

In the later grades, in grade eleven. (Yes) Would it be useful having something like that?

Very. It'll help.

You think so, and why is that?

Because some of us don't actually know what it's called or what, how to use it, so, this will actually, that will actually help us in guiding us in the future like if the TV breaks, you will know what goes where.

Okay is there anything like similar to that, that you worked with before?

I've watched people work with it, but I've never done it myself because the computer, our old computer broke down one day and my Dad fixed it, there's lots of what's joining the table to the computer.

The cables.

Ja, there were lots of those so it was joining that to different places.

And how would you feel if that was what you had to go and do?

If I had something like this to help me...

What the manual?

Ja, then I would do it.

Okay. Was there anything that you were doing over there that you didn't manage to finish or that didn't work for you when you were trying it?

No, I think everything worked.

Except for at the end there, those numbers, ja, and what was the difference, what made you think there was a difference between working with the little lights and then working with that multi board, with the numbers that you were sending to it?

It was the same symbols to use with both, all of the tables, but what was different was you had to add the numbers that you want and then the equal number you have to type in.

Was that different?

Ja.

So you didn't pick that up?

I did pick it up but it was just different to what I did before.

Okay so if it was the same as you did before would you have managed to get through it then?

Yes.

So when things are different with technology, does that make it more difficult to work with?

Not necessarily more difficult but it will make it more complicated where you have to figure out what goes where.

Is there anything else that you would have liked to have tried with that, anything that you didn't finish doing?

No.

Nothing. We were talking a few moments ago about having one of those multi boards as part of your curriculum in your classes, if it was in a classroom how do you think your friends will know how to work with it what do you think they would do?

They'll do the same as what I did.

Which is?

Read the manual.

And if they had a new video recorder that they received, or that they bought or got as a present, how would they learn how to work that?

Manual, ja.

Manual, not just pressing buttons?

No.

Why not?

Because it's an expensive thing and just in case you break it you will need to read the manual before just to know what is what.

Do you take things apart in the house?

No, I won't be sure where it goes afterwards.

And if you carefully take it apart?

Okay I have taken one thing apart, a video game. I didn't know what exactly was in it, so I just left it apart.

Did it ever work again?

No.

Okay and after that did you try taking anything else apart?

No.

Because of that?

I think so.

Okay, we were talking earlier with these photographs and things like that, what about this photograph here which is the photograph of the computer were you thinking about technology when you took that photograph?

Working with this now I can see that I've taken like the lights the cables in the computer itself.

Is that what technology is not the computer?

Ja.

Okay is there anything else about the computer which is technology?

No.

And we spoke about all these things earlier and the photographs you've just done and the activity. Is there any similarity between the activity over there and this technology over here?

Ja.

Is it the same stuff or different?

Similar stuff, like the computer and the TV are all the same as the thing that I did with the computer, but I don't think there is to the gate. This is the same as the heater.

Ahh so the heater, the photograph is the same as the heater.

Ja.

Okay, the same technology?

I think so and the fan could be...

Part of the washing machine.

Ja.

So what about the heater is the same then? The way that it makes the heat?

Ja, it generates heat, ja.

We spoke earlier about the photographs that you'd use on the cover of the textbook, was the vice over there. Would that that you done over there would that be a chapter in your textbook?

I think I will actually change my view of putting that on the cover I'll put a television that you open a television and all the gadgets and stuff in the television.

Why would that be a technology view?

The linking of different wires that help put the TV on.

Okay so is that technology? (Yes) So what will you call that chapter that forms part of that, the activity forms part of?

I'm not sure. Using a computer to work lights, something like in that direction.

So is that what you're doing you were using the computer?

To switch on and off lights and the heater.

And so what was the function of the computer then?

To put on the lights.

Thank you very much. I really appreciate you doing this for me.

Thank you very much.

University of Cape Town

Appendix F

Technology Profile Inventory – Discreet Option Type

Technological Profile Inventory

This questionnaire has been designed to explore people's ideas about technology. There are nine sets of questions below. For each question, please read through each of the statements about technology and **indicate with a cross (x) the ONE sentence** that you most agree with. If you agree with MORE than one statement, please make a cross (x) next to the one that you MOST agree with.

PLEASE ANSWER ALL THE QUESTIONS – ONLY CHOOSE ONE STATEMENT PER QUESTION

Do not spend too long thinking about your answer. Your first thought about which one to choose is probably correct for you.

Question 1

a	It is fun figuring out how technological things work without being given instructions to follow.	
b	I can usually use technological things when I follow instructions.	
c	To find new features on the technological thing and understand it better, manuals often help.	
d	I would rather get someone else to work a technological thing. I might get it wrong or mess it up.	

Question 2

a	Technology is a person making something to solve a problem and improve quality of life.	
b	Technology is using knowledge to evolve and develop to a product.	
c	A television is technology when you can watch a movie on it using signal from the air.	
d	Technology is all about computers and other electronic and electrical things like that.	
e	Technology is the changing or development of a product to help you in your life.	

Question 3

a	A map is technology because satellites were used to give the information needed to make it.	
b	Technology is something that has advanced over time and that makes life easier for you.	
c	Technology is using knowledge and skill to develop some product.	
d	Because a door has a handle and hinges and can be locked, a door is technology.	
e	Technology is making use of knowledge people have about something and using this to solve a problem.	

Question 4

a	I would rather watch someone work with a complicated technological thing instead of trying to do it myself.	
b	With a new technological thing, I play with it a bit and read the manual a bit – whichever helps me most.	
c	With instructions, I would be able to find out how to do what I want with this technological thing.	
d	I would rather play around with a technological thing than waste time first reading instructions about how to do it.	

Question 5

a	Things with complicated wires and parts that you don't understand are technology.	
b	Technology is coming up with an idea to solve a problem.	
c	An amplifier or CD player becomes technology when it is switched on.	
d	Technology is the process of progressing from something like the horse-and-cart to a motorcar.	
e	Technology is about using scientific knowledge to make something that makes life easier.	

Question 6

a	When I see a new technological thing, the first thing I want to do is play around with it to see what it can do.	
b	If someone first shows me how to do something with a technological thing then I can use it.	
c	I always ask permission before I use some new technological thing in case I break it.	
d	I like to understand a technological thing by playing with it as well as by reading more about it.	

Question 7

a	Something is technology because a person had a plan that was put into practice by making it.	
b	A washing machine thrown on a rubbish dump with no motor or wires is no longer technology. It is just a thing.	
c	Technology is an idea that has been put into place by someone to help people.	
d	A CD is technology when you put the CD into a computer and then copy music onto it.	
e	The process that goes into making (for example) a running shoe makes the shoe technology.	

Question 8

a	Technology is when a product progresses and develops over time.	
b	Technology is about solving a problem.	
c	Having wires coming out of things makes them technology.	
d	Technology is the planning and research of something and then the making of it.	
e	A door lock becomes technology when a key is turned in it and the levers move to lock it. Otherwise it is just a lock.	

Question 9

a	When using technological things, instructions tell me exactly what to do – and then I can do it.	
b	Finding out how a technological thing works is easiest by reading the manual and playing around at the same time.	
c	I always seem to do something wrong when I try to use technological things.	
d	I like opening up technological things to see what's inside.	

Please indicate your gender:

Male ☐ Female ☐

Appendix G

Technology Profile Inventory – Likert Type

Technological Profile Inventory

This questionnaire has been designed to explore people's ideas about technology. There are 41 statements below. Please read through each statement about technology and **indicate how much you agree with the statement by circling a number between 1 and 6.**

Circle the number ① if you **really don't** agree with the statement and ⑥ if you **really do** agree with the statement. The closer the number is that you choose to six, the more you agree with the statement. Do not spend too long thinking about your answer. Your first thought is probably correct for you. *Thank you for completing this questionnaire*

		Agree Less	1	2	3	4	5	6	Agree More
1	Technology is when a product progresses and develops over time								
2	Technology is coming up with an idea to solve a problem.								
3	Technology is something that has advanced over time and that makes life easier for you.								
4	With a new technological thing, I play with it a bit and read the manual a bit – whichever helps me most.								
5	The process that goes into making (for example) a running shoe makes the shoe technology.								
6	I like opening up technological things to see what's inside.								
7	It is fun figuring out how technological things work without being given instructions to follow.								
8	A television is technology when you can watch a movie on it using signal from the air.								
9	I would rather watch someone work with a complicated technological thing instead of trying to do it myself.								
10	Because a door has a handle and hinges and can be locked, a door is technology.								
11	I can usually use technological things when I follow instructions.								
12	Things with complicated wires and parts that you don't understand are technology.								
13	Technology is using knowledge and skill to develop some product.								
14	Something is technology because a person had a plan that was put into practice by making it.								
15	Technology is about solving a problem.								
16	An amplifier or CD player becomes technology when it is switched on.								
17	Technology is using knowledge to evolve and develop to a product.								
18	I would rather get someone else to work a technological thing. I might get it wrong or mess it up								
19	Technology is about using scientific knowledge to make something that makes life easier.								
20	Technology is an idea that has been put into place by someone to help people.								
21	A washing machine thrown on a rubbish dump with no motor or wires is no longer technology. It is just a thing.								
22	With instructions, I would be able to find out how to do what I want with this technological thing.								
23	Having wires coming out of things makes them technology.								
24	I would rather play around with a technological thing than waste time first reading instructions about how to do it.								
25	I always seem to do something wrong when I try to use technological things.								
26	Technology is the process of progressing from something like the horse-and-cart to a motorcar.								
27	When using technological things, instructions tell me exactly what to do – and then I can do it.								
28	Technology is all about computers and other electronic and electrical things like that.								
29	Technology is making use of knowledge people have about something and using this to solve a problem.								
30	To find new features on the technological thing and understand it better, manuals often help.								
31	Technology is the planning and research of something and then the making of it.								
32	Finding out how a technological thing works is easiest by reading the manual and trying things at the same time.								
33	If someone first shows me how to do something with a technological thing then I can use it.								
34	When I see a new technological thing, the first thing I want to do is play around with it to see what it can do.								
35	Technology is a person making something to solve a problem and improve quality of life.								
36	Technology is the changing or development of a product to help you in your life.								
37	A CD is technology when you put the CD into a computer and then copy music onto it.								
38	I always ask permission before I use some new technological thing in case I break it.								
39	I like to understand a technological thing by playing with it as well as by reading more about it.								
40	A map is technology because satellites were used to give the information needed to make it.								
41	A door lock becomes technology when a key is turned in it and the levers move to lock it. Otherwise it is just a lock.								

Please indicate your gender:

Male ☐ Female ☐