A STUDY OF THE CONTRIBUTION THAT PHYSICAL SCIENCE MAKES IN PREPARING STUDENTS FOR HIGHER EDUCATION AND THE WORKPLACE

by

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ABSTRACT

This work is a case study of the opinions of four young people who studied physical science while at a technical high school and then went on either to study in a scientific field at a tertiary institution or went to work in a technical field.

The purpose was to try and find out what contribution studying physical science at high school makes to learners who choose a career path in a technical workplace or in a scientific/technical field in tertiary education . The questions asked were firstly "What is the value of having studied physical science at high school to students entering the workplace and entering higher education?" and then "What skills and knowledge are required for employment in a technical workplace and for tertiary education?" and "What are the views of students, employers and lecturers on the preparation given to physical science students for the world of work and for tertiary studies?"

Questions were asked of the young people, their lecturers, and their employers. The idea was to find out whether subject-specific knowledge was important or whether there were certain skills which were considered more valuable. Skills were broadly defined as competencies that would enable a person to cope with the requirements of a new and different learning and work environment after leaving school.

Four young people with similar high school backgrounds were interviewed and their opinions noted. Structured interviews were conducted and compared for similarities and differences. The employers and lecturers were given a questionnaire to complete. They were asked what they expected of new employees and new students, and how their ideals matched the actual applicants whom they accepted. These answers were compared to those given by the young people.

It was found that although the subject content knowledge that learners received at high school was important, there was a general and definite lack of preparation in terms of critical thinking

skills and preparation for coping with unfamiliar problems. It seemed that the current examination-driven school system is not the best preparation for either tertiary education or technical employment, although much did depend on the particular teaching methods experienced by each student.

This study opens up a possibility of more detailed research into why so few learners who pass senior certificate physical science are adequately prepared for the fields which are under consideration in this enquiry.

PREFACE

The work described in this thesis was carried out in the School of Education, Durban, University of Natal, from January 2001 to June 2003 under the supervision of Dr Paul Hobden (Supervisor).

This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND : A TECHNICAL HIGH SCHOOL

I am currently the head of the physical science department at a large technical high school. This high school offers all its learners the opportunity to take subjects that will qualify them for employment in a technical workplace, or for pursuing tertiary education in a technical or scientific field. The school is governed by the local Provincial Department of Education and Culture. The learners follow the provincial (or national) syllabus in all subjects. There are five compulsory subjects during the final three years of the high school (grades 10, 11 and 12, or the Further Education and Training programme). These are: mathematics, physical science and technical drawing; English and Afrikaans. All these subjects are offered at both higher and standard grades. The sixth subject is classified as the technical subject. A choice of six subjects is offered: technika mechanica; technika electronics; technika electrical; electrician work; fitting and turning; motor mechanics. The first three are offered on both higher and standard grades, while the last three are offered only on the standard grade.

The learners are offered a programme that caters for a wide range of aptitudes, all specifically directed towards a technical field. Business related subjects or the liberal arts courses are excluded; the school is one of only a few that offers only technically orientated programmes.

1.2 RATIONALE : THE SAME OR DIFFERENT?

1.2.1 "Pure" science or science-and-technology?

I have wondered why there is no difference between the syllabi of technical and other high schools. One expects that science and the way it is taught at a technical high school, should differ from the science taught at a non-technical high school. If the point of a technical high school is to prepare learners to enter a technical field, then the focus should be on those technical fields. The content taught and the methods employed should all aim at giving the learners the best possible understanding of science, in particular physics and chemistry, that underpin all technical fields. They should be made fully aware that physical science is not a theoretical subject divorced from the technical subjects. It should be continuously and consistently interwoven with the technical subjects they are studying.

1.2.2 Content or skills?

In my experience as both a teacher and an examiner, I have found that the current broad science curriculum, involving mainly content knowledge and manipulation of learned facts and formulae, is not a necessary prerequisite for entry into the technical workplace or a tertiary education. I have wondered if perhaps it would be better to try to provide learners with more problem-solving skills and much less content knowledge. Specific content knowledge can be acquired comparatively easily, if learners have acquired suitable study skills, and have confidence in their ability to research a particular problem, or set of information, and glean from this the relevant factual knowledge for a specific purpose. With the rapid advancement of technology, one learner would be very hard-pressed to master all the factual information in any particular subject, or even any particular branch of a subject. I feel that it would be much more beneficial to know certain basic facts or figures, and then be able to access from modern high-tech sources or from reference books, further relevant information as required.

In order to cope with the increased pace of change in technology, there is a need is for school-based education to promote transfer of learning, so that skills and knowledge developed with success in one field can be applied in another. The present school curriculum is too compartmentalised: each subject tends too often to be taught in isolation. In technical high schools especially, there needs to be much more inter-connectedness across subject boundaries; science and technology must go hand-in-hand (Swift, 1992).
subject need to be related wherever possible to the facts of every other subject, but the way in which learning has been acquired successfully in one subject needs to be applied in other subjects. The way learning takes place is often more specific to the individual learner than to the specific subject. Thus school should be giving learners the confidence to try what works for them, in whatever subject-context they find themselves with a new problem.

There is much discussion about changing both the content and the methodology of teaching and learning of physical science (and other subjects) in what is now called the Further Education and Training (FET) band. The current emphasis is still on an examination-driven school curriculum which focuses on the content of science and solving problems with well-practised procedures.

The proposed changes will place more emphasis on a skills-based curriculum. To quote from the Draft Subject Statement for Physical Science (Physical Sciences): "The Physical Sciences curriculum should offer a relevant programme to prepare learners for future learning; specialist learning; employment; citizenship; holistic development; socio-economic development and environmental management" (Department of Education and Training, 2002, p.2). Learners will be required to consider the implications, for individuals and communities, of scientific and technological advances. This may mean fairly drastic changes to the way they are currently being taught, and also to some of the ways they have been encouraged to learn. This is the question that prompted my research: Is the way that learners are being taught physical science at high school adequate preparation for entering a technical workplace or tertiary education in a scientific or technical field?

1.3 OBJECTIVES OF THIS PARTICULAR STUDY

The Minister of Education has noted that more students are needed to study science and engineering at tertiary institutions. This is in part due to the lack of high school learners in the fourth phase of school education studying physical science and mathematics. At present, physical science is viewed by too many as being neither relevant nor valuable (Ramsden, 1994; Woolnough, 1995), when it should be viewed as fundamental to technical careers.

There have been numerous other calls for South African schools to provide a scientifically literate group of school-leavers. Specifically, there are calls for learners to be prepared for employment in technical fields that are vital to the economic well-being of the country as this can alleviate the high degree of unemployment in our country. To this end, there is an on-going revision of school curricula. This research may be able to inform the proposed changes by giving some insights from a small localised community. It may be able to impact directly on decisions that will be taken in deciding the direction for future physical science studies at school.

I will be considering the kind of science (concepts and skills) that has been taught to learners at this technical high school and how some of these learners have coped in the various scientific/technical fields they have entered after leaving school. I will also present the views of some of the employers and tertiary lectures involved with these students. I hope to show how these two groups of people see high school physical science teaching as fulfilling (or not fulfilling) their needs.

1.4 SCOPE AND LIMITATIONS OF THE STUDY

This is a small-scale study, limited to students from the local school that I am familiar with, and to tertiary institutions and places of employment in the same geographical location. I have tried to cover as broad a cross-section of school learners and post-school places of study and employment as possible. I interview an apprentice motor mechanic, an aspirant chemical engineer, a trainee computer programmer/network specialist, and a trainee technician in the civil engineering field. This study discusses the content of what has been studied in physical science at high school, and its value; and the science-related skills that are required in the workplace and at tertiary institutions. It researches matches or mismatches between what is taught at school and what is required post-school.

Because of the small number (four) of ex-pupils interviewed, it is not possible to draw broad generalisations from this study. But by choosing young people who have followed four very different pathways after leaving school, I hope to show that my conclusions are valid across a wide spectrum of school-leavers.

1.5 STRUCTURE OF THIS RESEARCH

I have assessed the research in this field both in South Africa and in other parts of the world.. This review is set out in chapter two. I have reviewed the literature under the headings: the purpose of school education, the purpose of science education at school, skills that should be developed at school, transfer of learning. My methodology is described in chapter three. I explain the design of my study, my choice of case studies, how I conducted the sampling, how I collected and analysed data. The case studies themselves are described in chapter four. The views of the young people are set out, as are the views of their employers and lecturers. Chapter five contains the analysis and discussion of my findings: the views of the young people and their employers/lecturers on how studying science at high school had prepared them for their planned courses of study or technical employment. My conclusions about the value of having studied science at high school are presented in chapter six.

CHAPTER 2

LITERATURE REVIEW

This study has as its main focus question "What is the value of having studied physical science at high school to students entering the workplace and tertiary education?" To answer this question, I have read the views of several authors who are concerned with science education at high schools and with the links between school education and preparing school-leavers for the workplace. I relate the views of authors who have written about the various reasons for studying physical science at high school and about the need to prepare learners for an increasingly changing and technological world. I also review the value of skills, both science specific and general, that are required and how it is possible for learners at high school to acquire these skills. It would appear that while much of the present high school physical science teaching is geared towards memorising scientific facts and procedures, and manipulating various mathematical formulae regarding these facts, the real need is for multi-skilled learners who can cope in an environment that is changing rapidly.

2.1 THE PURPOSE OF SCHOOL EDUCATION

What is the purpose of education? This is an age-old question. In the context of this research, I have chosen to respond in four different areas. Because I am teaching at a technical high school, which is different from other high schools, I have chosen to look first at the purpose of school education in general. Secondly I look at the specific purpose of science education at school. The third area I assess is the development of general life skills, as opposed to subject-specific skills. The fourth area involves the issue of transfer of learning: the ability of applying, with success, a method of learning acquired in one context to another, different context.

According to Schmidt (1953) a neo-humanistic ideal would state that an education should direct the mind of a learner towards the highest achievements of mankind and make the learner dissatisfied with the imperfect present. He goes on to state that the aim of education should be to develop the individual to the best of his/her abilities and to make the society in which s/he lives the best possible one for all concerned (p.79). He says that a "liberal" education should benefit both the learner and society as each learner will "leave school with an ability to judge contemporary affairs by clearly articulated standards and in the light of worthy human values" (p.81). Put another way, Jenkins and Whitfield (1974) state that the "basic objective of education must be an understanding of the world we live in and the world we hope for, understanding which can lead to effective action" (p.25). Lewin's (1992) view is that education must offer learners a means of trying to improve their quality of life without adversely affecting the environment we all live in.

These views emphasise aspects of education that go far beyond the mere mechanical learning and repeating of facts. They express a view of education that is holistic. It does not arbitrarily compartmentalise learning. It embraces the whole person; the society in which s/he lives – and this must also, by implication, be the whole of society and not just one small, isolated part of the society. It is a world-view of education. It is also a value-laden view. In order to make judgements about justice and freedom, a person needs far more than mere factual learning.

However, in order to be able to make judgements of any kind, an informed position is necessary. So information about many aspects of life is required. Thus each and every person must be given the opportunity to gain knowledge and understanding; and that knowledge and understanding should be as complete as possible. This again emphasises the inclusive nature of education. The 1995 syllabus for physical science states as its first broad aim that the teaching of physical science is to "provide pupils with the necessary subject knowledge and comprehension" (Kwazulu-Natal Department of Education and Culture, p.3). This contrasts with the later statement of the South African National Curriculum Statement for Grades 10 – 12 (schools) (Department of Education, 2002) which says that education prepares learners to enter "the world of work and take their roles as responsible citizens of South Africa" (p.2). The directive that education must make "responsible" citizens means that education does indeed have a broad, holistic aim. It is incumbent on educators to develop each and every learner to the fullest extent possible, for the benefit of the societies in which they live. School is not a place to merely learn facts, but a place where all individuals can grow and develop into well-rounded and well-informed people who can influence their surroundings for the greater good of all. In an increasingly technological world, a technical high school therefore has a central role to play: it is one place where learners can be exposed to the close inter-relationship between science and technology; how science underpins technology and how technology depends on science (Fensham, 2003).

2.2 THE PURPOSE OF SCIENCE EDUCATION IN SCHOOLS

A broad, general science education, accessible to all should be the starting point. The Department of Education and Training statement says explicitly that the study of physical science must give learners skills which will allow them to understand and deal with the world they live in. These skills are to be specifically relevant to working in scientific ways, as well as to stimulating curiosity about the physical world, developing respect for other scientific points of view, and enabling learners to be self-employed. How does the literature support these aims?

2.2.1 The importance of the context of taught science

Ayayee and McCarthy (1996) using data collected in Johannesburg, South Africa, argue for the need for 'scientific literacy' (p.56) and the importance of producing adequate definitions of science that are not limited to 'consisting of facts and processes' (p.55). In addition to helping learners cope with modern technology, school science must also take note of indigenous cultures and their technologies. Swift (1992), using studies conducted in developing countries, suggests that the context of science teaching could encompass 'high quality education, nutrition, health care, travel and entertainment' (p.1). Lubban *et al.* (1994) also write about the contextualised nature of science. What is taught at school must be based on both the learners' experiences and the wider world in which they live. School science thus has to prepare all learners to make responsible decisions on a wide range of issues that confront all citizens in their everyday lives. Black (1993) notes that science must be accessible, relevant and enjoyable to those who study it. He notes that the world in which we live is characterised by instability, and that the urgency of coping with these instabilities 'must surely affect priorities in science education' (p.10).

The literature demonstrates the need for a broad-based education, that contextualises science in the learners' own knowledge and social environment. The British research document, Beyond 2000 (1998) states that science education should, among other aims, 'help young people acquire a broad, general understanding of the important ideas and explanatory frameworks of science' and also 'appreciate the underlying rationale for decisions (for example about diet, or medical treatment, or energy use) which they may wish, or be advised, to take in everyday contexts, both now and in later life' (p.12). I agree with these views; but are they being implemented in our present school system? I hope to answer this question in the case studies I will present later in this research.

The content of school science must be carefully considered. But this is not easy. Van den Akker (1998) recognises that the proposed curriculum is not necessarily the one that is either experienced by the learners or attained by them in terms of outcomes. He quotes experiences in the United States of America and the United Kingdom, where educationists have tried to wrestle with the problems of reforming science education.

The need to obtain a 'relevant' science will, of necessity, mean that there will be quite a considerable variation in the work covered by different groups of learners. A national curriculum will not necessarily be the best one to follow. Careful pre-planning, can however, ensure that certain basic factors are covered by all participants. It is the "local" compared with the "other" that can make science relevant. This means that work compiled for one particular group cannot be transferred to another group without modification and/or adaptation. Cobern (1994) says that care needs to be taken during this adaptation process that feelings of inferiority are not engendered (p.66). Lubben et al. (1994) note a particular increase in interest among students when class-room science is shown to have direct relevance to their lives. Swift (1992) mentions that 'relevance in third world science education is ..... an attempt to modify science courses to better fit the ability of the student to take on board the new knowledge' (p.8). He writes that 'recontextualising science and technology education [is] the innovator's dilemma' (p.9).

Part of the problem is thus how to contextualise science. Lewin (1990) argues for the need for 'science policy and science education development ..... to be used in pursuit of more efficient and equitable deployment of resources' (p.2). Mphahlele and Kahn (1993) confirm what Lewin said, for the South African context: "The significance of locating science issues within the broader context of political, social and economic change cannot be overemphasised ..." (p.216). In South Africa the aim is to "enhance participation by citizens when they are called upon to exercise their rights in deciding on, and responding to the directions of science and technology" (Department of Education and Training, 2002). Lewin (1992) contributes further to this debate by noting that 'Each group with an interest in science education will have different perspectives' on what skills need to be taught to the learners. He goes on to say that 'without procedures to select and employ relevant knowledge and adapt it to new situations, the knowledge itself has little value' (p.46). He notes that learning that cannot be related coherently to the learner's conceptual frameworks 'proves fragile once the immediate need for it is taken away' (p.46).

It is thus apparent that what is taught in South African schools must have relevance to the contexts in which South African learners will encounter science and technology.

2.2.2 <u>School education for further study versus preparation for work</u>

Should school education be specifically designed to prepare learners for tertiary studies in an academic field or should it prepare them for the workplace? Ramsden (1994) helped develop the Salters' Method at the University of York to try to deal with this problem. Teachers and other stakeholders, including industrialists, were brought together to develop a curriculum that would be both appropriate and attractive to all high school learners. It is a guide that can be used to inform our decision-making processes in South Africa. Berryman (1990) notes the dilemma experienced by educationists in America where industry and commerce seem to be asking for one set of results from education by which "improving individuals' skills would shift the economy towards workplaces reorganised to make productive use of additional skill" (p.344) while at the same time noting that economic decline could probably be blamed on a failing school system because of the 'emphasis on access and relevance rather than excellence' (p.343). The question for all schools is how to balance these demands. Schmidt (1953) states: 'Vocational needs [since the Middle Ages] were a very powerful factor in promoting the growth of education and in creating a ferment of fruitful thought about it' (p.77). These two authors, separated by distance in both time and place, highlight a present educational dilemma.

The need to provide more science graduates from high school equipped for science careers focuses the debate of specialised vocational training over general school education. Swift (1992) states that 'Vocationally-oriented education is an increasingly popular, though controversial, response to the centrally-perceived lack of relevance of much of the general secondary curriculum to the needs of the less-academically capable students and the rural community's need for their services' (p.11). He adds that vocational education must however not be seen as an attempt to decide on just one focus for the future prospects of a whole group of learners. It is a suggested response to the needs of the society in which the learners live and will have to make their future careers.

Bottoms (1999) refers to an American study which found that academic skills needed by learners entering the workplace were enhanced at school if the learners were shown the direct relevance to a particular work situation. His study reports the success achieved by actually taking learners into the workplace. This is something that could possibly be used with similar success in South

Africa. While the American study was geared at "vocational completers" – learners who were not going on to tertiary education – there is surely a need to pursue all possible avenues to upgrade the skills required by learners entering the modern worlds of science and technology.

The literature thus shows that school education should be a preparation for both further study and the workplace. Both are part of life and are not mutually exclusive. I think that this may justify the existence of a technical high school that prepares its learners for a choice of entering a technical workplace directly from school, or to enter a technological field in tertiary education.

2.3 WHAT SKILLS SHOULD SCHOOLS BE DEVELOPING IN LEARNERS?

2.3.1 General skills

Skills that can be used throughout life, such as problem solving, decision making, investigating, communicating, must be promoted by all systems of education. According to Fensham (2003) the skills required are creativity, a desire to inquire, the ability to communicate, team spirit, personal interest, perseverance and social concern (p.16). These skills can and should also be taught in science classes.

It is necessary that the school system provides all learners with certain basic skills. This is especially true in science-related fields. Education must also provide the learners with the skills that will equip them for a future outside of the school. The need for life skills beyond school is emphasised in the following excerpt:

> The achievement of comparative advantage on world markets has moved from the traditional emphasis on low-cost production to that of high quality manufacture. This means that greater skills are now required to meet the "increased cognitive demands imposed both by the new computer-based technologies and the need for rapid responses to global fluctuations to product demand" (Kraak, 1992 cited Motala and Pampallis, 2001, p.125).

2.3.2 Specific science skills

Black (1992) advocates that specific science skills encompassed by the scientific method, such as observation, measurement, making generalisations, inventing hypotheses, devising fair tests, designing experiments, analysing data and interpreting results, should all be developed deliberately. They must be included in school science lessons as a matter of course.

Fensham (2003) has done recent research on what is needed in science education. He reports on work done in Canada, the United States of America, Britain and Australia. He states that science must be studied for itself: 'the excitement and wonder and challenge of science' (p.10). He did empirical studies in China and found that citizens needed students to study science that related to their everyday lives rather than unfamiliar text-book prescribed science. The skills Fensham identified were investigative skills and scientific method in order to learn concepts and develop problem-solving habits so that what he calls 'scientific habits of mind' (p.18) will be acquired. For example, measuring is a specific skill, and measuring accurately is necessary in many tasks. Millar and Osborne in "Beyond 2000" write about the need to inculcate the concepts of 'uncertainty' in measuring and why it is necessary, and the need to develop the ability to investigate the interaction between variables and to communicate the results in different but clear and understandable ways (p.21). This takes specific everyday skills and puts them into a scientific context.

2.3.3 Vocational skills

The skills mentioned in the preceding section will be used primarily in science related fields, but have applications to other fields of education and life as well. The SCANS Report (1991) in the United States of America outlines the necessary skills that school-leavers need to succeed in the workplace. The first group of skills required are basic skills. They include reading, writing, arithmetic and mathematical operational skills, listening and speaking. The second group of skills is thinking skills. Included here are creative thinking, decision making, problem solving, seeing things in the mind's eye, knowing how to learn and to reason. The third group is described as personal qualities. A person is required to display responsibility, self-esteem, sociability, self-management, integrity and honesty. These skills are then contrasted with workplace competencies. Management of resources such as time, money, material, facilities, and human resources constitute one group of skills needed in the workplace. Interpersonal skills are also required competencies. Acquiring and using of information; understanding complex inter-relationships; working with a variety of technologies are further competencies that the workplace requires.

The Schools to Work report (2000) cites the benefits to both businesses and schools of the 'schools to work' initiatives that have been taken in parts of the United States of America. This was a project aimed at improving learners' abilities at school by exposing them to the workplace where they could see the "real world" applications of their school studies. Relevance of school subjects and new enthusiasm for traditionally difficult subjects were the learning experiences of most participants. Renewed enthusiasm for learning was very much in evidence after completion of the programmes. I will refer to these documents again in the analysis and discussion of data.

2.4 TRANSFER OF LEARNING

Learning is not a neat, compartmentalised activity. It is a unique, ongoing process that each person embraces throughout his or her life. One way of trying to cope with the modern world is to apply transfer of learning (Learning and Transfer, 2002), that is, to apply methods of learning which work in one context to learning something new and different in another, unfamiliar context. The aspects of the modern world that are concerned largely with scientific and technological advances are changing rapidly. Many learned techniques become outdated almost as soon as they are learnt and mastered. School education has to equip learners to cope in this kind of environment. They must feel confident to enter a rapidly changing world and not just survive but thrive there.

Black (1993) notes how 'notoriously difficult' it is to transfer learning to new contexts (p.14). Unseen problems can be a major "problem" for some learners. The difficulty is not just a mental difficulty. It is one that requires determined effort on the part of the learner. And many learners are unwilling to make this new effort within, say, their science classes. The school system in South Africa as elsewhere has traditionally packaged its education in water-tight compartments, thus making transfer difficult. Science learning patterns are not seen by many learners as usable in other subjects, nor are successful learning methods in other subjects applied in science classes. Lewin (1992) states that the nature of science and the nature of learning must both be considered when deciding what to teach, when and how to teach it, and to whom to teach it.

Modern theories of learning and transfer emphasise several aspects that will promote the successful transfer of learning. The first is the need for learners to master the original subject matter. Without this, there is nothing to transfer. But learning must not just be memorizing a set of given facts or following a fixed set of procedures. Understanding is also required. This is the second important aspect. To achieve understanding in any context, time is important. 'In all domains of learning, the development of expertise occurs only with major investments of time'

(Learning and Transfer, 2002). Another effective aspect is engaging in the 'deliberate practice' of actively monitoring one's learning experiences (Ericsson et al., 1993, cited in Learning and Transfer, 2002). Learners of all ages are more motivated when they can see the usefulness of what they are learning. Teachers need to make sure that one successful context of learning is not limited to that single context. Learners need to be encouraged to see how that learning can be applied with equal success in new, but related contexts, then how it can be applied to an *un*related context. This will enable transfer to occur more readily. Relevant features of learning can be extracted from situations in which they have been successfully achieved, and then applied to other situations. As learning and understanding progress, higher levels of abstraction can be presented to and represented by learners. All these processes are dynamic; learners should be involved in cyclic patterns involving choice, evaluation, consideration, feedback. This pattern does not just happen; it has to be actively and deliberately implemented. It can be compared with the heuristic method that Schoenfeld (1985) teaches for solving mathematical problems.

Difficulties in achieving transfer of learning can occur. A learner's previous experiences are not always helpful foundations on which to build new knowledge. Sometimes they can be a hindrance. Preconceptions can hinder the development of new understanding. Those who want to produce new learning or possibilities for new learning will have to be aware of this, and ensure that misunderstandings are at least reduced if they cannot be entirely eliminated. The social and cultural background of a learner can also hinder the transfer of knowledge. Ideally diversity of background should be seen as an advantage to learning. The trick is to say if it could work in one context, could it work in another? This is transfer – and it can become learning.

Woolnough (1995) quotes from international studies to show that science activity in schools and its links to related activities outside the school environment were strong factors that influenced learners to continue their studies in science in the later years of high school. Ramsden (1994) notes the primacy of classroom atmosphere in promoting a favourable attitude to science among learners. Learner perceptions of the benefits to be obtained from following a science career were also factors that positively influenced their choice. These factors are similar to those which I think apply in South Africa. They include the perceived difficulty of subjects like mathematics and science, be the latter physics, chemistry or biology. Another perception prevalent among learners is the non-relationship between their own lives and science, between science and work prospects.

If transfer of learning were actively promoted in classrooms, then much of this negativity could be overcome. Learners would be better "educated" – they would have better developed skills which have a wider application; they would be able to take their place as scientifically literate members of their community and would also be able to progress into rewarding careers in scientific and technological areas.

2.5 CONCLUSION

The literature supports the importance of presenting learners with science that is related to their own life – their present circumstances and experiences; science that is relevant to possible further study and career opportunities.

Science education at school can provide learners with skills that are necessary for further science education. It can also provide skills that are required by workplace employers. This study wants to find out if our high school science education is actually providing learners with these skills.

CHAPTER 3
METHODOLOGY

The main question that I wanted to answer in this research is "What is the value of having studied physical science at high school to students entering the workplace or tertiary education?" To obtain answers to this question I contacted some ex-pupils who are employed in technical workplaces and some who are studying at tertiary institutions. I then asked the same question to their employers and lecturers to find out their answers. Finally I compared the two sets of answers.

3.1 DESIGN OF THIS STUDY

3.1.1 Case studies

I decided to do short case studies of four learners. Following Skate (1988), I hope that the case studies will show how these young people found that their high school education, and in particular, their science education, has helped them in their chosen fields of employment or study. I will present their reflections on their high school experiences, particularly in physical science, and their present reflections on what was or was not helpful in those experiences. I will also relate the comments of the lecturers and employers directly involved with these young people, on similar issues. It seems to me that these case studies would be classified by Skate as 'instrumental case studies … or [a] collective case study' (p.237). This is also what Bassey calls 'story telling … case studies' (Bassey, 1999, p.62.).

When I decided to do this small-scale study, I needed to find students who would give me a suitable diversity of post-school experiences. I had some difficulty in obtaining more students but felt that the four who did agree to participate, would give me both the diversity that I was seeking in terms of different aspects of their career paths after school, and rich, personal experience of what they had gained by studying physical science at high school. This is an interpretative type of research. I chose this method because, like Gallagher (1991), I wanted to use the idea of 'How are events occurring here [in the interviews] related to events … outside the school?' (p.13). I hope that, from these cases, some generalisations may be drawn for further investigations into what is taught in high school science and why and how it is taught.

3.2 SAMPLE

3.2.1 Size of sample

I felt that four persons would provide sufficient diversity for a small-scale study. They would give a sufficient spectrum of the types of tertiary education and places of employment involved: two full-time students, one at a university, the other at a technikon; and two who are currently employed by technical concerns which are providing post-school training in their particular fields. Both these latter students are studying part-time through a technikon, and the practical work they are doing forms an important part of their final diploma. Three of the four students were all at the same local technical high school, while the fourth attended a different technical high school in the same city. All four are currently still living at home while studying or working.

3.2.2 Limitations of sample

This is a limited sample, but it represents a sample that represents students who did their school study at a technical high school and then moved on to four different post-school technical fields. Three of the interviewees were male and one female, and they represent two different South African ethnic groups. Three of the four interviewees were students whom I had taught during at least one year of their high school education, and in particular, during their grade 11 and/or grade 12 years at high school. The fourth student was selected by the human resources manager of the company where he was currently being trained. I did not continue to search for more students to interview because of the limits of time and financial resources.

3.2.3 Ethical issues involved

The ethical issues of informed consent and confidentiality involved in this (as in any other) interview were cleared with the four young people verbally and by means of a letter, explaining what it was that I was doing and why I was doing this research (Cohen, Manion and Morrison, 2000). I emphasised to each of the four interviewees that there were no intentions of trying to influence anybody involved, either positively or negatively. I stressed that I was only interested in obtaining their views about the current high school physical science syllabus and how it had helped, or not helped, them in their present positions. All the candidates agreed to be interviewed; they agreed that the interview could be tape-recorded and transcribed. They were assured that their confidentiality would be respected; they would not be identifiable by anyone reading transcripts of their interviews. None of them seemed unduly concerned about this (Cohen *et al.*, 2000).

3.3 DATA COLLECTION

I have chosen two main methods of data collection for the case studies. The first involved interviews with the post-school learners, and the second involved questionnaires given to the present employers or lecturers involved with these learners.

3.3.1 Interviews

Who was interviewed, and where: The first three interviews were done with the three people whom I had previously taught at high school. The interviews were conducted at their homes in order to make them feel as comfortable as possible, and to allow the conversation to be natural (Walford, 2001). Although I had not been in any of their houses before conducting the interviews, I had spoken to the interviewees in contexts outside of the original classroom and teaching context. The interviewees seemed happier to be interviewed at home, perhaps because I had my own transport and could reach them conveniently, whereas they would have had to involve a third person to transport them to any other venue (Bell, 1993). The atmosphere was a little formal at the beginning of the interviews, but relaxed noticeably as the interviews progressed. Cohen *et al.*, (2000) note the need to overcome 'likely asymmetries of power' (p.279). Each of these three interviewees was a confident and outgoing person. They were not afraid to state their own opinions, which I knew from their time at school.

Bell (1993) and Walford (2001) both note the danger of bias creeping into an interview. They state that there is a danger that the interview may become a reflection of what one party perceives is required, rather than an honest exchange of ideas. The interviewees, I am sure, wanted to show themselves in the best possible light, but it became apparent that they were very willing to admit their own shortcomings and difficulties, and quite pleased that they had conquered some, if not all of these problems. They were capable of seeing their own strengths and weaknesses, and thus there was no evidence of any bias towards projecting a glamorised picture of themselves.

The fourth interviewee was a complete stranger to me. He had been selected by the Human Resources Manager at the company where he was currently undergoing training. The interview was conducted in a boardroom of that institution. This was very different to me being in the home of one of my former students. Both of us, the interviewee and the interviewer, were a bit nervous at the beginning of the interview, but the young man relaxed as soon as the purpose of the interview was explained in detail (Tuckman cited in Cohen *et al.*, 2000). The young man answered the questions confidently, and was quite prepared to ask for clarification when he did not understand any specific question. He, like the others, was quite prepared to state his strengths and to explain how he had overcome his weaknesses.

Type of interaction: The interview method was chosen to 'interchange … views between two or more people on a topic of mutual interest ….' (Cohen *et al*., 2000, p.267). Bell (1993), however, states that interviews allow for more than the exchange of views. They also allow for probing of responses and follow-up on ideas discussed. Although an interview is mainly an exchange of ideas between two people, it must not be forgotten that an interview is 'an unusual affair' (Walford, 2001, p.87). There is a definite and specific purpose to the conversation. Particular questions will be asked, and it is expected that answers will be given to those questions. The conversation and the exchange of ideas is not entirely spontaneous; it is requested by one person, the interviewer, and agreed to by the other, the interviewee.

The interview format chosen for this study was 'non-scheduled structured interview' (Bless, Higson-Smith, 2000, p.105). There was a definite time and place for the beginning of the interview, but the course could not be strictly predetermined. The questions that were asked related not only to the content of the secondary school physical science syllabus, but also inquired about other skills and knowledge that the young people had found beneficial. Questions were also asked about particular gaps in their preparation, perceived or real, and how these gaps were filled during their work or learning experiences; also how they might be filled at school level in the future.

Questions were drawn up and given to each of the young people before the interview (see Appendix A). The language in which the questions were framed was carefully considered, so that it was as clear and unambiguous as possible (Cohen *et al*., 2000). These questions formed the basis of a recorded interview. The interview was not limited to just these questions, as other probing questions were also asked, depending on the responses from each person. The same schedule of questions was given to each interviewee, so that the researcher could be reasonably certain that the same ground was covered each time. The questions and answers had to be 'more than just an interesting conversation' (Bell, 1993, p.94). It was important that the answers obtained would indeed be helpful in answering the research questions.

Although each person interviewed was asked the same questions in the same order, each interview was different. Walford (2001) states that every person interviewed will have a different idea of what an interview is, and will bring his or her own construction of an interview into the answers that are given. The way in which the questions were answered varied quite significantly from person to person.

The interviews lasted between forty-five and sixty minutes each. Each person agreed to be contacted again if it should prove necessary, either to clarify points initially made or to obtain further information. Notes were made during the interviews. These however tended to serve as checks on content answers rather than on the non-verbal responses of the interviewees. The answers were not rated as correct or incorrect, good or bad. There was a degree of freedom to comment on answers, either to agree with feelings expressed or to probe for specific answers when vague or general answers were given. The comment in Cohen *et al.*, 2000, 'that the interview is a social interpersonal encounter, not merely a data collection exercise' (p.279) seems to sum up the feeling at the end of each interview. The young people seemed glad to have had an opportunity to say why they had chosen their particular career paths.

Each interview was transcribed by an outside dictaphone typist. This was done for reasons of time and accuracy. The transcriptions were then used, with the original tapes, for writing up the case studies. This allowed me as the writer to keep to a minimum the possibility that 'the transcript data can become an opaque screen between the researcher and the original live interview situation' (Cohen *et al.*, 2000, p.281). Although Walford (2001) states categorically that he rarely uses full transcription of interviews, I felt more comfortable with this method. I have had little experience of taking field notes, so did not want to rely on inadequate notes. Also, it was not always possible to do transcription of any kind immediately after the interviews. I felt that this transcription method would provide an accurate record of what was said. By keeping the original tape of the transcript, I felt that most of the factual content of the interview was also available for future reference.

3.3.2 <u>Questionnaires</u>

Why questionnaires? Time constraints suggested a questionnaire format for obtaining data from lecturers and employers rather than another set of interviews like those with the four young people (Cohen *et al.*, 2000, and Sanders (1995). The questionnaire also provided a second method of obtaining data for this research. The questionnaires were drawn up in order to find out whether the school-leavers who apply for positions of employment or for study at tertiary institutions have the skills that these places require of their intake people. Sanders (1995) notes the difficulties of drawing up a suitable questionnaire. It was nevertheless thought worthwhile to use this method because of the time constraints of both the researcher and the employers and lecturers concerned. The questionnaire was first tried on an employer of people in a technical field who was not in any other way involved with the research; then it was refined before using in this research.

How were the questionnaires administered? Questionnaires were taken to the two tertiary institutions where interviewees are studying and to the two places of work where interviewees are currently employed. The first employer used one form of the questionnaire. After careful consideration of the answers obtained on this form, I felt that the questionnaire needed modification in order to get a clearer focus of questions, and then, of answers. (see Appendix B). The other employer and the tertiary educators were given a modified version. These questionnaires were given so that the answers provided by the interviewees could be compared with those provided by the persons who were directly involved with their on-going technical education.

I personally went to the lecturers and employers concerned, at a pre-arranged time, and explained the purpose of the research itself and the visit in particular. I stayed with the people while they filled in the questionnaire, and therefore I was available to clarify any problems or ambiguities that arose. The respondents were asked to answer the questionnaire twice, using different coloured pens. The first answer was to gain an ideal picture of what these people would really like, or felt they really needed, from new intakes into their organisations, and the second was to give a picture of what they were actually getting from the most recent intakes.

Format of the questionnaires: Most of the questions required a rating scale response. The example of a Likert scale (cited in Cohen *et al*., 2000, p.253) was used. This was done to enable responses to be as discrete and unambiguous as possible so that later analysis could be simplified. After answering each group of questions, an opportunity was provided for a more detailed and individual response. Open-ended questions were included to allow the employers and lecturers to express views other than those directly asked for in the rated questions. Cohen *et al*., (2000), recommend this approach both to allow the respondents to feel that they have a worthwhile individual contribution to make, and to get a richer response than a rating scale allows.

To find out whether students from a school like the one at which I teach would have had markedly different skills or knowledge at university intake level compared to students from historically disadvantaged schools, an extra perspective was obtained from an access programme at the local university. This programme that caters specifically for students who have had comparatively poor preparation for tertiary education but still show an interest in, and an aptitude for, technically oriented studies. One of the faculty members of this programme was given the same questionnaire as the other tertiary lecturers. His answers provided an additional perspective of the benefits of studying physical science at high school as preparation for tertiary education in a technological field.

3.4 ANALYSIS OF DATA

3.4.1 Comparisons: Interpretative analysis

The data obtained from these two sources, interviews and questionnaires, was compared with two sets of written documents: one being the objectives of the Department of National Education and the other the written admission criteria used by the specific institutions where the interviewees are currently employed or studying.

The two sets of experimentally obtained data were analysed to see how they provided answers to the questions 'What are the views of students, employers and lecturers on the preparation given to high school physical science students for the world of the workplace and for tertiary studies?' and 'What skills and knowledge are required for employment in a technical workplace and for higher education?'. The answers to these two questions were then compared and analysed in order to answer the question 'What contribution does the study of physical science make in preparing learners for the workplace and higher education?' It was hoped that in this way, reliability could be achieved by having the same set of interview questions and the same (in fact, very similar) questionnaire for all participants (Cohen *et al.*, 2000). There would also be some triangulation between the different sets of data collected. Stake (1988) also notes that comparison and triangulation are needed in order to allow for clarification of meaning.

3.4.2 Summary of data

A summary of the data gathering techniques and results is contained in the table that follows. The main question to be answered was "What contribution does the study of physical science make in preparing students for higher education and the work place?" This was broken down into two smaller questions.

The following table (Table 3–1), shows the relationship between the instruments used to collect data and the research questions.

Table 3–1 Relationship between instruments used to collect data and research questions

Instrument	Question 1 What skills and knowledge are required for employment in a technical workplace and for higher education?	Question 2 What are the views of students, employers and lecturers on the preparation given to physical science students for the world of work and tertiary studies?
Interviews with students	4 interviews	4 interviews
Questionnaires for lecturers / others	3 completed questionnaires	3 completed questionnaires
Questionnaire for employers	2 completed questionnaires	2 completed questionnaires
Documents	Entrance requirements Provincial Education Department syllabi Introduction to C 2005	School curricula, examination results

3.4.3 Coding of data

After reading through all the answers, given in interviews and questionnaires, the answers were coded into specific categories (Merriam, 1998). Some of the important categories identified were: subject knowledge from school, understanding rather than just memorising: seeing the relevance between school science and the world of work; learning time management; the ability to work on your own; learning through "hands on" experience; determination to succeed. Once this was done, the descriptive case studies were written up (Merriam, 1998). The significance of these studies and the possibility of drawing conclusions from them was done. The four case studies were assessed in order to find similarities and differences (Wisker, 2001). The identified codings were used. The documents that detailed the entrance requirements were then considered to see how the expectations of the workplace and tertiary institutions were realised in the actual candidates who were accepted. This was all done with a focus on answering my research questions.

3.5 CONCLUSION

I found that the interviews did yield some rich data about the views of the four young people on the benefits they felt they had got from studying science at high school. Being with them, I could probe their responses and check that I understood what they were actually saying. The questionnaires given to the employers and lecturers also gave me usable data. I found that being present when the questionnaires were filled in helped me to clarify questions and it gave the respondents the opportunity to sort out immediately any problems they had with the questions being asked.

Analysis and comments are presented in chapter five. Conclusions based on interpretations of the analyses are presented in chapter six.

CHAPTER 4
CASE STUDIES

This chapter contains the stories of the four young people who were selected for this research. The stories presented here represent the thoughts of these people, compiled from transcripts of the interviews and answers to the questionnaires. I decided on the most appropriate headings from my own data. I used the SCANS Report (1991) for the categories of skills required in the "workplace". These seemed to apply to tertiary institutions as well. The headings are much the same as those used by Fensham (2003). I integrated the young people's answers with the views of their employers and lecturers.
The names used in this chapter are fictitious.

4.1. JOE

4.1.1 School career and work situation in the present

Joe is a young man who passed his senior certificate exams at the end of 1999. He studied a common combination of subjects at a technical high school: English, Afrikaans, mathematics, physical science, technical drawing and wood-work. He says he was an average to above-average student who always wanted to "do" things and then understand why things happened the way they did, rather than a student who just memorised what was put in front of him. He wanted to know about things and then progress to higher levels of understanding.

After school, Joe enrolled for a civil engineering diploma at a local technikon. As part of the course, he has to complete a certain amount of time doing practical work in his field of study. When I met him, he told me that he was at the end of a six month practical training period at a national public utility corporation concerned with transport. This training course would complete the third year of his four-year course at the technikon. He would then return to the technikon for lectures for a further six months, and then complete another practical training period of six months before graduating as a qualified technician.

At this public utility corporation, Joe has been involved in project design and partial design of projects. He goes out on site to help initiate projects and do inspections. The team he is part of works on various on-going projects, like building bridges and drains; and helps to find solutions to problems that arise in these and other projects. He and the team also check of equipment and built structures. According to Joe, the team as a whole is tasked to work jointly on any given situation; and either complete the next step in a project or find solutions to problems that present themselves.

4.1.2 Subject knowledge from school

Joe feels that his high school subjects did prepare him for his tertiary studies, and that he built on the work he did at high school. He finds that with more practice and experience, he gets better at his work all the time. The sections of the high school physical science course on electricity and mechanics were the ones that helped him most. Mr West, his training manager, confirmed this. Joe also thinks that the sections dealing with forces, stresses and strains, and materials, were important, but that not many other parts of the physical science syllabus were very relevant or helpful. He remembers his science studies as being largely calculation-based rather than geared towards problem solving. He feels that he didn't receive many skills to help him do these calculations. He was forced to spend a lot of his time on his own, out of class, practising these calculations. Some value did come from the class-room situations because he said: "Just look at the sum (meaning a calculation), go to the class, practice the sums …" This emphasis on calculations at school was perhaps too high, but being able to do these calculations correctly is, nevertheless, an important factor, according to Mr West.

Neither Mr West nor Joe thinks that the content of the present high school physical science syllabus is sufficiently linked to the real world . This may be the fault of the teacher as much as the content. Joe said to me "Maybe they [the school teachers and the technikon lecturers] can work hand in hand". Mr West feels that a subject like geography which deals with society and its needs and problems would be very beneficial to learners – especially those who come to work for his corporation where they will need to understand how communities are established, what the needs of different communities are, and what are the links between various communities. The training manager would also like to see his new trainees have more computer skills. He says that they need to be able to use the computer for design purposes, so it would be helpful if more practice at this could be given at schools, particularly at technical high schools. Joe also wishes he had had more experience and practice with computers at school. He says it would have made his studies much easier.

4.1.3 Skills required in the present

Communication : Report writing: Joe says that at the end of each week on site, he and all the other trainees have to write a report on what they had done. This report forms the basis for obtaining recognition for the work he has done, and provides direction for those things that still need improvement or correction. Joe does not find the writing of these reports difficult. Mr West, however, stresses the need for workers at all levels to be able to express themselves clearly and concisely in English. Although not all the trainees and technicians have English as their mother tongue, they all have to be competent in English because it is, at present, the language of technology.

Team Work: Joe says that all the team members are given some instruction by the team leader before embarking on the set tasks, and they are then expected to come up with a plan of action which will be implemented. The team members have varying levels of expertise but there are approximately equal numbers of qualified technicians and trainees. The trainees are not all at the same stage of their training; some have almost completed their qualifying period while others are just beginning. Joe says he enjoys the degree of responsibility that the members of the team are given in whatever tasks they have to complete. He knows that each member has something unique to contribute to the task in hand. This is confirmed by the training manager. He stressed the priority given by his company to team work, and the need for trainees to learn the importance of social behaviour patterns. They must realize that they do not work in a vacuum and that the work done by the corporation is social in nature; it is designed to provide a social service namely public transport. The smooth-running, on-going ability of the company to continue to provide and improve these social services depends on teamwork of various kinds. Mr West feels that team-work is not sufficiently stressed at schools. Joe confirms this: "I found it difficult when I first joined the team, because I did not have much experience."

Time management: Joe found the "classroom" part of his studies difficult. Time constraints, during lectures and at the computer, was one of the reasons. There was very little time for reflection: "you just copy, quickly write it down, get it out…" However, he found that the theoretical preparation was necessary for field-work: "you come where you are working outside, … you should know basically …" . According to Joe, the teaching methods used at the technikon are different from those at high school. At the technikon, there is not much time in class for practice; this has to be done in the student's own time, and was something thing he found difficult in the beginning. But he soon realised that he had to take responsibility for his own time-management and thus for his own success. Although he had to do a lot of work on his own, he also spent a lot of time with his class-mates going over lectures and doing the necessary revision so that understanding and real learning did take place. Joe found that when he spent time going over the lecture content, it became much clearer than the first time he was exposed to the work.

Decision-making and thinking skills: Mr West pointed out that it was necessary for trainees to quickly acquire the skill to work on their own without close supervision. They also need to learn, at the outset, to take responsibility for all aspects of their own work. It is required that they always try to contribute their own unique perspectives and integrate these with the perspectives of their team members, so that the maximum benefit for all is obtained. He thinks that an important skill, not sufficiently emphasised at school, is that of thinking in innovative ways. Creative solutions to common problems are needed in modern society. Joe seems to realise this. He says "When you come to the problem you come with the solutions and then you start [working on it to solve the problem]." According to Mr West, his corporation is constantly taking on new trainee employees who have to work alongside full-time technicians, so he sees people with wide variety of educational backgrounds. In general, he says, most trainees have a reasonably adequate background of subject knowledge from high school physical science and a fairly good grasp of how to follow procedural instructions, but in terms of lateral thinking; trying out new ideas; knowing what opportunities await them; and having a sense of ambition to achieve something worthwhile; most of them are not well prepared.

4.1.4 Personal dedication and perseverance: Once Joe found that his time in the lecture-rooms actually gave him some expertise, he says he willingly and enthusiastically applied himself to practical field work. He freely admitted to finding the practical work much easier than the theory he received in the rather isolated lecture-rooms. In spite of the practice he received on computer simulations at the technikon, he still found it difficult to do the work required of him there. For him the real, on-site work with a team around him was much easier to do and understand.

4.1.5 Feelings about the future: Joe feels that he is now equipped with many more skills; both those needed specifically for the workplace, and those which he can apply throughout his life. "Now I am feeling very confident. ... I can work for any company."

4.2 BOBBY

4.2.1 School career and work situation in the present

Bobby chose to attend a technical high school. He wanted to do technical subjects and this was the only school available to him where he could study the subjects he wanted to. Bobby enjoyed high school – having lots of friends and a "simple stress-free lifestyle." He had to do English, Afrikaans, mathematics, physical science and technical drawing as compulsory subjects in his final three years of high school. He chose to study motor mechanics as his "trade theory" subject. This is not just a theoretical introduction to the subject, but a "hands-on" course, which is assessed on 50% theory and 50% practical application and competence. Bobby received the "Most Improved Motor Mechanic" award in his final year at high school. His school was granted permission by the Motor Industries Trade Board to allow some of the top motor mechanics students to do the first year of the MITB apprenticeship during their final school year. This involves taking extra theory classes and also an extra 10 weeks of practical training on different makes of motor vehicles during school vacations. Bobby was the first student to complete this additional course. He says he was an average student at high school, but his academic results of C symbols (60%+) for both maths and physical science, are above average. Bobby was focussed on achieving his goal of becoming a top-class motor mechanic. He worked hard and conscientiously, applying a general principle that he regarded (and still does) as a major factor in achieving success in life. He said that his school "gave me all I needed to get a good job and work my way up."

Bobby is presently employed as a trainee motor mechanic at an upmarket motor manufacturer in his hometown. He has signed up for a four year apprenticeship programme. At the end of this period he will be a qualified motor mechanic: a master technician in the company's terms, and be able to continue to extend his training with his current company or move on to another motor manufacturer. Bobby's daily tasks centre around general repair and maintenance of cars that customers book in for service. He is given job cards by the controller who distributes the work among various apprentices. The work is allocated according to the capabilities of the apprentices. There are four apprentices, and Bobby is the 'second to bottom' in terms of time served. Bobby is chiefly involved with electrical work in the general repair bay. He has also worked in the wheel alignment bay.

4.2.2 Subject knowledge from school

In order to qualify for his apprenticeship position, Bobby needed to have passed both physical science and mathematics in his matriculation examination. Bobby said that both subjects provided him with necessary factual knowledge. Maths was necessary because he has to be able to do various calculations and understand how they were done. He also needed mathematical skills for his own personal experiments. As far as the physical science was concerned, he found the physics component most useful. He also enjoyed this part more; doing mechanics involving forces and angles, friction and momentum. School work on heat expansion has also proved useful. As far as chemistry is concerned, he found that the present work he does related to air pollution, catalytic converters, and the working of exhaust systems, does tie up with what he was taught at school. Some school work also covered fuels. This knowledge is important in terms of the compatibility of fuel and engine type. Problems that might occur must be anticipated by those working on the vehicle; they must also know how to solve them. Bobby feels that links between parts of the science syllabus and the world of the workplace could have been more actively stressed at school. He recognises the need to provide skills for learners who will go into diverse technical fields but feels that everybody needs to know *why* certain sections of the work are included in the syllabus. Additional content on areas like electronics would be a good addition to school syllabi.

4.2.3 Skills required in the present

Teaching methods: The teaching methods at school were not always the best preparation for Bobby's present work. At school the work was more compartmentalised, and Bobby had to learn how to integrate all these small parts into some kind of coherent whole. However, the fact that he had learnt all the bits at school meant that he was now able to do it at work. He didn't have to start from a base of no knowledge at all. He did receive experience in following instructions, and proceeding logically through a problem, at school. Of course he has now had much more practice in the new system and so has honed his skills in these areas. The teachers who tended to focus on giving him life skills that he can and does use now are the ones that Bobby calls "the best". He feels that the focus on passing exams is not the best preparation for the workplace. Bobby thinks that his English teacher, among others, did give him skills that he could use after school, even though he didn't regard English as a particularly useful subject. Presumably communication skills were given to him at school, because the training manager noted that these were important, and he said that Bobby was a model student! The training manager also noted that being able to weigh up alternatives and plan a course of action based on decisions made after careful consideration, is an important positive asset. This type of skill was not common enough among school leavers applying for apprenticeships, according to the training manager.

"Hands on" experience: Bobby believes in the motto "practice makes perfect". A "hands on" method of teaching was the one that appealed to him most at school. He found that this was the way he came to understand much of what he needed to learn. Now he finds that reading and mental preparation before going into a "hands on" situation are necessary. He has managed to do both successfully, according to Mr Jones, the training manager.

Computer competencies: Mr Jones told me that the motor manufacturing company he works for has a very up-to-date and easily accessible computer system which is used for diagnosing problems on the vehicles and then suggesting what needs to be done by way of repair. The computer is also used to train the apprentices how to do the repair work before they actually get to the real cars. Most work in the workshop is computer-based. The local workshop is kept up-to-date with the latest technology and in touch with both national and international branches of the company via computer. All the workshop staff, from the training manger to the newest apprentice, are expected to be computer literate on the manufacturer's terms. Employees are sent on computer training courses on a more or less continuous basis. Computer skills, specifically being able to navigate your way around a system, rather than just being able to use a word-processing package and a spreadsheet, should therefore be given more prominence at school. All students will benefit from being able to use a computer as both a tool and a resource.

Team work: Bobby's general work takes place in a well-organised team system, which has been in place for a long time. In his day-to-day work, he receives support from a journeyman. This man supervises the apprentices as well as doing his own work, so Bobby often has to work on his own. He knows he can approach either the journeyman or the controller if he needs to but he can also go direct to the computer for advice and help. The other apprentices may also be able to help him if he asks. Although the system was new and unfamiliar at first, Bobby found it easy to fit in, in part because of the way in which his school experience had prepared him. He thinks it would have been much more difficult for someone who had not had his school experience in motor mechanics, to cope with the apprenticeship.

4.2.4 Personal dedication and perseverance

Bobby remembers school discipline as being externally imposed rather than instilled as self-discipline. He now has to get on without constant supervision and take responsibility for his own work and break times. He is thus quite grateful that he learnt to cope in a strict school regime. Also, Bobby has familiarised himself with the computer, partly in the actual teaching and training sessions, and partly in his own time after work in the evenings. The training manager spoke very well of Bobby and mentioned his dedication and willingness to do extra work to make himself completely *au fait* with the required work and more. According to the training manager, Bobby is the most advanced apprentice mechanic in terms of levels of competency achieved, even though he is not the longest serving.

4.2.5 Feelings about the future

Bobby feels confident about the future because of what he has learnt and what he is still learning. "…to be a good mechanic you need to work on some good products … try and do as well as you can." He said that "If I have to go on my own, I know their systems and that can help me a lot in the future."

4.3. SAM

4.3.1 School career and studying in the present

Sam spent five years at a technical high school. His choice of school is interesting: he says he came to my school because it was convenient: it was just two blocks away from his home. He didn't particularly enjoy school, because he found it too restrictive; he felt that he had to obey rules all the time. During his final three years of high school he studied English, Afrikaans, mathematics, physical science, technical drawing and technika electronics. The prime reason for attending my school was to prepare himself for further study in the field of electronics and computers. He felt that the more thorough his preparation was and the sooner he got properly involved, the better. He was an above average student, who received a matriculation exemption with an A symbol (80%+) for physical science and a B (70%+) for maths. He worked just "hard enough to get decent marks" so that he could get access to the tertiary education he wanted.

Sam is now a third year student at the local technikon, studying electronic engineering. He has had a successful school career. He achieved a good enough matriculation result to enable him to register at the local university to study electronic engineering. Unfortunately he failed mathematics in his first year, and so decided to transfer his studies to the technikon. He is now enjoying his studies and finding that he is coping much better than he did at university. He passes all his subjects, and even scores, in his own words, "a couple in the high 80's". He is really pleased to be nearly finished with his studies and looks forward to doing a year of full-time practical work in the field before being awarded his diploma.

4.3.2 Subject knowledge from school

At school Sam studied technika electronics as his "trade theory" subject. Much of the work he did in this subject at school had the same content as the first year course at the technikon, so the transition was easy if rather boring for him because of its repetitiveness. But he has now found that all that he had done at school in technika electronics fits into a larger picture and that the whole now makes more sense.

Sam did not enjoy the chemistry that he studied at school. He says that the chemistry is irrelevant. At the technikon neither he nor his lecturers seem to have any interest in why they use one type of material rather than another for any particular piece of equipment. Of the physics that he did at school, he feels that only the electricity part has been of any use to him in his studies. But Sam did find that the comparative difficulty of both mathematics and physical science and the need to study hard at school to pass these subjects was in itself good preparation for his technikon studies. It wasn't the content, but the fact that he had to think about what he was learning. Mr Smith, the faculty head at the technikon says that an ability to see the links between school science and real world science is important, as is an understanding of basic science concepts. He thinks these skills are probably more important than knowing a large number of facts, although factual knowledge is always useful.

4.3.3 Skills required in the present

Examinations: Comparing school and technikon, Sam thinks that school exams are not ideal preparation for exams at technikon. His school relied a lot more on students memorising facts, and restating them, rather than applying the knowledge about those facts in different situations. Sam knew that facts were important, but not just for themselves. They have to be used, and used with understanding. Basic formulas that he learnt at school were a good foundation but at technikon he needed to be able to do more than just manipulate formulae in calculations. Exams at technikon test conceptual understanding and application of factual knowledge.

Communication: One gap in Sam's preparation was report writing. He says "We [didn't] know what's expected of us. We [were] unsure about the whole set-out, how to put it out on paper." He had to use his own initiative, and work with the other students who were in the same position, to find out what was required and then get on and do it. That was difficult. According to Sam each new student had to try out for him/herself and see "which one [version of the report] looked better [and hand in this one]." The head of the department, Mr Smith, noted with concern that many students come to the technikon with very poor language and communication skills, even though they had a matriculation pass in English. Development of thinking skills, logical and lateral, were also lacking in student preparation for tertiary education. Mr Smith did point out, however, that progress was being made towards making technical course material available in other indigenous languages. But it is a slow process, and students for the foreseeable future will still need English language skills. Sam and Mr Smith both stress the need to be able to express ideas clearly, verbally, in writing, and graphically. Much extra reading (books and the Internet) and research, beyond the immediate scope of a particular lecture or experiment, is required as this enhances a student's learning and understanding of what is being done, as well as show modern applications of the work.

"Hands-on" experience: The focus of Sam's studies at the technikon is the programming of microprocessors and network administration. Much of his time is spent in what he called "the prac room" – a laboratory. Here not only the required practical work is done, but the underlying and accompanying theory explained in context. This he much prefers to ordinary lectures. Doing "hands-on" work is the way he learns best. Help in these sessions was always available, either from lecturers or from more senior students. Sometimes these people were in the laboratory when Sam was there; otherwise a committee roster is set up so that those with the required expertise can be contacted. Sam finds some of the lectures boring because he can't see how the content will be useful to him. However, he makes certain that he "get[s] through it" so that he can get back to the practical work.

Transfer of learning - lateral thinking and understanding: According to Mr Smith an ability to transfer knowledge from one context to another is important. He says it is important for students to be willing to experiment on their own, and to try out different approaches to any one problem. He says students need "a questioning attitude – they must not just accept." One of the realities of modern computers that Sam has to deal with is the rapidly changing and up-dating nature of the work he is studying. He has been using programming languages that are rather out of date: "We're using 4.1; the new one came out about a year and a half ago, and they haven't had time to update the whole syllabus. but it's all basically the same." Sam sees no real problem with what he's doing and how it's going to affect what he'll have to do. He can transfer the skills he has learnt in this computer language to the learning of any new language.

Sam can do his practicals because he knows various basic facts and understands processes and procedures. This understanding is crucial; it's what Mr Smith calls an ability to "conceptualise a problem". And it is one that many students do not have. Sometimes a particular problem that has to be solved, is one that Sam, according to Mr Smith, "hasn't a clue" about while others he only "has a vague idea what's happening." But in either case, he is invariably the one who has to make it work; who figures out what is happening. A determination to succeed is important but according to Mr Smith determination alone is also not sufficient. Students need what he calls "technical literacy". There is no substitute for "playing with machines" as a forerunner to a successful technical education at tertiary levels. He says that there wasn't enough time at a tertiary institution to give students a basic knowledge of technology. Schools should be providing this. This links back to Sam's conviction that "hands-on experience" is a better way of learning.

Time management: Sam has also had to develop time management skills since leaving school. At school, most work was done and completed during a lesson period and the teachers constantly reminded learners about handing in the required work on time. At the technikon he has to structure his "own" time to complete practical and written work and remember what has to be handed in when.

4.3.4 Personal dedication and perseverance

At the technikon Sam has had to learn to work on his own. Individual work, as in being able to work without close supervision, is important. According to Mr Smith students need to be motivated to understand what they are studying rather than to merely pass exams. The former is a much more difficult process than the latter and only the dedicated students will really succeed.

4.3.5 Feelings about the future

Sam feels that he has indeed learnt a lot about computers, programming, and studying, as well as how to pass his exams. He will soon be able to work as either "a network administrator or a programmer ... at a company where you can make use of smart technology."

4.4 ROBYN

4.4.1 School career and studying in the present

Robyn attended a technical high school. She chose this school because it was one of the few local high schools that offered technical drawing for females. She says that high school was a pleasure: "I enjoyed the subjects I did, enjoyed being a prefect and enjoyed my extra-mural activities." In her final three years, she studied five compulsory subjects: English, Afrikaans, mathematics, physical science and technical drawing. She chose technika mechanika as her sixth, technical or trade theory, subject. Robyn was a bright, outgoing and very focussed pupil at high school. She obtained an A aggregate, with A (80%+) symbols in both maths and physical science. She knew what career path she wanted to follow, and directed her focus in order to achieve this. Science and mathematics always interested her and were a challenge in themselves, and in related fields. Determination to succeed was a very important motivating factor in her school career. She said she always worked "at my peak. The best I could muster."

Robyn is studying chemical engineering at the local university. She has completed the second year of a four year programme. Robyn entered university with a very good academic record and a high degree of enthusiasm, but still found the going tough compared with high school programmes. In her first year, Robyn took mathematics, physics, chemistry and design. The design course combined engineering and drawing. In the second year, she did a fundamentals course which included dynamics and speed transfer in chemical plants and processes. Minerals processing was another course. She says that these new subjects opened up new horizons and were very exciting for her. They explained what happens during various chemical reactions and processes in particular types of processing plants. She kept going because of her interest, and in spite of the pressure of work both in its academic content and volume. In the next two years of her course, she will do more in-depth work in some of the areas she has already studied and also do completely new courses. However, Robyn said that having completed two years, she now knows what is expected of her, and knows she is doing the right course, so she is more than willing to continue the required hard work and long hours.

4.4.2 Subject knowledge from school

When asked what particular parts of her school education and science in particular, had helped prepare her for this course, Robyn said that all of the science was important. She feels that the physics parts (mechanics, dynamics, gas laws, waves and electricity) helped, as did her course in technika mechanica. The chemistry (inorganic chemistry of sulphur, nitrogen and the halogens, acids and bases, rates of reactions and chemical equilibrium, and electrochemistry) was also helpful, as it explained a lot of what happens during particular chemical reactions. She thinks that more organic chemistry could perhaps be included in the high school science course. In Robyn's opinion chemical engineers have to know chemistry before they can cope with the engineering parts; once she understood the chemistry, she could establish the relationship to the physics and how to design a suitable plant or part of a plant to ensure that reactions proceed with maximum efficiency.

4.4.3 Skills required in the present

Teaching methods: Teaching methods at university are very different from those at school. According to Robyn " a lot of engineering is problem solving, that's what it is about." At university she was taught problem solving skills so that she could tackle unfamiliar problems in unfamiliar situations. In school there was a greater emphasis on memorising and repetition, rather than on understanding. Robyn finds in her current course that she has to be able to sort through lots of given information and find out what is relevant and what is not, and find out what extra information is required. These are skills that could have been taught and practised at school.

Examinations: When it comes to examinations, the contrast with high school is just as pronounced. At school, going over past papers almost guaranteed that Robyn (or anyone else) could predict the format of the next paper and so expect to pass well. "It's stuff you have to know off by heart. You don't have to worry about any kind of strategy." She finds that university examinations are much less predictable and require a very different type of preparation; she has to master all the work covered in lectures. But with practice, Robyn has come to an understanding of how the lecturers teach, and how they emphasise the more important parts of a particular course, and thus where she should expend most of her time and effort in order to succeed.

Time management: Robyn says that although the subject matter is not too difficult from an understanding point of view, the sheer volume of work, right from the beginning of first year, has made it difficult to cope as well as she had expected to. Time constraints were the biggest problem, because, like many South African students, she has to work part-time to fund her studies and living expenses. Daily lectures from 08h00 to 13h00, practical laboratory sessions or tutorials from 14h00 to 17h00, research in the library, and experimentation on the computer, are all demands on her time. She feels that "[t]rying to fit everything into a day is hard, especially with me working on weekends." This was something quite different from what she had experienced at school, and something she was not prepared for at first.

Understanding and thinking skills: Robyn does her afternoon practical sessions either individually or in small groups but the reports on the chemical engineering laboratory practicals are discussed and the reports written up, in small groups. The "post interviews" are done when Robyn and her group meet with the lecturer concerned. The students are then asked questions like "How does this [piece of apparatus] function? What equipment did you use? Can you explain the theory behind this?" to make sure that they understand the work previously done in the laboratory. Each student needs to understand the chemical processes involved, and the workings of the apparatus (plant?) used, since they are the major concerns for a chemical engineer. Robyn knows that understanding, rather than merely following procedures, is important.

4.4.4 Personal dedication and perseverance

One of the major differences between high school and university for Robyn, is the large number of people involved in each course. There are large groups of students in morning lectures (sometimes as many as 400 engineering students from all the different schools in the faculty) and smaller groups (about 35) in the afternoon practical sessions in the laboratories. Individual contact with teaching staff is thus minimal, and it is up to each student to make sure s/he has understood the lecture content. It is up to each student to make sure that s/he copes as the days pass. There is no school system of constant reminding and nagging to hand in work or to make sure that revision has been done. Each day brings new work, and it is assumed by the teaching staff that the students have understood the previous day's work. Robyn found this difficult at the beginning since there was no built-in time for revision. Each student had to do whatever s/he thought was necessary in order to cope. Robyn said that from being "third in the standard at high school [to] bottom of her class at university" was a jolt yet she says "I knew I could never study anything outside a technical field"; she wanted to be a chemical engineer, so she enrolled for the course, with great enthusiasm. "The engineering course has always been tough. I think chemical engineering is the hardest of them all. You have to be dedicated, hard working. ... You have to have patience, you have to have the dedication and will power to actually say 'I am going to succeed'."

4.4.5 Feelings about the future

Generally, Robyn has followed a dream. Because the course is expensive in monetary terms as well as in effort and time, and she doesn't want to waste the money (in fact she can't afford to!). She is determined to continue her studies and put in the long hard hours in order to achieve her dream. Success will follow, but it will not come cheaply.

4.4.6 The professor's views:

Much of what Robyn has described was confirmed by the professor of chemical engineering at the same university. The professor thinks that students need to have, in addition to content knowledge in physical science and mathematics, and English language skills, also a positive outlook on life; an ability to work independently without supervision; and an ability to manage their time efficiently. He also emphasises the need for research skills, which Robyn says she was not taught at school. Logical and lateral thinking and decision making are not skills given to students in high school. Another requirement that the professor considers essential in his students is the ability to see the relevance to the "real world" of their high school physical science course. Robyn feels that she only had limited links pointed out to her at school. The professor added that students are required to work as part of teams, sometimes consisting of peers, sometimes of members with varying levels of expertise. But many school learning experiences were purely individual and this causes problems for some students.

The professor drew attention to the high failure rate among first year engineering students, even among those with A aggregate passes in the senior certificate exams. He thinks that the type of preparation given to students at high school was not really adequate for first year university study. Robyn's comments about her own experiences confirm this for her. But both Robyn and the professor agree that there is very little substitute for determination and directed hard work in achieving success.

4.5 COMMENTARY

I have presented the views of the young people I interviewed and the views of their employers or lecturers in this chapter. In the next chapter I present my analysis of, and comment on, these views. I try to show how the data answers my research statement: "The value of having studied physical science at school to students entering the workplace and entering higher education."

CHAPTER 5
ANALYSIS AND DISCUSSION

5.1 INTRODUCTION

I found, from my analysis of the case studies and other interviews, questionnaires, and official documents, that there are seven specific skills that students and trainees need in order to cope in their new learning environments. And, according to my collected data, these skills have not been sufficiently developed at school. The skills will be individually discussed below.

5.2 SKILLS AND KNOWLEDGE NEEDED IN THE PRESENT

5.2.1 Thinking skills

There is a general recognition among the participants, namely the young people and their employers or lecturers, that thinking skills are essential for success in the workplace and in tertiary studies. The young peoples' experience at school was that while some thinking skills were considered important, they could get by on being able to memorise facts and procedures, and do mathematical calculations, to pass exams in physical science.

One of the questions in the questionnaire for employers/lecturers concerned logical thinking and decision making. Everybody who answered the questionnaire said that these skills were very important. They all rated these particular skills as being either the most important or very important skills that young people needed in order to succeed in their particular technically-related fields. Thinking about what is being done, why it is being done, how it is being done, or whether there are any other ways of doing it, are some of the kinds of thinking approaches that need to be developed.

The evidence given by the young people supports this. They said that an ability to think about what they were doing and/or studying was important. Sam was very clear on the value of having studied physical science at high school. He said that "We went through … thinking …It was one of the subject courses that gets you thinking and that." He also said that he had "to change [his] whole way of thinking …" (Interview 01/10). School had given him *some* practice in developing thinking skills, but not enough to cope at tertiary level. Bobby said that he "realise[d] the systems are quite basic and logical, and you are able to work out a lot of them by yourself" (Interview 21/10). He was referring to systems of motor-car maintenance and repair. Robyn said that only at university was she given the skills to help her "to work through like problem solving ... You can't start anywhere ...you have to know how to work through your problem ..." (Interview 08/01).

All the lecturers/trainers interviewed said that it is important for young people to be able to think logically in particular contexts and also to think innovatively about problems that confront them. They said that this skill is not developed sufficiently at school. The university professor said "There is not much room for the [high school] students to develop their lateral thinking capabilities" (Questionnaire 29/01). It is clear to me that all the people involved here, the young people and their lecturers or training supervisors, acknowledge how important it is to be able to think through whatever it is that is being studied, learnt or practiced. It is not nearly good enough to just memorize a collection of facts which can be reproduced or recalled on demand.

These results of my study are supported by the literature. For example Ayayee and McCarthy (1996) argue for the need to recognise the importance of producing adequate definitions of science that are not limited to definitions that restrict science to something "consisting of facts and processes" (p 55). The new draft subject statement for physical science put out by the Department of National Education (2002) also emphasises the importance of developing thinking skills. Learning Outcome 1 states: "Learners are able to investigate physical and chemical phenomena ... and solve problems ... using their skills and strategies of scientific inquiry, and critical thinking" (p.3).

But thinking skills do not just occur automatically at any level of learning or practice. They must be cultivated and deliberately taught to learners. Black (1993) breaks down thinking skills into such specifics as "making generalisations, inventing hypotheses, devising fair tests, designing experiments, analysing data, interpreting results ..." (p.16). If high school learners are not given practice in developing these skills, they will not easily acquire them. Hobden (2001) confirms my experience that trying to provide learners with these kinds of thinking skills is not sufficiently encouraged by the examination-driven high school system we have at present. Too much of the present senior certificate examination requires a recital of facts and procedures and mathematical manipulations of various numbers and formulae; there is not much place for any answers that require or demonstrate real thinking or an ability to solve problems.

5.2.2 Learning with understanding

An assessment of my collected data reveals that a second skill that is regarded as important is learning with understanding. All the respondents to my questionnaire noted that workers and students needed to understand concepts rather than only accumulate factual knowledge and procedures. There are certain scientific "facts" that must be memorised; for example accepted symbols for components of electric circuits and the chemical symbols for the elements. But understanding how various electrical components function in circuits, and how the elements react in specific conditions is more important. The former skill is only a precursor to the latter.

One part of the questionnaire specifically focussed on learning with understanding. When asked how important it is that students or apprentices can understand basic science concepts, all the lecturers and employers rated this skill as very important or most important; yet they all say that the young people that enter their programmes are inadequately prepared in this way.

This view was supported by the answers given to a similar question during the interviews with the four young people in my case studies. The four young people all held similar opinions about their post-school learning experiences. Sam said that at the technikon he is required "to know some facts and *understand* what is happening" (Interview 01/10). This contrasts with what he remembers from school: "..you basically have to learn it [factual content of the recall type] all and then the stuff you don't understand you can just leave out" (Interview 01.10). Bobby said that "you need to know where those problems will arise and how they arise and how you can solve it" (Interview 21/10). He was referring to an ability to understand the workings of a motor car, rather than just be able to follow 'blindly' a set of memorised instructions. Robyn mentions the need to understand what is done in the laboratory rather than just doing the work; after her laboratory practical sessions, she has to report to the lecturer and answer questions on the work that was done: "How does this function, or what equipment did you use, can you explain the theory behind this" (Interview 08/01). Joe says that you have to "just go over the work till you understand" (Interview 27/01).

The literature has many references to the need to understand what is being studied or learnt or taught as opposed to just memorising many pieces of factual knowledge. Jenkins and Whitfield (1974) state that the "basic objective of education must be an understanding of the world we live in and the world we hope for, understanding which can lead to effective action" (p.25). Lewin (1992) says that one main objective of education is the development of skills: "science is defined as a learning activity which results in process skills and enquiry strategies rather than content based knowledge" (p.36). Later, he goes on to say that science at high school should "develop theoretical understanding and formal reasoning skills" (p.38). Black (1993) says that one of the main purposes of having science for all is "that pupils should be given a basis for understanding and for coping with their lives" (p.11). He also states that "understanding the applications and effects of science in society" (p.12) and pursuing the goal of "authentic understanding of the nature of scientific enquiry" are skills that contribute to good learning experiences in the classroom or laboratory and to "pupils' general development" (p.13). My data thus bears out what has been found elsewhere. The young people I interviewed went through, and many learners still at high school are also going through, a system that places too little emphasis on these "understanding" aspects of science, and too much emphasis on the "memorising and manipulating" aspects.

5.2.3 Transfer of learning

Learning in different contexts is another area where the young people I interviewed say that they experienced difficulties. No-one at high school gave them sufficient practice in deliberately applying a way of learning successfully in one subject to trying to learn successfully in a new and different context or subject. They had not been given a chance to develop sufficient skills in transfer of learning: 'the ability to extend what has been learned in one context to new contexts' (Learning and Transfer, 2002, p.1). Joe said "It was hard for me [to learn new work in civil engineering at the technikon] because I was not confident" (Interview 03/02). Robyn said that she found the new work difficult to cope with. When she realised that she could transfer her methods of learning to the new contexts, she found new learning much easier. Sam, who is studying electronic engineering, said that he copes adequately with different programming languages because he can transfer his learning skills: "if you can do that [C++] it will take you a short time to pick up any other language" (Interview 01/10). He had similar comments about operating systems. What he has learnt in one context he can apply in another. But Sam learnt programming at the technikon and not at high school. Bobby says that he can transfer what he has learnt on one type of motor vehicle to any other type because this transfer of learning is part of the training during his apprenticeship. Mr Jones thinks that future apprentices in the motor industry will need to "adopt new skill/traits to keep up with technology." He notes that with the advances which happen so quickly in technology, it will be imperative that schools equip learners to cope in the changing world.

Many authors, including Lewin (1992), Ericsson *et al.* (1993), Woolnough (1995) and Ramsden (1994), state the need to provide a stimulating environment for the first learning experiences in science so that the learners will be able to have pleasant and successful experiences in learning science that can then be transferred to other contexts. Black (1993) and the authors of Learning and Transfer (2002) both note that the skill to transfer learning from one context to a new one is a difficult one to achieve, and one that only occurs if deliberate attention and much time is devoted to it.

It seems to me that this is a completely new skill that is required in our classrooms. The need to be able to transfer learning skills from one context to another was another specific question that I asked employers/lecturers. They rated it as a very important skill required by students and apprentices. The employers and lecturers again noted a mismatch between what they required of their trainees and students and what they were generally getting in the first-year intakes: the skill of transfer is important to them, but the schools are not adequately developing this skill in learners.

Instead of giving learners a narrow focus aimed at passing a factual content examination at the end of a high school career, we as teachers should be broadening our own focus on how students have successfully mastered all or some parts of their school career, and in addition show them how the links in learning can benefit them.

5.2.4 <u>Making links between factual knowledge and real-world situations</u>

The young people I interviewed expressed the need to see many more examples of how their high school science is related to real-world science and technology.

In my interview with Robyn, she had the following to say about what she called good teaching methods which makes these links obvious:

> going with specific examples, giving practical application and not just explaining the theory but saying like this is used in all motor cars, or this is used here and there ... and somehow understand like certain things like sulphuric rain [sic!] and stuff like this, makes it easy to visualise and better to understand" (Interview 08/01)

Robyn appreciates those occasions when parts of the high school science syllabus course were shown to have links with the real world, even though she confused sulphuric acid and acid rain in the interview! Robyn found out, when talking to her "old" teachers on return visits to the school, that her school teachers did not know what chemical engineers do! It was thus understandable that they couldn't link the classroom science with her career.

Bobby listed the parts of his course that had been helpful to him: fuels and engine compatibility; friction and forces; momentum; electric circuits. Bobby said in his interview that he had to do several weeks of preliminary training in the workshops of various motor manufacturers to make sure that he could relate even his very practical motor mechanics school subject to the "real world" of motor cars. He could not expect additional credits until he had had varied experience in the "real world".

The data from my questionnaires also emphasises the need for this link to be made. The employers are, of course, in the "real world", and the lecturers should also be close to the "real world". They are unanimous that the young people coming to work for them or study under them should be able to see these links. Mr West, the training manager at the public utility corporation, specifically noted that there needs to be a very direct link between the "real world" and school science. He said that it was not important to have an accumulation of science facts memorised unless these facts had some relevance in the technical workplace where the student found himself. His reason was that, without knowing what sorts of jobs were available after their training, the learners would not know whether their training was suitable or not.

The literature supports the importance of being able to make the link between the "real world" and school science. Lubban *et al.*, (1994) write about the contextualised nature of science. What is taught at school must be based on both the learners' experiences and the wider world in which they will live. Swift (1992) and Black (1993) both emphasise that learners must study science that is accessible, relevant and enjoyable. Jenkins and Whitfield (1974) write that education in general and science education in particular must give students an understanding of the world they live in. Berryman (1992) and Bottoms (1999) quote from different American studies that found that learners' academic progress in science at high school improved noticeably when they saw for themselves the relevance of what they were studying. And consequently, the better their academic progress at high school, the better equipped they were for post-school employment or tertiary study.

My small-scale case study confirms these views. The high school science taught to these young people did not have sufficient links to the "real world" that they chose to enter. An example would be the Contact process for the manufacture of sulphuric acid. This process produces one of the most important chemicals needed in an industrialised country, and involves the concepts of reversible reactions and chemical equilibrium, yet the exam questions set on these sections question only the knowledge of the process in a step-by-step manner, and the theoretical factors influencing a chemical equilibrium, without ever asking why either the process itself or the chemical equilibrium reaction is important. It is made into "textbook science" rather than being shown to be "real world" science.

5.2.5 Time management

The young people I interviewed all note that they have had to be very disciplined about how they manage their time in their present positions. This is very different from what they experienced at school. They said that as high school learners, they were given constant reminders about work that needed to be done, times that assignments should be handed in, dates when tests or exams were to be written and what preparation should be done for these. Although it was up to them to ictually do the work, they were seldom allowed to make too many decisions about how they nanaged their time to do the amount of work they needed to do. Once they had left school, that changed: they now have to make all these decisions for themselves. Tea-breaks do not have bells ringing at the start and end of the allotted time; apprentices have to keep an eye on their own watches (Bobby, interview 21/10). The considerably larger volume of work means a much nore careful allocation of time. According to Robyn "It's just time management, and trying to it everything into a day is hard" (Interview 08/01). Sam says "You just have to work, it doesn't natter if you're tired" (Interview 01/10). He has found that he has to manage his time much nore carefully in order to fit in all the work he has to do. Three of the five tertiary ecturers/employers also mentioned time management specifically as a skill which school-leavers acked. They say that the lack of this skill is one of the reasons that new students and pprentices battle to succeed when they first come to a new institution.

s a teacher I remind learners constantly about work in my own subject and the deadlines they ive to meet, as well as other school-related activities that they are involved in. While I admit at some reminders are necessary in the case of younger learners, I feel that the responsibility r noting what is expected of them and when, should more and more devolve onto the learners emselves as they move up through high school. This will prepare them better for life outside school.

5.2.6 Perseverance and dedication

All the participants agreed that self-motivation is a powerful tool to achieving success. No-one I interviewed felt that the courses they had embarked on were easy. Rather, they all admitted to finding them difficult, but the desire for success was a sufficient motivator for them to persevere and be completely dedicated to achieving what they set out to do. Bobby has what he calls a "high persistence" while Robyn just felt that students need to be "prepared for hard work, for long hours …" and Joe's formula is "lots of practice, because the more practice [you] do the more confident [you] will be." Mr West at the public utility corporation said that apprentices need "ambition" in order to succeed, both at their present studies and in their future careers. The lecturer at the access programme said that all the new students he dealt with needed to "develop academic coping skills". The access programme is specifically designed as an emergency programme for learners who have neither the subject knowledge nor other required skills at an acceptable level for direct entry into tertiary studies, but who still show some aptitude and enthusiasm that can, with careful mentoring along with perseverance and dedication on their part, allow them to succeed in the chosen scientific field of study. The training manager at the motor manufacturing company said that "patience and commitment" were necessary skills for an apprenticeship.

Joe said that he had to do all the hard work at school on his own; he didn't "think teachers are that important …" (Interview 27/01). He admits he was only an average student, but still says he made the effort to master what was required. Robyn is a bright student, but still worked hard to be third in her grade in her final year at school. She was rewarded with academic honours for this effort. Bobby had to give up his school holidays to do studying on his own in order to complete the additional apprenticeship work on top of his school work.

This is something that I have experienced in my teaching as well. The learners who are determined to succeed often do. I have often been disturbed by the supposedly encouraging statements like 'You can do anything you want to' that are made by well-meaning people who are trying to encourage learners at high school to follow a technical or scientific career. Rather, learners should be made aware of the complexities of these fields, and should be encouraged and helped to develop the necessary skills for dealing with them. Black (1993), Swift (1992) and others state that students need to be able to cope in an ever-changing world. These authors say that the skills required for success need to be developed over time and with much practice. Berryman (1990) notes the need to develop skills at school that can be taken into the workplace and used and/or adapted for use there. All these authors emphasise the common themes of time and patience.

5.2.7 Content knowledge required in present circumstances

After assessing my data, I found that the young people said that they needed much of the physical science content knowledge that they had studied at high school. The content was important as a basis for what they were doing in their post-school experience. Robyn said that "Physics is everywhere around us. Chemistry is everywhere around us" (Interview 08/01). She has found correlation between what she studied at school and what she is learning in her chemical engineering degree at university. Bobby said that he needed "angles and that type of things. You get your momentums and friction and that type of thing come into play. Also heat expansion, all that type of thing" (Interview 21/10). He also mentioned catalytic converters, air pollution, leaded fuels as topics which he needs to know about in his present training as a motor mechanic and which he did get some exposure to at high school. Sam, by contrast, said that he had not found the chemistry he did at school to be of any use at all in his technikon studies. While he was aware that he had indeed gained much of value from his science studies, he was much less impressed with the value of the content, saying that the physics part was more useful to him than the chemistry. Even when I tried to point out to him that some chemistry might be involved in the functioning of computer chips and even computer hardware, he was unimpressed. He was much more focussed on the programming, which didn't need much chemistry at all!

It must be noted that the four young people I interviewed were highly motivated learners at school; they knew that they needed to pass physical science well in order to enter the post-school career they wished to follow. Perhaps this influenced what they felt they have gained by studying physical science at high school A less-motivated group may have felt differently.

Maybe all of this suggests that much of the content is perceived as being relevant only to those students who are going on to study in those specifically related fields at tertiary institutions. That their new students need to have a certain basic content knowledge is assumed by the lecturers at the tertiary institutions; they rated a good mark in physical science at high school as very important. But they were very perturbed that this one skill (being able to remember scientific facts) was given so much emphasis at high school level to the almost complete exclusion of the other skills I have listed. Subject knowledge is not an isolated collection of facts. It needs to be accompanied by what Black (1993) calls specific science skills: "logic of explanation … pursuing practical investigations … helping pupils to reflect on what they have done … [gaining an] authentic understanding of the nature of scientific enquiry … and [relating] the way in which they work in science to the ways in which they work in other disciplines" (p.13). The lecturer of the university access programme said that high schools generally do not prepare students adequately for tertiary studies and that in future "there should be a greater emphasis on the developing the life and academic coping skills." The university professor is even more blunt. In answering the question "Do you think school has adequately prepared the students you have accepted over time?" he just answered "No." He then suggested that schools should not place so much emphasis on factual knowledge; rather the application of knowledge should be emphasised. According to Mr Smith at the technikon most high school students lack a "basic knowledge of technology – how things work." He laments the amount of time he has to spend in tertiary education to show students "how things work." He feels that it is the school's responsibility to provide students with a greater degree of "technical literacy". Those students who arrive at tertiary institutions without this particular tool will be disadvantaged when it comes to comprehending scientific and technical data. Lewin (1992) states that "Without procedures to select and employ relevant knowledge and adapt it to new situations the knowledge itself has little value" (p.46). He goes on to state that "process skills cannot be taught in a vacuum" (p.46). This is what I found in my study: content knowledge is important, but only as a basis for further use.

5.3 SUMMARY

From all of the above, I think that it can be seen that although the study of physical science at school does, to some degree, prepare students for the world of work and for tertiary education, the preparation is not entirely adequate for requirements in the modern technological world. All the respondents of this study have noted that it would be far more difficult for school leavers to cope in a technological workplace or in a tertiary institution in a technological field, without having studied physical science at high school, yet they all feel that they could have been better prepared. They feel that they were not given sufficient opportunity to acquire critical skills.

They feel that there is benefit in obtaining subject specific knowledge. But there is perhaps greater benefit to be obtained from the thinking and reasoning skills that were taught, or that they had only *begun* to acquire, while studying physical science. The nature of the subject and the way it was handled in the classroom or laboratory helped to make it a subject that benefited them in their present situations. Other school subjects, especially the technical subjects they had taken at high school, also prepared them for their present situations. But there was also a general consensus among the four young people and among their employers and lecturers that school did not *"skill"* them sufficiently to make an easy transition into their post-school careers. The words of the access programme's lecturer sum this up: "There seems to be a discrepancy between what schools teach and what is required at university."

CHAPTER 6
CONCLUSION

6.1 RESULTS

From the case studies, I can say that the young people generally all felt that they benefited from studying physical science at high school. They felt that this was one of the 'harder' subjects at school and that it made them work hard to get good results. They think that without physical science they would have been severely disadvantaged in their present careers or tertiary studies. They learnt scientific facts and processes, and they learnt about scientific concepts. They had to work fairly hard at school, which prepared them for the much harder work-load that they are faced with now, and the determination that they began to develop at high school has stood them in good stead in their present positions.

All the employers and lecturers whom I spoke to felt that physical science at senior certificate level was an essential prerequisite for the work or studies that were being embarked on. The entrance requirements for the tertiary institutions and the workplace employers all demanded a senior certificate pass on the higher grade in physical science. So studying physical science at high school does make some contribution in terms of preparing learners for future careers and employment.

The subject, and the way it was taught forced the young people to think about what they were doing. Understanding as opposed to mere rote-learning was important, even though much of the examination system emphasises an approach that rewards memorising of facts and procedures, and doing mathematical calculations correctly rather than demonstrating deeper understanding. But they also feel that once they encountered 'science' beyond high school, they needed to reach much deeper levels of understanding, and to think more about what they were doing. There is almost no place in their present circumstances for reproducing answers by rote. They are now seeing (or being made to see) the links between science and the real world they are encountering. They are learning how to transfer their ever-increasing learning skills to new situations, and to manage their time more profitably.

Without exception, the employers and lecturers said that the preparation given by high school teaching and senior certificate exams were inadequate and wrongly directed. They think there is too much emphasis on recall of factual information and manipulation of formulae and too little emphasis on understanding of scientific concepts. Application of scientific knowledge and procedures in real world situations is not sufficiently emphasised. The constant link between physics and chemistry, which are fundamental parts of all technical and technology-based subjects, should be emphasised more. Physical science should not be an isolated, theoretically remote, classroom exercise (Ramsden, 1994). Learners will need to understand the limitations imposed by the physics and chemistry of substances and systems they are working with and in, and they should also be encouraged to explore further untried possibilities that stretch the technology to the limits of the physics and chemistry involved. They will need to know more than just how to pass an examination that relies largely on factual recall and manipulation of formulae in calculations.

Atkin and Helms, cited in Fensham (2003) have suggested that school science should be taught "as a human activity powered by both internal and external forces (i.e. its intellectual and social history), practical reasoning and habits of mind" (p.6). Fensham then goes on to say that school science should progress along lines like: investigate an interest; use the scientific manner to pursue the investigation; learn scientific concepts through this investigation; learn to solve real problems; develop habits of mind that prove useful in similar contexts in future. In this way, what is studied at school would be relevant to students and would also provide them with skills that will be useful in post-school experiences. A similar view is expressed in the SCANS Report: What work requires of schools (1991). This report deals with what "young people need to succeed in the world of work" (p.1). Although the document was generated in the United States, much of what it states is applicable to South Africa. The data generated by my small-scale study confirms the present applicability of their findings.

6.2 POSSIBLE REASONS FOR THESE RESULTS

5.2.1 <u>The content of the senior certificate examination</u>

[think that a large part of the problem encountered by young people lies with the set senior :ertificate examination which must be passed by learners wishing to proceed to a technical vorkplace or tertiary studies in a scientific or technical field. This examination, in addition to)eing part of a school leaving certificate, is used almost exclusively as an 'entrance test' by :mployers and tertiary institutions. But the examination is set in such a way as to ensure easy .chievement of the maximum pass rate for school-leavers. To achieve this aim, the examination places large emphasis on rote-learning and reproduction of well-practised calculations. Thus the examination is being used for two almost mutually exclusive purposes. The high schools need to have good senior certificate examination pass rates to call themselves successful and to entice the best learners. The technical employers and tertiary institutions need to find learners who have a good understanding of scientific concepts. As long as the current format of the senior certificate examination is continued, I see no way out of the dilemma. Lewin (1992) argues that "too much of what passes for science education in practice is dominated by the acquisition of facts that are not coherently related to conceptual frameworks" (p.46).

6.2.2 The format of the senior certificate examination

The focus on passing the senior certificate examination also precludes much by way of lateral thinking on the part of learners. Because of the vastly diverse backgrounds of the high school physical science learners country-wide, the examiners have to try and find contexts that are understood by all learners when setting their questions. This often leads to repetitive and almost unreal contexts being used year after year. There is little scope for learners to display any kind of alternative thinking about, or give innovative explanations for particular scientific concepts. Yet these alternative ways of thinking about and dealing with scientific problems are exactly the prerequisites required at post-school level. This means that many learners are not given sufficient opportunities to develop their own understanding of science concepts or to present alternative explanations for situations because they are too preoccupied with passing this all-important examination. Jenkins and Whitfield (1974) state that "[p]eople learn what they need and are allowed to learn" (p.25). Until the format of the examination changes, the benefits from it are unlikely to change.

6.2.3 High school physical science teachers

Another reason for the non-match between what is achieved at high school and what is required beyond that, is the fact that many high school physical science teachers lack knowledge about the actual relevance of much of the high school physical science subject matter to the modern technical and scientific world. Many teachers perceive the subject as a 'book learning' subject, rather than one which is constantly applied in the 'real' world. I'm not sure how already busy teachers can overcome this 'gap' in their knowledge. The SCANS Report (1991) mentions a similar problem when it states: "Despite sincere, well-intentioned efforts to respond [to the requests from outside institutions about the type of school-leavers they required schools to produce] the schools ... continue with the system and methodologies they inherited ... nearly

100 years ago …" (p.5). Ordinary school textbooks do not make more than a brief passing reference to any type of relevance of the high school physical science syllabus to 'real world' science, and most teachers rely heavily on textbooks for their knowledge and classroom practice. I certainly did, and still do, although I have found out a lot by talking to ex-pupils about their careers, not least those involved in this research project. I'm fortunate that many of the pupils from the school where I teach live and study or work in the vicinity and return to school to see their teachers. This could not happen where learners left the region to pursue careers or studies in other parts of the country.

6.2.4 Specific skills training at high school

Another area where schools fail to prepare students adequately for post-school situations, is one of time-management and taking responsibility for their own actions. Once they leave school, young people are expected to be able to manage their own time: there are no reminders, no bells ringing. They must just get on with it. And it takes quite a lot of effort for a young person to change from one system to the other.

6.3 IMPLICATIONS

Overall, I think my research has shown that the learners themselves feel they have received *some* preparation for post-school careers, *some* skills training, and thus *some* benefits for their present situations. However, it has also shown that the employers/lecturers feel that the skills they have received are not sufficient. The fact that the four young people I interviewed were all highly motivated to do well at school, and particularly in physical science, may be partly responsible for the apparent mismatch between the views of the two groups. Indeed, at one point, his training manager said that Bobby was actually one of his best apprentices who had been really well-prepared for his apprenticeship! The responses to the questionnaires given by the employers/lecturers were for students in general, and not about the four interviewees specifically. Although my work was done with a small sample, I think that it has shown that the modern technical and scientific fields for both immediate workplace employment and tertiary studies need as good a level of preparation as possible at school level. But educators at high schools, and physical science educators in particular, must try to develop skills in their learners beyond just passing a rather predictable senior certificate examination. High school educators must try to broaden their focus and help learners to broaden their understanding of what they are studying in physical science and why they are studying it. High school education must become more than just passing exams well!

Students need to be taught how to develop thinking skills, how to think creatively about problems, and how to come up with innovative solutions. They need to be taught how to think logically through a problem so that it can be solved. They need to be taught how to make decisions based on scientific reasoning. Students need to be taught to manage their time to maximum effect. They need to be taught how to learn effectively in one context so that they can transfer their learning to new contexts. In short, they need to be prepared to cope in an ever-changing and increasingly technological world.

The new National Curriculum Statement for Grades 10 – 12 (Schools) Physical Science (2002) emphasises all these skills. It offers the possibility (probability, if successfully implemented) of producing school-leavers who will be quite capable of making an easy and successful transition to tertiary institutions and technical workplaces because they will be equipped with all the necessary skills.

In order for students to be given these skills, their teachers must know something about them too. Perhaps a two-pronged starting point is needed: re-equip teachers so that they can equip the pupils. I would suggest that exposing more teachers to documents like the American SCANS Report: What work requires of schools (1991) and the School-to-work National Customer Dialogues (2000) might be advantageous. I understand that there are some approaches being made for closer co-operation between certain companies and the schools in parts of South Africa. (My own school is, for example working closely with the national rail commuter industry and the motor industry to ensure that the technical training our learners receive is what employers such as these require.) This kind of initiative should be encouraged: when the "real world" tells schools directly and explicitly what they require, schools will be in a better position to direct learners appropriately. And then surely, the value of having studied physical science at high school will be considerably more than it is at present.

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APPENDICES

APPENDIX A QUESTIONS TO BE ASKED AT INTERVIEWS

Group 1 : Context

1. Please tell me how long it is since you left school; and what you are currently doing?
Working full-time; working and studying part-time off-site; working and being trained on-site.

2. Tell me about your daily "job". What do you have to do? How difficult do you find it? Are there specific people who help you? Have you been given special training?

3. How long have you been involved like this? How much has changed since you started here? How were you prepared for these changes?

4. What does the immediate future hold for you? Will you still be doing the same things sometime further down the line? If not, what changes are likely to occur?

Group 2 : Subject Specific

5. You said you do this each day. What particular skills do you think are necessary for this? Could an uneducated person do it?

6. What in your school education prepared you for this?

7. How did school science prepare you in this area?
Parts of the syllabus – maybe physics, maybe chemistry.

8. What particular science knowledge did/do you need for success in your field?
Some reference to science content; also technical subject from school.

9. What particular skills – thinking, following instructions, making a plan, remembering steps in a process – do you need now?
Detail of requirements.

10. Can you identify any obvious links between what is required of you now and what you were taught, or what you learnt at school?
What is required of you in your day-to-day activities? What responsibilities do you have? Who do you report to? About what? How often?

<u>Group 3</u> : <u>Teaching</u>

11. How successful was your experience of science at school?
Your own experiences, your attitude, your individual achievements.

12. How did school teaching, particularly in science, help you in what you are doing now?
Methods of study; methods of reading; recording; remembering; coping in a group or team; coping on your own; meeting deadlines.

13. Which subject of those you studied at school helped you the most? Second most? Least?
Maybe English language skills; writing skills; maths skills; technical drawing skills. Specifically any other than science and technical subjects.

14. Do you think you learnt more from some teachers than from others? Can you remember what made them different?
Style of teaching; expectations of you and/or of class; atmosphere in classroom; forced to learn content, rules, patterns; forced to think, understanding what you were doing; seeing relationships between different parts of the whole.

<u>Group 4</u> : <u>Wish List</u>

15. What would you have liked to have received from school that would be useful to you now? That would be useful in the future?
(i) in a science context?
(ii) in other subjects?
(iii) in terms of skills? (general/specific ...)

16. What do you think should be left out of the school science curriculum?
Specific topics; types of exam questions

17. Would you encourage your younger brother or sister to take science at school? Someone intending to do a course similar to yours?
Give reasons!

18. What advice would you give to other learners wanting to follow a course similar to yours?

19. What would you introduce at school over and above the standard course that would benefit people taking your course/doing your line of work?

APPENDIX B QUESTIONNAIRE FOR EMPLOYERS AND LECTURERS

Questionnaire for employers :

When you select people for a training course or employment what do you look for?

A Consider the general education of the applicant:

Please **rate the following criteria** on a scale of 1 to 5. **1 = very important**
5 = not important

Please check **X** the appropriate box next to each of the following criteria.

1.2 IT IS IMPORTANT FOR THE APPLICANT TO HAVE

	Very important 1	2	3	4	not important 5
passed physical science at matric higher grade level					
passed maths at matric higher grade level					
passed English at matric higher grade level					
a good general knowledge					
attended a technical high school rather than an academic high school					

B Consider the personal attributes of the applicant:

Please **rate the following personal criteria** on a scale of 1 to 5. **1 = very important**
5 = not important

Please check **X** the appropriate box next to each of the following criteria.

1.3 IT IS IMPORTANT FOR THE APPLICANT TO

	Very important 1	2	3	4	not important 5
show self-confidence rather than be a shy reserved person					
have a positive outlook on life					
show commitment to developing new skills for the new South Africa					
be committed to transformation and change					
show evidence that s/he can work independently without close supervision					
show personal honesty and integrity					

Are there any other personal attributes that you consider important? If so, please specify:

____

____

C Consider the general skills of the applicant:

Please **rate the following skills** on a scale of 1 to 5.

1 = very important
5 = not important

Please check **X** the appropriate box next to each of the following criteria.

How important are the following skills?

1. Language and communication

An applicant should display an ability to:

	Very important 1	2	3	4	not important 5
express him/her-self clearly and concisely **verbally** in English					
express him/her-self clearly and concisely **verbally** in another language					
express him/her-self clearly and concisely **in writing** in English					
express him/her-self clearly and concisely **in writing** in another language					
listen to, and consider, the ideas and views of others when expressed verbally					
listen to, and consider, the ideas and views of others when expressed in writing					

2. Following instructions

An applicant should display an ability to:

	Very important 1	2	3	4	not important 5
read and comprehend written articles, reports and diagrams					
follow verbal or written instructions given in English competently and without much further close supervision					
follow verbal or written instructions given in another language competently and without much further close supervision					

3. **Logical thinking and decision making**

An applicant should display an ability to:

	Very important 1	2	3	4	not important 5
think clearly and logically in specific contexts					
think clearly and logically in unfamiliar situations					
weigh up alternatives and make decisions based on this					
plan a course of action based on these decisions					
think laterally and innovatively					

4. **Learning skills**

An applicant should display an ability to:

	Very important 1	2	3	4	not important 5
learn new trends under supervision or training					
transfer learning skills from one situation of learning to a different situation					
use a computer for such skills as report writing, doing calculations, drawings					
obtain additional information from a library, the internet or other resource					

5. **People skills**

An applicant should display an ability to:

	Very important 1	2	3	4	not important 5
work as part of a team of peers					
work as part of a team that has varying degrees of expertise					
understand the need for teamwork					

Are there any other skills that you regard as important in trainees? If so, please specify:

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D Consider the physical science knowledge that applicants have:

Please **rate the following skills** on a scale of 1 to 5.

1 = very important
5 = not important

Please check **X** the appropriate box next to each of the following criteria.

In your opinion, how important is it that the applicant

	Very important 1	2	3	4	not important 5
has achieved a good mark in physical science at matric level					
can see links between the classroom science that has been studied and the "real world"					
can understand basic science concepts					
has memorised many scientific facts					
can manipulate relevant mathematical formulae and do calculations					
can use basic physics and chemistry apparatus					

In general, do you think high school has adequately prepared the applicants you have interviewed over time?

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In general, how do you think that high school physical science could be improved to make school leavers more employable?

Please specify, with regard to skills, knowledge and attitudes, and if possible, provide examples.

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