

**FROM THE PARTICULARITIES OF PRACTICE
TO
THE GENERALISATION OF THEORY**

Faizul Bhyat
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Faizul Bhyat

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Doctor of Philosophy Degree in the School of Education,
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Supervisor : Professor R. Osman

DECLARATION

I, the undersigned, hereby declare that *From the Particularities of Practice to the Generalisation of Theory* is my own original work, written under the supervision of Professor Ruksana Osman, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete reference. I submit it to the School of Education, University of the Witwatersrand, for the Doctor of Philosophy Degree.

Signed :

Name:

Date:

ABSTRACT

This thesis has situated the Government's new integration of education and training policy within post-apartheid South Africa's wider socio-economic and political context. It has shown, how in its relation to education, post-Fordism required a highly skilled labour force that was able to employ the new technologies and add value to goods and services. This, it was argued, would enable South African goods to compete more effectively in the global market. There is a strong stress related to the notion of 'continuous innovation' with its implication of skilled workers constantly adapting existing technology through incremental innovative steps. The study has among others, drawn on South African academic Kraak's (1994) segmented labour market thesis (which has decisively influenced both ANC and Cosatu's educational policy process) to argue that this notion of 'continuous innovation' was highly dependent on the presence of two knowledge forms in society and work – an abundance of formal (scientific and technological) knowledge and skilled worker 'know-how' or tacit knowledge. The implication was that, in sharp contrast to job-specific or a narrow Taylorist oriented enskilling process reminiscent of South Africa's past industrial training system, the new skill needs in late industrial societies now required the worker to understand the deeper conceptual underpinnings of his product/process nexus of work. This was to be instituted through South Africa's new learnership programme.

These developments came under strong attack from a left critical discourse that had taken issue with the policies neo-liberal underpinnings of subjugating education to the dictates of capital. However, such an integrated system had a particular significance for South African trade unionists. It offered an alternative to the divisions that were such a dominant feature of racial capitalism by providing for the possibility of occupational mobility through training that had been systematically denied to black workers under apartheid education. The new possibilities of linking tacit, or working knowledge to scientific knowledge, or theory to practice, through the integration of education and training would thus provide the capacity to bridge the social stratification divide related to race, class and gender which was historically

entrenched and prevalent in the racial economy, and maintained and mediated through high and low status knowledge forms.

The process of policy implementation, however, is proving to be exceedingly difficult in South Africa. The problem reportedly lies in the epistemological difficulty of integrating working knowledge with the more formal disciplinary knowledge domains. This affects both its redressive aims of achieving quality education and training, occupational mobility for workers, and enskilling for the new technological needs of late industrial society. This argument was derived from the Bernsteinian theoretical distinction between two discursive knowledge forms, characterised as horizontal and vertical discourse. It is stressed that formal and informal, working and scientific forms of knowledge are structured differently, and therefore are associated with different learning processes or modes of learning. Describing the two knowledge domains as 'epistemologically' and 'sociologically' distinct however, tended to present them as mutually exclusive, which further polarised the mental/manual divide. At issue, was its implication for the division between high and low-status knowledge forms. This thesis through its argument effects a synthesis between working and scientific knowledge by positioning the technologies that form an integral part of the workers tacit working knowledge as a modality of vertical discourse characterised by a horizontal knowledge structure and tacitly transmitted. Repositioned in this manner, the different modes of learning are brought into collaboration with each other. This also bridges the stark polarisation between contextualised and de-contextualised knowledge forms.

A second problem that needed serious consideration was the difficulty that candidates encountered in terms of understanding formal scientific syntax. These resembled wider general trends, where, in relation to these formal discourses, historically disadvantaged students struggle to master the 'curricular version of its rigorous language'. As previously mentioned, verbal proficiency is an entrance requirement for occupational mobility. In this way it constitutes symbolic capital, and confers symbolic power. Thus, the problem in understanding the difficult syntax of these formal scientific discourses has been identified by concerned educationalists as an exclusionary mechanism needing radical reform.

The thesis drew on participatory action research as its methodological approach to address this challenge. This was strongly informed by neo-Vygotskian insights, that stressed that language acquisition – and especially formal conceptually underpinned language acquisition – was extremely context bound, and could consciously be pushed to more complex levels through the aid of a tutor. This takes place within the ‘zone of proximal development’ – the necessary interplay between inductive, experiential learning of the subject which gives rise to word sense, and the deductive generalising instruction of the teacher and the curriculum which helps expand understanding of generalised and abstract word meaning. The methodological slant of the thesis draws on ‘action research’ because of its abiding concern with social issues of justice, and in this way resonates well with the concerns raised in the political economy of knowledge debate within which the aims and objectives of this thesis are also grounded. The stress on the dialectical relationship between theory and practice, as advocated in participatory action research compliments further the study’s theoretical underpinnings which supports the generalisation of theory from the particularities of practice. Through a dialectical process from practice to theory and back to practice again, we believe we were able to make incremental shifts in terms of the zone of proximal development of our students. This led me to re-assert the role of the educator as a crucial participant in the process of transformative learning. It was especially important within the context of the new outcomes-based education with its stress on a learner-centred approach.

This thesis draws on its empirical findings to raise some important problems related to the conceptual coherence of South Africa's new integration of education and training policy. It shows through argument that the integration of education and training stressed through this policy was not rooted in socio-cognitive theory, and argues that a more conceptually coherent alternative should root itself in new emerging socio-cognitive theories on learning. This stresses the importance of re-conceptualising the learning process within a socio-cognitive approach, as opposed to a fundamentally ‘mentalist, or ‘biological’, view of the learning process. I believe that the nature and findings of this research could contribute both theoretically and conceptually towards a wider evolving social theory of learning.

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ABBREVIATIONS & ACRONYMS

ACTU	- Australian Congress of Trade Unions
ANC	- African National Congress
CBMET	- Competency-Based Modular Education and Training
COSATU	- Congress of South African Trade Unions
DL	- Department of Labour
ELM	- External Labour Market
ET	- Education and Training
FIETA	- Forest Industries Training Authority
HLM	- High Level Manpower
HSE	- High Skills Equilibrium
ILM	- Internal Labour Market
ITC	- Indigenous Technological Capacity
MAPPSETA	- Media, Advertising, Publishing and Packaging Sector Education and Training Authority
MERSETA	- Manufacturing, Engineering and Related Services Sector Education and Training Authority
NEPI	- National Education Policy Initiative
NQM	- National Qualifications Framework
NSDS	- National Skills Development Strategy
NTB	- National Training Board
NUMSA	- National Union of Metalworkers of South Africa
OBE	- Outcomes Based Education
RPL	- Recognition of Prior Learning
SAQA	- South African Qualifications Authority
SETA	- Sector Education and Training Authority
WPET	- White Paper on Education and Training

CHAPTER ONE

Introduction to the Study

The relationship between the abstract world of academic education, unaffected by the world of practical reality and vocational education, rooted in practical work, but not consciously linked to the laws of science which underlie the practical, is a classical theme in the sociology of knowledge and in education policy. The issue of further integration of vocational and general studies has now emerged as a political issue (Mjelde, 1997:331).

1.1Background

This thesis gives an account of a study that has been undertaken to explore possibilities of meaningfully linking tacit or working knowledge to the more formal technological and scientific knowledge domains. The study has been conducted through an action research methodology in the form of a pedagogical programme underpinned by developing theories of learning that stress the situated cognitive nature of learning. These theories stress the importance of learning within meaningful contexts as opposed to abstract de-contextualised learning. The sample consists of workers engaged in learning lithography within the designated trade of machine-minding at a specific printing company affiliated to the Media, Advertising, Publishing, Printing and Packaging (MAPP), and the Sector Education and Training Authority (SETA).

This action research emerged out of a sense of disillusionment experienced while conducting preliminary research into the South African Government's newly launched 'learnership' programme. These 'learnerships' were to differ from the previous apprenticeship system, which had been severely criticised for its work-specific enskilling process. In keeping with the notion of 'flexible' skills arising from

debates surrounding the new post-Fordist economy detailed later, workers now needed 'generic' skills and knowledge, such as the ability to understand a task theoretically, to apply skills and knowledge to it and to transfer the skills to another context. Whilst these developments came under attack from a leftist critical discourse that took issue with its neo-liberal underpinnings of subjecting education to the dictates of capital, it is important to note that such an integrated system of linking theory to practice, and education to training, had a particular significance for South African trade unionists. This system offered an alternative to the divisions that were such a dominant feature of racial capitalism by providing for the possibility of occupational mobility through training opportunities that were systematically denied to black workers under *apartheid* South Africa. The linking of tacit working knowledge to the more formal scientific knowledge domain was to be realised through the new integration of education and training. It needs to be stated at the outset that whilst the link between the tacit and the scientific assumed increasing importance in comparison to other curriculum areas in terms of providing the requisite skill needs for a new globalising economy, Gamble (2004) drawing on Young (2001) states that:

...other curriculum areas which appear very diverse also share a common heritage in that they all derive from formal bodies of knowledge in the natural or social sciences or in the humanities and because of this, they all require a combination of conceptual and practical expertise for their successful realisation (Gamble, 2004:192).

Following from the above, it is argued that if the distinctive knowledge and skill base of these occupational areas is not recognised – as has been the case in our past curriculum history - they will be treated similarly to areas that have little or no formal conceptual basis and which are driven by the logic of work rather than by the logic of knowledge. This is required not only by the skill needs of new competitive global economic conditions, but also to ease the social division between mental and manual labour- between conception and execution between practical subjects and

theoretical subjects – between high status and low status knowledge forms as these divisions have historically developed through capital's industrialisation process.

My initial enquiry into the nature of the new enskilling process embedded in the learnership programme increasingly showed its narrow vocational orientation. This was a problem that was not only experienced at this particular case study level. At that juncture, in early 2003, it had also begun to manifest itself more generally at a wider national level.

The problem – as a council of higher education commissioned enquiry in 2003 (detailed later) suggested – was more endemic in nature, and was related to the difficulty of meaningfully linking tacit working knowledge to the more formal academic knowledge domains. This will be detailed in the sub-sections to follow. As a result of these emerging problems, this researcher was faced with the choice of basing his research purely on critique, or, choosing through an action research oriented pedagogical programme, to try to effect a deeper relationship between theory and practice in terms of meaningfully linking the tacit or working knowledge to the more formal technological and scientific knowledge domain as it concerned the candidates under this study. This researcher chose the latter option because of reasons related to sympathy with trade union sentiments about the neglect of quality training and occupational mobility denied to people of colour under *apartheid* South Africa. A second reason was related to a belief influenced by anecdotal experience (detailed in the theoretical chapter three) of the possibility of achieving the meaningful integration of theory and practice, education and training, which was proving in general to be so elusive. In order to understand the formulated responses to these problems, undertaken through this action research approach, we need importantly to deepen our understanding of the nature of these problems themselves.

The discussion that follows examines these issues within the context of post-*apartheid* South Africa's attempted integration of education and training policy. It examines why the link between the tacit and the scientific has assumed such

importance within this context, and why its non-attainment posed a problem. The following sub-section which relates to the statement of the problem is foregrounded within this context because the nature of these problems and their formulated responses (undertaken in later chapters) only assume meaning within context. The deeper social-economic and political rationale underpinning the integration of education and training policy itself is examined at a much more detailed level in chapter two.

1.2 Statement of the problem

Post-*apartheid* South Africa's educational policy, which commits itself to the integration of education and training, was first enshrined in the 1995 *White Paper on Education and Training*. It is basically an integrated unitary system of education and training with a common qualifications system, which aims to facilitate access to formal education, to ease articulation between different learning contexts and to ensure progression through various learning pathways, such as learnerships. In order to enable it to restructure the existing divided and fragmented education and training system, the state introduced the National Qualifications Framework (NQF), developed through the 1995 South African Qualifications Authority (SAQA) Act. The learnerships that were developed through this framework differed from the previous apprenticeship system, which had been criticised for its work-specific enskilling process. They were geared towards a more theoretically informed enskilling process. Thus, in keeping with the notion of 'flexible skills', workers now need 'generic' skills and knowledge, such as the ability to understand a task theoretically, apply skills and knowledge to it and transfer them to another context (De Clercq, 1997:157). Furthermore, a principle referred to as the 'recognition of prior learning' was an important tool introduced by the NQF to achieve educational redress. It constituted a lever to formally accredit the experiential knowledge of people who were denied educational opportunities during the *apartheid* years. In this sense the South African education policy interweaves two discourses:

... alongside a discourse of human resource development is an ultimately more powerful discourse of human rights (Christie, 1997: 116).

The evolving changes could in general be traced to the process of globalisation as well as the emergence of 'post-Fordism' in advanced capitalist economies. This economic paradigm was characterised by technological and industrial innovations combined with organisational changes to ensure that economies that are able to compete successfully in the world market do so on the basis of trade in value-added manufactured goods. In its relation to education, post-Fordism requires a highly skilled labour force that is able to employ the new technologies and add value to goods and services. At the heart of the new production paradigm is the notion of 'continuous innovation' with its implication of skilled workers constantly adapting existing technology through incremental innovative steps. Moreover:

Continuous innovation is highly dependent on the presence of two knowledge forms in society and work: an abundance of formal (scientific and technological) knowledge and skilled worker 'know-how' or tacit knowledge (Kraak, 1997:54).

The challenge is to effect a more meaningful relationship between tacit or working knowledge and the more formal scientific and technological knowledge domains. This is necessary for innovation as well as the ability to adapt and respond quickly to rapidly changing technology under post-Fordism. The implication is that, in sharp contrast to job-specific or narrow Taylorist oriented skilling, the new skill needs in late industrial societies must be underpinned by 'technological literacy'. This notion entails a deeper understanding of the scientific principles underpinning the product/process nexus of work. These conditions have had strong policy implications for the integration of education and training in South Africa and internationally. This recognition of the importance of a deeper conceptual and cognitive dimension to skills, as it relates to technology, resonates well with the notion of 'technological literacy' alluded to by Gleeson (1990). Drawing on Wellington (1987) he writes:

Skills are not entities, which are in short supply. What industries need are people with the abilities to develop new skills to learn new knowledge, to acquire new concepts and theories and to adapt to technological change with enthusiasm and lack of fear. This is the essential meaning of technological literacy as opposed to technological skill. The job of both education and training is surely to provide people with the ability and enthusiasm to learn, to adapt to change, and to be aware of and at home with new technology (Gleeson, 1990:197).

Skills related to the concept of 'technological literacy' discussed above give a reading of the authors' intention to stress the importance of the conceptual and cognitive underpinnings to the notion of skills preferred. This is in sharp contrast to a narrow work-based orientation to skilling. The question that arises relates both to what these broad and transferable technological capabilities are, and as to how they are developed. Gamble (2002) argues that the relationship between science and technology is a crucial part of the debate concerning technological capability and innovation, showing historically how as technologies became more sophisticated, their link to science became stronger. Gibbons (2000) states that we need to abandon the notion that science and technology are distinct, institutionally-defined activities. This is because since actors do not move in accordance with linear, sequential and hierarchical models, step by step from research to development to innovation and diffusion. He argues that basic science has become inseparable from technological development and that the two are often linked by the innovative use of instrumentation. Thus the notion of technological capability importantly entails within it the ability to understand the scientific principles embedded within the technology itself. The contention is that once the learner understands the principle, s/he then has the ability to extrapolate beyond well-known concrete situations. This is the important ability that is most often lacking in the way in which production trades are taught and passed on in both formal and informal sector practices. It is also this ability that provides the basis for technological innovation and adaptation, characteristics identified as crucial to survival under new global economic conditions (cf. Gamble, 2002). The nub of the issue is that the enskilling process should empower the student/worker with 'technological literacy', a concept which, as

indicated above, implies deeper conceptual and cognitive underpinnings and entails an 'insight into the processes of scientific and technological development'. British academics Fuller & Unwin (1998), writing within this same field, argue for the importance of the production worker to understand the science behind the artefact. Indeed, science and technology, together with mathematics as well as languages, are identified as part of the critical components considered important for 'generic' learning within a learnership (Bird & Elliot 1993).

It was within the context foregrounded above that I ventured to study the relationship between theory and practice as constituted in a learnership. The case entailed a group of workers studying lithography within the designated trade of machine/minding. In keeping with the specific conceptual framework, I chose a site wherein both the product/process nexus of production (detailed in chapter 5) was strongly underpinned by principles of science. The preliminary research gradually convinced me of the increasing vocationalisation of this learnership programme. Despite the fact that the entire product/process nexus of work in this instance was underpinned by science and engineering concepts, there was no effective and meaningful relationship between the tacit and the scientific. Its importance must be seen within the context of workers understanding the deeper conceptual underpinnings of their practice. An example of the learning outcomes, objectives, criteria and assessment strategies of a very important aspect of the lithographic process – to make a lithographic printing plate for a 'process colour job' contained in a technical theoretical related module (outlined in the table in sub-section 4.5 in ch.4) – gives an indication of its very narrow vocational and trade related nature.

The outcomes based pedagogy specified only work oriented learning outcomes in unit standard format without reference to any of its underpinning concepts. As Gamble (2002) observes, it clearly resembled the problematic nature of unit standard formats in general, where learning outcomes, as explicated in unit standard format, focus on what can be observed and stated in procedural form and derive from a functional analysis of work itself.

The importance of teaching underpinning concepts in terms of the link between the tacit and the scientific, needs to be seen in the following context. The introduction of

sophisticated technology in some sub-sectors of the manufacturing industry (within which this study is also based) is increasingly replacing the artisan at the lower levels of production, while simultaneously creating the demand for 'high-tech' maintenance artisans such as electricians, fitters and turners. The expected demand for these artisans is bound to increase in 14 of the 18 sub-sectors in manufacturing, even though the sector as a whole is characterised by declining unemployment (Gamble, 2002:12). Studies conducted within the printing sector also attest internationally to the changing nature of technology within the industry (Mjelde, 2003). Indeed the printing and publishing SETA, within which this particular study is located, has as a result of the changing nature of the technology within it, introduced both mechanical as well as electrical engineering maintenance-related courses related specifically to printing machinery. During the course of preliminary research, the candidates within this study all expressed a strong desire to study these occupational categories. In particular, they see in it both economic and occupational potential. They also identified with it because of their strongly developed tacit knowledge within these fields. There was, however, no pathway from the lithographic and machine-minding process through to the printers mechanical and engineering related fields introduced within their industry. A state affiliated council for education commissioned enquiry in early 2000, related to problems bedevilling the National Qualifications Framework (NQF), seemed to suggest that this was a more generalised problem (2003:10). This researcher's personal enquiry from course assessors in 2003 revealed that, as a result of their poor grades in maths and science subjects, candidates in this study would not qualify. Moreover, access through the NQF depended upon prior higher level qualifications, the minimum being a very good pass at the higher grade in matric in both science and mathematics related fields. Despite the fact that all the candidates in this particular study had attempted maths and science at the standard lower level grades in school, they still expressed great anxiety about these science knowledge domains at higher-grade levels. It was also their reason for dropping out of the higher grade in these subjects at school level. They sadly expressed the view that they did not see themselves ever attempting these subjects at the higher grade again. They totally lacked the confidence – 'confidence in their ability to learn' as expressed by Norwegian academic Liv Mjelde in relation to vocational education students in similar circumstances in Norway (Mjelde, 1997). This state of circumstances in South Africa

could also be traced historically to the legacy of *apartheid* education where race and gender add an additional dimension to the variable of class.

This researcher also noticed that despite the fact that the lithographic and machine-minding process was underpinned by science and engineering-related concepts, the curriculum designers within the industry did not see any possibilities of being able to link it, even at the most basic of levels, to the printers' mechanical and engineering related fields. This is indeed what this research has tried to do, as will be subsequently shown. Workers thus feel entrapped within the *status quo*, and are disempowered both in terms of occupational mobility, and the development of any generic skills. There are quantitative studies that suggest that this is indeed a more generalised problem (Baatjes, 2002; Aitchison, 2002). These writers have indeed called for the termination of the NQF.

Moreover, in view of developing research that argues that learning is extremely contextual, there were also no theories of learning, if any, drawn upon by those administering the learning process. The new enskilling process was not addressing its advocated epistemological and political aims of redress, equity and worker empowerment. In relation to the preceding question, the new enskilling process was also not meaningfully bridging the theory/practice divide. The significance of this question needs to be seen within the context of the political economy of knowledge debate, where the divide between the work of the hand and the work of the mind, emanating from the development of capitalism, has in South Africa, historically differentiated workers in terms of race, class and gender.

To sum up, the narrow enskilling process of the theory/practice relationship under the specific learnership programme was restrictive both in terms of its redressive aims of occupational mobility and worker empowerment, as well as in terms of the economic aims of enskilling for global competitiveness and technological change. These are both well articulated aims of the NQF. It indeed lacked any conception in terms of linking workers' tacit knowledge to the technological and scientific knowledge domains.

The discussion will now turn to focus on related concerns emanating from the more general terrain. Whilst the following discussion raises general concerns related to the same broad subject under discussion, it also shares important pedagogical and epistemological concerns related to both terrains.

Some writers have raised important epistemological and pedagogical concerns related to the National Qualifications Framework. In privileging an epistemological assumption about the 'constructed nature' of knowledge, education department officials advocated a 'paradigm shift' from the previous teacher-centred approach associated with *apartheid* education to a new learner-centred approach in which students were expected to engage knowledge, not as passive recipients of it, but as active participants in its shaping (Moll, 2002). Many of its critics were not against its criticism of the old ideologically laden curriculum of the past, accompanied by the unequal power relations between teacher and learner. Rather, they took issue with the loss of crucial content material through the negation of a syllabus advocated by the new 'paradigm shift' which they argued tended to work against thorough subject matter coverage, the conceptual advancement of specialised skills and concepts, as well as coherence in domain-specific or disciplinary knowledge (Reeves, 2002:5). Indeed the belief that those students who are capable of developing curricular knowledge on their own, assumes that they have some prior mastery of that domain specific knowledge. This may not necessarily be true, and as Muller and Taylor (2002) argue, it may act against, rather than for, students emerging from the legacy of *apartheid* education. In a similar reflection on a learner-centred approach in the United Kingdom, Fuller and Unwin (1998) comment that such an emphasis too early on apprentices' responsibility for their own learning seems to be in 'danger of putting the cart before the horse'. Moreover, they argue that a programme structured in terms of outcomes and not processes is liable to produce inconsistent learning experiences which may lack both 'content' and the sort of pedagogy leading to 'expansive' learning. This they define as deep reflective learning obtained through a transmission pedagogy which need not be autocratic in nature.

Breier (1998) takes issue with the principal of 'equivalence' related to the recognition of prior learning articulated in the NQF. In other words, how does one formally accredit experiential knowledge? Drawing on the social practice theories of Lave and Rogoff, she argues that, because learning and knowledge are inextricably bound up with context, this raises immediate doubts about whether one can expect equivalence between 'street' or 'workplace' learning and that which occurs in formal sites of learning (Breier, 1998:120). She also takes issue with the principle of generic skilling required for transfer across contexts. In addition to the above theorists she draws from the perspectives of socio-linguistic theory and poses the question:

If knowledge and skills are linked as closely to context and mode of learning as these theories suggest, how can competence acquired in one context be equated with (or recognised or accredited as) competence acquired in another? (Breier, 1998: 122).

Citing Ensor (1997) on the relationship between mathematical knowledge and working knowledge, she argues that by imposing the template of schooling on workplace knowledge, the NQF attempts to render equivalent what many would regard as sociologically and epistemologically distinct. Although I can appreciate these writers' concerns in terms of the difficulty in finding formal standards of measuring experiential knowledge, I think describing the two knowledge domains as 'epistemologically' and 'sociologically' distinct tends to present them as mutually exclusive, which further polarises the mental/manual divide.

As a result of epistemological problems experienced at policy implementation levels, strongly related to the concerns raised above, a 'Study' team followed by a 'Task' team was jointly appointed by both the Department of Education and the Department of Labour to look at problems of implementation. It found, among other issues, that the greatest difficulty was that of articulation between working knowledge and academic knowledge. Dissatisfaction with the recommended proposals led to a report commissioned by the Council for Higher Education in which Young (2003) was asked to offer a conceptual critique of the consultative document. He suggested that the entire NQF structure needed to be re-conceptualised because of a fundamental

tension between working knowledge and the more formal disciplinary knowledge domain. It is believed that they are irreconcilable because of epistemological differences related to their respective modes of learning. This line of argument is again derived from the Bernsteinian theoretical distinction between two discursive forms characterised as horizontal and vertical discourse, which, because of the argument's theoretical nature, is taken up in chapter three.

Whilst I may agree with Young that certain work-place occupations may not need deep conceptual learning, he does not limit his argument to this. Also included are "technicians" who may be aspiring to become engineers (Young, 2003:12). I take issue with the broad generalisation that includes technology-related work-occupations. My questioning emanates from anecdotal experience of technology related work (detailed in the theoretical chapter) that shows the possibilities of bridging this epistemological based divide between the two modes of learning. In a quest to deepen my understanding of this experience, I realised that it identified very strongly with developing theories of learning related to situated cognition. It was indeed this exciting possibility that initiated a study of this nature. A deepened theoretical understanding of my experience convinced me that one could further deepen one's conceptual understanding through a conscious dialectical move from practice to theory and back to practice, the one informing and being re-informed by the other. Thus, the process of learning takes place through consciously bringing to the worker's consciousness the conceptual underpinnings of his/her work. This is especially true of technology related occupations because they are underpinned by principles of disciplinary science. Thus, what is generally abstract now becomes concrete. This identifies very strongly with developing theories of learning that argue for working out the meaning of an idea within the context of its use, and argue against the abstract de-contextualisation of knowledge as taught in schools.

The prospect of testing these possibilities is important because a significant proportion of workers are engaged in technology related work. I also saw this as a chance to de-mystify power discourses that limit occupational mobility.

It is on the basis of this calculated assumption informed by the logic outlined above that this study examines the possibility of establishing the epistemological link between the tacit and the scientific. This would be driven through the process of explicit transmission in the form of conscious intervention methodologically, influenced by an action research oriented learning programme. The pedagogical process is underpinned by newly developing theories on learning. In this way the study tries to address the polarisation between the mental and the manual, created by the argument that because of the epistemological differences between the tacit and the scientific, their respective modes of learning also differ. Thus, at the case level the study tries to retain the emancipatory concerns of action research related to equity issues such as occupational mobility and bridging high and low status knowledge forms. At another level the study broaches the possibility of a theoretical generalisation related to its epistemological linkage of working knowledge to the more formal knowledge domain, especially within the context of the view that:

Progress in science knowledge has, however, irrevocably affected the nature of vocational knowledge and a shift from particular to general scientific principles now characterises knowledge at intermediate and higher levels of technical and technological expertise (Gamble, 2004:179).

To very briefly sum up, the sub-section above has raised both pedagogical and epistemological questions related to integration of education and training. The narrow enskilling process, which does not empower previously disadvantaged workers, also questions its claim as a philosophy of equity and redress. Such a polarisation of the mental\manual divide must raise important concerns for the new knowledge economy with its demand for a deeper theoretical underpinning of praxis. It also affects the redressive aims related to occupational mobility. Indeed, historically disadvantaged workers cannot access higher occupations without prior induction into the academic knowledge domains. This, together with more generalised problems related to articulation between the respective knowledge forms, and indeed to problems of implementation, persuaded me to reconceptualise

my study. Sensing that I would eventually have to make a choice between either basing my research purely on critique, or critically attempting to change at least some of the circumstances through action research, I chose the latter. My choice of some form of action research was influenced by the fact that it shared similar objectives to that of critical educational theory (detailed in chapter 3), with its equity implications for participants concerned. The process of participatory action research is generally thought to involve changing participants' practices through a spiral of cycles of critical and self-critical action and reflection. It has been described:

... as a deliberate social process designed to help them learn more and theorise their practices, the social structures that shape and constrain their practices and the social media in which their practices are expressed (Kemmis & McTaggart, 2000:598).

My decision was informed also by a belief influenced by anecdotal experience (detailed in chapter 3) of the possibility of dialectically integrating practice to theory! This action-research must be seen also within the following context:

... critique will not be enough. Internationally, there is a growing discourse of user-orientated research. Students, parents, teachers and state officials do not want to know simply that the system is succeeding or failing. Rather, they expect academics to be able to suggest ways of improving practice or, if the practice is irredeemable, of radically reconceptualising the learning process.
(In McGrath 1998:116).

1.3 Aims and Objectives

This dissertation explores the possibility of integrating practice and theory in terms of meaningfully linking tacit or working knowledge to the more formal technological and scientific knowledge domains. It does this through educational intervention in the

form of an action research methodology. It aims to empower workers in terms of deepening their understanding, and of enabling them to access the more formal academic knowledge domain. In this way it aims to provide for the capacity to bridge the social stratification divides maintained within the economy through high and low status knowledge forms, and make a meaningful contribution towards the political economy of knowledge debate that is so close to the heart of many critical educational theorists. The research also attempts to pursue the following objectives:

To investigate theoretical perspectives on situated cognitive theories of learning and study their pedagogical and epistemological implications in terms of:

Designing a pedagogical programme to enable a more meaningful linkage between the tacit and the scientific, and between practice and theory. This implies deepening the conceptual underpinnings of praxis;

Demystify power (academic) discourses that inhibit access and occupational mobility. The relevance of both this and the question preceding it needs to be seen within the wider context of the political economy of knowledge debate, balancing the equity/development tension in terms of enskilling for both technological literacy as well as for worker occupational mobility and empowerment;

To investigate participants' perceptions of this learning process;

To investigate whether the learning programme has in any way given rise to the notion of 'technological literacy' among its participants;

To critically evaluate the significance of this approach to learning that re-affirms the centrality of the teacher's role. Its importance must be seen within the context of the present state of polarisation between transmission and acquisition pedagogies;

To probe what appears (from within the context of researching this case) to be a theoretical generalisability between praxis that increasingly embodies technology and its deeper scientific underpinnings. Its importance needs to be seen within the context of the Mulerian debate that argues that 'reality' – in this instance, context needs to be conceptually relevant to vertical disciplinary knowledge for it not to constitute 'symbolic violence';

To try to provide a model to “promote work-based learning in workplaces, that have no tradition of pedagogy or even instruction” (Young, 2001: 28).

1.4 Outline of the thesis

Chapter two attempts to understand South Africa’s integration of education and training policy within its wider socio-economic and political context. It takes into account concerns emanating from a left-critical discourse that argued that the education and training proposals were purely economic-rationalist in nature. In a rebuttal of this argument it details the view put forward by economists aligned with the Congress of South African Trade Unions (Cosatu) that the capitalist orientated macro-institutionalist perspective that they adopted contained within it strong social-democratic tendencies. It was an attempt to balance the tension between equity and development. There was on the one hand the need for economic development to meet the challenges of the new international economic conditions, and on the other, to overcome the debilitating effects of labour-market segmentation and education and training fragmentation inherited from *apartheid* South Africa.

Chapter three provides the theoretical underpinning of the study. It problematises a central research concern related to the epistemological problem of linking tacit workplace knowledge to the more formal scientific or engineering related knowledge domains. It does this within the context of two oppositional theoretical perspectives. The one theoretical stance emanates from the neo-Bernsteinian discourse that has come to be known as the Mullerian debate after the academic Johan Muller who very strongly advocates this perspective in his book, *Reclaiming Knowledge* (2001). Indeed, as the early part of this chapter has shown, many academics such as Gamble (2002) and Breier (1998), as well as Young (2003), have adopted this neo-Bernsteinian theoretical perspective in their critique of the failings of the National Qualifications Framework (NQF) - the embodiment of South Africa’s new integration of education and training policy framework. Drawing on the neo-Bernsteinian theoretical distinction between vertical and horizontal knowledge forms, which characterises knowledge as differently structured within these respective forms, these writers take issue with the ‘principle of equivalence’ between disciplinary

learning and workplace learning. In other words, because of their different knowledge structures, their modes of learning also differ. This implies that there can be no effective bridging of learning between the two knowledge forms. The chapter shows how, through a process of theorising the nature of the borders in this particular study, this researcher effects a synthesis between the two oppositional theoretical perspectives by meaningfully integrating the tacit to the scientific.

Chapter four describes the research paradigm, including a rationale for selecting an action research methodology. The chapter shows that this choice was strongly influenced by the fact that action research shares similar spiritual and moral sentiments as critical adult education theory, with its concern for empowering marginalised communities, within the context of their practice. In this sense, this means sharing the trade union stance of providing high quality education and training to black youth and adults, who were previously denied this under *apartheid* education. These sentiments are shared by Cooper (1998:108), who holds the view that the emphasis on raising workers' skills levels, and on formally accrediting workplace training, represents a response by unions to authenticate worker aspirations, and that this resonates deeply with workers' desire for recognition, respect, greater equity and opportunities to progress. The chapter drawing on developing literature related to participant action research argues that it complements the theoretical underpinnings of this thesis which is related to the situated, rather than abstract, nature of cognition within the context of communities of practice. This chapter also draws on literature to suggest that participatory action research tends also to complement the theoretical underpinnings of this study, which stresses the dialectical relationship between theory and practice.

Chapter five constitutes the empirical part of the thesis. It provides a profile of the participants, and details how the nature of the learning process was informed by both neo-Vygotskian and newly developing socio-cognitive theories of learning. In this way it tried to conform to the object of the learning process, which was to try to teach from the particularities of practice towards the generalisation of theory. It details and problematises aspects of the teaching and student take-up process. The information

is provided through both narrative and official presentation of students' explanations of some basic science and engineering principles that underpin the product/process nexus of their work. The chapter also provides a brief analysis of this approach to learning that re-affirms the centrality of the teacher's role. This needs to be seen within the context of the present state of polarisation between transmission and acquisition pedagogies. It also raises an important issue related to the conceptual coherence of the ET policy alluded to in chapter two. Through analysis it provides a more coherent conceptual interpretation of the problem of policy incoherence. This chapter also discusses and problematises an important feature related to the nature of learning itself. This relates to Guile & Young's (1998) distinction between a mentalist/biological view of learning as opposed to a culturalist and social-cognitive view of learning. The chapter finally points to certain issues that could be developed upon further through new research.

Chapter six provides a conclusionary summary of some of the central objectives and findings of the thesis. It outlines the challenges that were involved, and the formulated responses to these challenges.

CHAPTER TWO – PART ONE

A Social, Economic, Political and Historical Context

2.1 Introduction

The notion of integrating education and training, officially outlined in the 1995 South African White Paper on Education and Training (WPET), has become a cornerstone of policy in South Africa. However, debate still continues about the nature, form and implications of this policy document. This chapter attempts to understand the debate within the wider context of political economy. It tries to analyse the rationale underpinning this notion – its origins, why was it considered so important, what its proponents hoped to achieve through it, and why South Africa, with its unique history of militant trade unionism, seemed to have accepted these patterns so uncritically.

The chapter starts by tracing the origins and motivations underpinning the education and training integration agenda within both a historical and socio-economic context. It thereafter engages the new ET policy framework within a left critical discourse that takes issue with its neo-liberal underpinnings. The discussion situates the debate within the context of the tension between equity and development. It draws attention to the fact that the integration of education and training cannot be divorced from South Africa's wider historically embedded economic and political philosophies in terms of the debate between socialism and capitalism. It shows how, within the context of the collapse of socialist economies internationally, and the hard reality of being able to survive within the new global and competitive international economic conditions, a call was made by trade-union and early ANC economists and educationalists for a more coherent perspective of how equity and development could complement each other.

The new integration of education and training policy was an important part of this process of attempting to balance the tension between equity and development. It was aimed on the one hand to combat the minimal training opportunities provided for black workers under *apartheid*, and to counter a racially segmented labour market, a

fragmented and divided education and training system, a racial and gender discriminatory occupational structure, and massive black unemployment. On the other hand, it aimed to create the requisite skill needs demanded of the new production paradigm characterised by the notion of 'continuous innovation', with its implication of skilled workers constantly adapting existing technology through incremental innovative steps. The challenge in terms of integrating education and training was to bring about a deeper conceptual or theoretical relationship between tacit or working knowledge and the more formal scientific and technological knowledge domains. This is necessary for the purposes of innovation as well as for the ability to adapt and respond quickly to technological changes under the new competitive global economic conditions characterised as post-Fordism. As the chapter shows, the implication is that, in sharp contrast to job-specific or narrow Taylorist oriented skilling characteristic of South Africa's past history, the new enskilling needs in late industrial societies needed to be supported by deeper conceptual underpinnings.

Part two of the chapter fleshes out Maurice et al's (1986) argument (which the macro-institutionalist perspective has strongly drawn upon) that the process of skill formation is mediated by the form of work organisation adopted. It shows how Cosatu had drawn on best-practice forms of work organisation developed in the more advanced socio-democratic economies of Western Europe and proposed 'active-labour market strategies', 'broad banding' and a unified ET system as critical components of a reconstruction programme which aimed to dismantle these structural features of *apartheid* capitalism and simultaneously position workers for the new skill needs demanded by late industrial society. It also shows how the deeper conceptual relationship between education and training was critical to meeting this challenge.

Integrating education and training in terms of the above was thus a very important factor in trying to balance the tension between equity and development. However, as the preceding chapter has shown, this was proving to be exceedingly difficult to achieve. This was because of the epistemological difference between the two

knowledge forms and an implicative difference in their modes of learning. This has implications for any balancing of the tension between equity and development. The importance of this must be seen within the context that this is the objective and aim of this thesis which is to indeed achieve a deeper theoretical relationship between the tacit and the scientific.

2.2 The Early Policy Process, 1990-1994

The ANC, along with its alliance partner, Cosatu, played a pioneering role in the evolution of the education and training policy process. This could be traced to the launch of a 'Vocational Training Project' by the National Union of Metalworkers of South Africa (NUMSA) in July 1990. It was an attempt to develop union policy on industrial training as a counter to Nationalist Party reforms during this period. This early initiative by NUMSA grew into a larger concern taken up by Cosatu and the ANC and culminated in the adoption of a set of education and training principles at Cosatu's Fourth National Congress in July 1991.

These proposals, which were to have a deep influence on the ANC's evolving education and training policies, were aimed at winning substantial gains for black workers and at increasing labour's bargaining power. It was proposed that workers have access to a process of lifelong education and training that emphasised a broad education foundation, the acquisition of flexible, transferable skills, and horizontal and vertical occupational mobility for all workers. This would in turn be coupled to the development of broad bands of skill categories and access of workers to career paths, and would lead to greater job security and job satisfaction. The proposals also included a strong emphasis on Recognition of Prior Learning (RPL) aimed at ensuring that the skills and knowledge that workers acquired through work and life experience would be recognised and accredited, thereby ensuring that they could continue to learn further and enhance their prospects of occupational mobility. The Cosatu principles argued that a highly skilled and motivated workforce should be given substantially more power on the shop floor. Finally, proposals for worker education and training, drawing strongly on similar developments within the Australian labour movement, envisaged new forms of participatory work organisation and a flattening of management hierarchies. This attempted to advance workers'

long standing struggles for democratic worker control of the workplace (Cosatu, 1992; Cooper, 1998; Kraak, 1994).

These proposals were to have a deep influence on the ANC's evolving education and training policies, and pre-figured and shaped the policies now accepted across the broad spectrum of industry and government. As Cooper (1998) points out, since the early 1990s Cosatu has increasingly been involved in policy development through the National Training Board (NTB), and in development of the National Qualifications Framework (NQF), as well as in establishment of a South African Qualifications Authority (SAQA). Thus, Bird and Elliot (1993), two prominent educationalists within the South African trade union movement, (strongly influenced by the Australian and New Zealand trade union movement and their Qualifications Structures) co-authored the ANC's influential document *A Framework for Lifelong Learning* (1993b). This introduced a new approach around the idea of a nationally integrated curriculum with a single qualification structure. The NQF was viewed by the labour movement as the key vehicle for integrating the historically fragmented and separate systems of education and training in order to 'establish one, equitable system of recognition and accreditation of all learning irrespective of where and how it takes place' (Cooper, 1998:3). The development of the concept of the NQF was also part of a consultative process initiated by the National Training Board (NTB) in 1993, which involved organised capital, labour, the previous state as well as civil society organisations (Christie, 1997:118). Two additional policy texts during this period - the National Education Policy Initiative (NEPI) reports on 'Human Resources Development' (NEPI, 1992), and the concluding 'Framework Report' (NEPI 1993) - also importantly influenced the integration policy process. The former report on human resource development which was strongly influenced by Kraak's Segmented Labour Market Thesis (detailed in the sub-section to follow) played a pivotal role in influencing the union movement's labour market policies, and was subsequently drawn upon by the ANC government (Cooper, 1998: 5-6).

Among other ANC policy documents that espoused the idea of an integrated education and training system, the most important was the January 1994 ANC booklet *A Policy Framework for Education and Training* and the 'preparing to govern' manual *An Implementation Plan for Education and Training* released just before the

April 1994 elections. Both documents consolidate the ANC's commitment to an integrated education and training framework (Isaacs, 1998:19; Kraak, 1999:34). The 1995 South African White Paper on Education and Training (WPET) officially sanctioned the idea of an integrated Education and Training system. It is important to note that Kraak's (1992) Segmented Labour Market Thesis, as well as Finegold's (1990) high\low skills equilibrium thesis, strongly influenced both the union and the newly emerging ANC government's macro-economic and education and training policies during this early period. It is for this reason that Kraak's (1994) key argument, which has been drawn from the macro-institutionalist perspective subsequently adopted by Cosatu, will be taken up in much more detail in the second part of this thesis.

In a complex analysis (detailed in part two of this chapter) Kraak (1994) has drawn upon British literature on education and economic change, and in particular adapted and applied Finegold's (1990) high skills equilibrium thesis to the South African political economy. He shows how historically South Africa had a racially defined labour market, which was divided into three sectors. There was the independent primary market entailing white collar and professional occupations manned almost exclusively by whites, a subordinate primary market occupied predominantly by White, Indian and Coloured semi-skilled operative workers, and a secondary labour market comprising unskilled and un-unionised African migrant workers (Kraak, 1994; Cooper, 1998). This sectorally divided labour market was in-turn mirrored by three fragmented modes of delivery in terms of vocational education and training, each associated with a distinct labour market segment, and each with highly differentiated access and outcomes. According to Kraak, recruitment practices and selection procedures intensified racial discrimination by privileging particular ideological and social skills, which emphasised the cultural and social-network nature of labour markets. Drawing on a macro-institutional approach, his key argument (subsequently adopted by COSATU) is that education and training cannot independently improve economic performance nor achieve economic redress. It needs to be accompanied by substantial restructuring of accompanying institutional spheres within state, business organisations and the labour market. Thus, the requirement is a 'well structured, state regulated external labour market (which will open up or externalise the employment benefits of internal labour markets to all workers) with an associated

external (state provided and co-ordinated) mode of VET provision' (Kraak, 1994:46; Cooper, 1998). He has also strongly argued for an 'active labour market' strategy in which he defines 'active labour market policies' as those, which are designed to ensure training, occupational mobility and job security for workers. These policies aim to counter a racially segmented labour market, a racial and gender discriminatory occupational structure, minimal training opportunities for workers' and massive black unemployment (Kraak, 1994; Cooper, 1998). This analysis strongly influenced the labour federation Cosatu and was later taken on board by the ANC government. The government, in early 1995, appointed the Comprehensive Labour Market Commission to critically examine prevailing labour market conditions. The commission concluded that racial and skill distortions in the labour market had served the policy of 'inward industrialisation' inherited from the previous regime. They recommended that achievement of economic growth and improved productivity would necessitate engagement in 'labour market deregulation' to enable de-racialisation of the workplace. According to Ray (1997), such a framework introduces 'flexible production' as an alternative to the centralised, rigid and racist regulation of the labour market practiced under the previous regime.

Kraak's segmented labour market thesis drew on Finegold's (1990) high skills thesis which in turn was influenced by the international literature on globalisation. As Young (2001) points out, Piore and Sabel's (1984) writing on changes in the organisation of work were undermining the traditional division between mental and manual labour, and that this was of particular significance to British scholars of education and economics such as Finegold and others. In other words, the process of globalisation demands new conditions of competitiveness between countries that have to do with attaining higher quality manufacture and higher productivity, both on the basis of a more highly skilled and educated workforce. The high skills thesis argues for the necessity of educational reform to interface with macro-economic, industrial and labour market reforms such that their combined impact can enable economies to meet the new conditions of global competitiveness, and thus the attainment of high quality manufacture through a highly skilled and productive workforce. The literature on globalisation argues that both the nature of occupations and a country's economic competitiveness are increasingly defined in terms of the ability to adapt to the

phenomenon of rapidly changing technology under this new accumulation paradigm. It is within this context that the integration of formal (scientific and technological) knowledge and skilled worker 'know-how' or tacit knowledge has assumed increasing importance (Kraak, 1997:54). The influence of both the segmented labour market thesis as well as the high skills thesis on the government's White Paper on Education and Training can clearly be seen from the following excerpt. The report also situates its argument within the context of the political economy of knowledge debate.

An integration approach implies a view of learning which rejects a rigid division between 'academic' and 'applied', 'theory' and 'practice', 'knowledge' and 'skills', 'head' and 'hand'. Such divisions have characterised the organisation of curricula and the redistribution of educational opportunity in many countries of the world, including South Africa. They have grown out of, and helped to reproduce, occupational and social class distinctions.... Successful modern economies and societies require the elimination of artificial hierarchies, in social organisation, in the organisation and management of work, and in the way in which learning is organised. They require citizens with a strong foundation of general education, the desire and ability to continue to learn, to adapt to and develop new knowledge, skills and technologies, to move flexibly between occupations, to take responsibility for personal performance, to set and achieve high standards, and to work co-operatively. In response to such structural changes in social and economic organisation and technological development, integrated approaches toward education and training are now a major international trend in curriculum development and the reform of qualification structures. Ministry of Education is convinced that this approach is a prerequisite for successful resource development and it is thus capable of making a significant contribution to the reconstruction and development of our society and economy (Department of Education, 1995 :15-26 , see also ACTU, 1987).

The White Paper argues further that the academic/vocational divide is linked to well-entrenched patterns of class and race inequality. The link drawn between human resource development and equity policies to redress the racial legacy builds on the earlier ANC and Cosatu political platform of 'growth through redistribution' which, as Christie (1997) notes, 'links popular demands for social equality with strategies for economic development. According to Wolpe (1992) re-conceptualising a new educational policy for post-*apartheid* South Africa poses a fundamental dilemma. The newly emerging state will face popular demands for the equalisation of educational provision. Thus in tension with this push for equity as a basic human right is the need for a clear human resources programme to service economic development. In this respect the high-participation/high-skill education and training proposals have been described as an attempt to transcend the development/equity dilemma (Badat, 1997). The National Qualifications Framework (NQF) provided the framework for linking education and training. Its defining features entailed flexible combinations of academic and vocational curricula, portability of skills across differing employment contexts, and recognition of prior learning. Its development can be traced to the consultative process initiated by the NTB in 1993. It is important to note that whilst it is a national structure for registration and accreditation of qualifications, it is also underpinned by a particular approach to the process of effecting this linkage, namely outcomes-based education (OBE).

While the sub-sections above have attempted to trace the origins and motivations underpinning the integration agenda within both a historical and socio-economic context, the sub-sections below try to examine some critical questions raised in relation to the policy's neo-liberal underpinnings.

2.3 A Neo-Liberal Agenda?

Post-Fordism and its relation to both economy and education have been critiqued by many academics from various positions. Commenting on its economic aspects, many writers have taken issue with the generalised application of post-Fordism to the economy as a whole. They argue that few sectors of the South African economy are post-Fordist and few have the potential to shift successfully to post-Fordist strategies in the near future (Chisholm, 1997; Vally, 1998). Such a view has also

been supported by Young (2001), who drew on studies in the UK, where there was a re-emergence of both Fordism and neo-Fordism in the service sector. The new technologies are used with new forms of managerialism to maintain hierarchical relations of production. They argue that the post-Fordist analysis was over-simplistic in its all-embracing claim that changes in the economy would provide the basis for a future democratic curriculum. Although not denying that the form of capitalist production is changing as a result of globalisation and the impact of new technologies, they argue that the outcome is complex and uneven across the world. In keeping with this, Natrass (1994) argues that employers tend to employ a form of flexible specialisation, which is stressful and oppressive for workers. Their use of new technologies and application of managerial techniques also intensify forms of labour exploitation. Problematising the notion of 'flexible production', Lehure (1997) also shows how this important construct of the NSDS has more to do with forms of deregulation which lead to the lowering of labour standards, and which allow employers greater freedom to hire and fire at will instead of allowing workers opportunities for recurrent training and greater occupational mobility. Denis Gleeson (1990) commenting on New Vocationalism in the UK writes that the kinds of arguments which favour generic skills training, do not find their expression in the actual realities of work practice or labour market. He argues that they exist in 'idealised conceptions' of how industrial relations ought to operate under free market conditions:

The ideological significance of skills training is that it projects the learner within this fantasy as a flexible entity, capable of being employed or re-employed in a variety of jobs and settings (Gleeson, 1990:191).

Canadian unionist, Sam Gindon (1996), also argues that the ideology of competitiveness central to post-Fordism is itself anti-worker. Competitiveness according to him, creates a false alliance between workers and capitalists against the 'external threat' posed by foreign workers and capitalists. It thus serves to obscure class divisions. Gindon stresses that training should revolve around the

‘democratic development of our capacities’. Instead of starting with the needs of companies (profits), training should be based on the needs of workers and should capacitate their communities.

Cooper in the citation following seems to capture quite adequately the tensions and countervailing tendencies embedded within the new Education and Training policy in the following statement:

There is on the one hand, the Union movement and its educational allies, driving a project of social justice, redress and empowerment. On the other are the employers and post-Fordist theorists, promoting a market- oriented pedagogy associated with the commodification of knowledge and an emphasis on flexibility, mobility and retrainability (Muller, as cited by Cooper, 1997:80).

International experience of a similar integrative educational strategy necessitates further problematisation within the context of certain aspects of the critical discourse that has evolved with regard to its form and content. Jane Kenway (1997), focussing on recent developments in Australia related to education and training in the workplace, shows how education is dropping out of vocational education and how the language of macro and micro-economic reform and markets is gaining hegemony. She argues further that the policy’s agenda was not entirely successful in Australia because both employers and employees at grassroots level in the workplace remained unaware of its many dimensions, or became overwhelmed by its complexities:

It was certainly too centralised, too bureaucratised and ‘economised’. Too concerned with matters technical and

managerial, and too remote from and insensitive to localities, institutions and people (Kenway, 1997: 49).

Closer to home, Tony Kgobe (1997) questions both the cumbersome nature of the NQF bureaucracy as well as its highly technical details and language, stating that 'it is questionable whether it will be comprehensible and accessible to workers'. Gari Donn (1998) urges us to see the ways in which social institutions such as those in educational systems are constructed through highly scientific terms and rationalised by technical experts and, as a result, how political problems are transformed into manageable technical ones with technical solutions. Donn further argues that qualifications frameworks instil highly developed bureaucratic practices and as such tend to exclude 'from discourses those who are not conversant with, or (competent in) the reasoning of logic for and language surrounding that construct' (Donn, 1998). He argues that if through the specificity and peculiarity of language used, the possibility of entering into the qualifications discourse is seriously hampered, there is an argument that its role as an empowering, even transforming construct has to be questioned (Donn, 1998).

Trade union educationalists have also taken issue with the hegemonic construction of knowledge, and the argument that if redress is to be effective, previously marginalised forms of knowledge and learning must be recognised. There is an element of contradiction because both unions and management emerge from different epistemological traditions of knowledge that stems from different economic and political philosophies of education. Historically, both have privileged different forms of knowledge. Unions, for example, have always fore-grounded 'horizontal' forms of knowledge, common sense and experience, which were seen as a source of communal knowledge. Capital, on the other hand, fore-grounded 'vertical' and 'hierarchical' (Cooper, 1998) forms of knowledge, and specialised languages more distant from everyday experience. Experience under the NQF, thus becomes a commodity, which individuals may exchange for a qualification that may be of value within a competitive labour market (Cooper, 1998; Sampson and Vally, 1996).

The above concerns clearly indicate the political and economic embeddedness of the form and content of NSDS. It also alerts us to the relationship between knowledge and power. This stresses the importance of understanding the form and content of the NSDS within the wider political and economic context. These aspects of a left-critical discourse about globalisation, which take issue with both the neo-liberal subjugation of the educational process to the dictates of capital as well as the wider epistemological concerns of education, have been taken up by South African academics as well.

Concerns about the narrowing of the curriculum policy agenda have also been raised by South African academics. Some anxiety has been raised about the increasing vocationalisation of the curriculum as a result of its more direct links to the economy via the new modularised competency-based training. They anticipate the subsequent marginalisation of those aspects of the 'various policy documents' that have emphasised the encouragement of 'independent and critical thought' (Chisholm & Fuller, 1996; Fataar, 1999; Wolpe & Unterhalter, 1992).

In the light of all these criticisms, the question arises as to why has the labour movement driven the NQF project forward. In fact the labour movement has unproblematically drawn on 'global market' discourses around worker education and training. Notions of 'multi-skilling', 'competency-based learning' and 'flexible specialisation' are not neutral and form part of broader managerial discourse related to globalisation of the world economy.

Cooper, however argues that it is over simplistic to collapse the labour movements approach to worker education and training into 'neo-liberalism'. She outlines some of the problems faced by workers under apartheid. The legacy of apartheid education and job reservation excluded black workers from skilled jobs while white workers with little experience, but with formal certificates had access to skilled jobs, the work

experience of black workers was seldom valued and never accredited. In addition to employer investment in training, which was extremely low, the training that black workers received was job-specific, narrow Taylorist oriented and unable to be upgraded.

Thus the emphasis on raising skills levels of workers and on the credentialing of workplace training represents a response by unions to authenticate worker aspirations and resonates deeply with workers' desire for recognition, respect, greater equity and opportunities to progress (Cooper, 1998:108).

Moreover, having accepted South Africa's re-instatement into the global capitalist economy, the labour movement has attempted to ensure that economic restructuring happens on terms that are favourable to workers. Webster and Adler (1994, 1999) complement this view, who see it as part of the tradition of trade union strategies to try and gain a tactical advantage in their negotiations with capital. Cosatu's drive towards the Reconstruction and Development Programme which foregrounded internal stimulation of demand was coupled with its proposal for life-long education and training; flexible and transferable skills that can ensure 'horizontal' and 'vertical' mobility; skills broad-banding and career paths; and a strong emphasis of the Recognition of Prior Learning (RPL). All of these would help create a highly skilled and motivated workforce which could be given substantially greater responsibility on the shop floor through forms of participatory work organisation and a flattening of management hierarchies. The labour movement notes Cooper (1998) has thus injected the NQF with emancipatory potential, with its emphasis on the social justice, redress and empowerment dimensions of a new education and training system.

The following section would like to expand on the sentiments expressed above. Firstly the realisation by Cosatu that within the context of the collapse of socialist oriented economies internationally, economic growth is presently premised on a strong export orientation and a competitive economy. As Webster and Adler (1999)

argue, that having accepted South Africa's re-instatement into the global capitalist economy, the labour movement has attempted to ensure that economic restructuring happens on terms that are favourable to workers.

In a rebuttal of the argument that their economic as well as their education and training policy proposals were purely economic-rationalist in nature, Cosatu aligned economists argued that their economic reforms were regulated by a strong state committed to the attainment of meeting basic needs through internal stimulation of the economy which would also create employment opportunities, and simultaneously direct South Africa's manufacturing sector more competitively on global markets. Their argument was that the capitalist oriented macro-institutionalist perspective that they adopted contained within it strong social-democratic tendencies, in the sense that it proposed state regulation of the market in areas related to socio-economic concerns in favour of marginalised communities. These policies remained distinct from the highly dualistic and divisive economic policies of the state and capital adopted through GEAR after 1996, which viewed redistribution as a mere adjunct to the more important task of maximising industrial growth. The early Cosatu / ANC policy proposals also resonated well with Saul's (1992) concept of 'structural reform' which argued for change which is realistic and attainable under prevailing economic conditions and yet creates the possibilities through struggle for future socialist oriented reform. Thus, the realisation that economic growth under prevailing conditions is premised on a strong export orientation and a competitive economy. Within this context COSATU and ANC aligned economists and politicians posited the view that if South Africa's manufacturing sector, (which has fallen way far behind the production practices of other industrialised nations) was to achieve export competitiveness, than some post-Fordist forms of work organisation and new technologies are inevitable and unavoidable (Gelb, 1991; Kaplinsky, 1989; Joffe *et al* 1993; Kaplan, 1991).

As Kraak (1994) has commented, 'Growth through Redistribution' is about both adapting to the requirements of the global economy and addressing the social and economic needs of the historically disadvantaged in South Africa. In his reply to the

debate, he calls for a more realistic and pragmatic interpretation of the education / economy link. He cites Mathews et al's problematisation of the equity /development tension :

Development can be characterised as a form of 'economic instrumentalism', seeking to subordinate the output and structure of the education system to today's vocational requirements, but ignoring the demands of tomorrow. The latter (equity) demand can be characterised as a concern to develop a democratic curriculum, divorced from its economic and industrial context and predicated on a non-problematic assumption of endless economic growth (Mathews et al., 1988: 498).

Following this, Kraak argues that similar conceptual distortions are visible in the South African context where the 'development' imperative is often read by those critical of the ANC/COSATU proposals as a form of 'economic instrumentalism' which demands the subordination of the entire ET system to national economic requirements. Similarly, the logic of the 'equity' imperative is articulated in the language of 'principled egalitarianism', which abstracts the curriculum and the ET system from questions of economic sustainability. He argues for a more coherent perspective of how equity and development can complement each other. Reacting to the marginalisation of wider democratic and liberal humanist educational concerns, Kraak replies that the trade union movement that pioneered the NSDS aimed to incorporate within such a model of industrial training a theoretical module which would aim to equip workers with a critical awareness of the work environment and the ability to challenge the unequal social relations which govern the world of work. These concerns for generic training (alongside technical skilling) and the development of a critical consciousness seem to resonate with Spours and Young's (1992) notion of 'connectivity' embedded in their conception of a curriculum for the new century. They argue that based upon new needs of an age of science, technology and innovation, students would need to acquire modern language skills and technological, scientific and mathematical understanding to maximise use of

changing technologies as well as social, economic, political and historical awareness to enable them to critically understand the complex forces of changing world.

Such a conception of the curriculum tries to address some important dimensions of the tension between equity and development. It does this by empowering the student or worker with 'technological literacy'. A concept which implies deeper conceptual and cognitive underpinnings as opposed to 'technological skill', which is associated with a narrow Taylorist orientation of work based skilling (Wellington, 1987). The issue of technological capability as both a political and economic imperative can be borne out by South Africa's dependence on overseas technology, which has initiated strong calls for the need to develop an appropriate South African technology. Commenting on the chemical industry, Bloch shows how South Africa's 'heavy reliance on imported technology' and on specialists with technical and engineering skills ensured South Africa's dependent location within the world capitalist economy and locked the industry further in a chain of dependence and subordination (Bloch, 1980). This is also confirmed by Kraak(1994) who writes that South Africa is far from being able to embark on export-led growth given the extreme shortages of well trained engineers, technicians, artisans and production workers in the key export sectors.

The above view is strongly supported by King and McGrath, (1996), whose considerable research work in African countries has enabled them to discern trends indicating the increasing marginalisation of these countries as a result of the impact of certain structural forces of globalisation. To strengthen Africa's position vis-a-vis the developed economies in relation to the central concern of technological innovation they suggest:

As technology becomes ever more central to competitiveness, so a greater emphasis must be placed on the development of technological capabilities at the level of the individual, the enterprise and the society. This suggests a greater and more

critical consideration in education and training systems of issues of knowledge and skill use (King and McGrath, 1996:1-2).

This illustrates the importance of seeing technological literacy and capability as the new economic and political demand of conditions created by the process of globalisation and stresses the importance of the role of education in trying to meet the challenge. Commenting on South Africa's increasing exploitation as a result of its lack of technological capability and resultant inability of the beneficiation process Mech (2002) writes:

The developed countries take the raw materials which countries like South Africa dig out of the ground and manufacture them into products that increase the material value by several thousand percent. You can't join this tech race without Maths and Science (Mail&Guardian *October 4 to 10 2002*).

Thus, the increasing marginalisation and exploitation of developing economies that lack this technological capability poignantly points to its socio-economic and political ramifications. Such a view also resonates well with the techno-economic paradigm under post-Fordism. Writers within this paradigm argue that 'diseconomies of competition' occur mainly as a result of the lack of scientific and technological capability on the part of developing economies. They thus stress policy priority within these areas.

This thesis shares certain commonalities with this approach because of its strong focus on the vulnerability and needs of African and developing countries as a whole. This is in stark contrast to the flexi-spec paradigm, which primarily puts the 'efficient manufacturing' and 'investment effectiveness' needs of capital first. The struggling economies are thus seen to benefit from the ripple effect thereof. The calls for the need to develop an appropriate South African technology echoes well from within the context of a techno-economic paradigm.

In conclusion, this chapter has led its argument by situating the government's National Skills Development Strategy (NSDS) within a wider socio-economic and geo-political context. The notion of skills was problematised within both a neo-liberal and an emergent left-critical discourse. However, while acknowledging the neo-liberal underpinnings of the State's educational policy, this chapter simultaneously shows how developing countries and emerging economies are increasingly being exploited and marginalised as a result of their lack of 'technological capability'. The integration of education and training to provide this capability has thus become not only an economic imperative but an important political issue. The relationship between theory and practice is presently being examined within the context of this conceptual distinction between the notion of a narrow 'technological skill' and 'technological literacy' developed in this paper thus far.

This recognition of the importance of a deeper conceptual and cognitive dimension to skilling has critical connotations and highlights the tension between knowledge and skills and over Taylorism, behaviourism and competencies. McGrath (1997) in keeping with a concept of critical education, writes that this will determine whether those within the system get learning opportunities which enable them to act upon the world or simply to be better reconciled and socialised to a world that they lack the power to change.

This study will draw on both this strong work-based experience as well as on insights provided by Lugg (1990) who argues that despite the neo-liberal underpinnings of the government's skills development strategy, the integration of theory and practice embedded within it, could deepen our understanding of learning and is indeed more meaningful from a 'knowledge construction' perspective. People would thus gain access to learning opportunities in which both content and skills were developed. In this sense with its emphasis on situated cognition and contextualised learning, it could provide innovative ways of learning. Indeed, meaningful integration in the sense that the workers understand the deeper underpinnings of their practice and could contribute to the emancipatory principles that COSATU bargained for during the early 1990's. This could also contribute to the political economy of knowledge debate.

These emancipatory principles were related to emancipation from the legacy of the apartheid education and training system through combating racially segmented labour markets and a fragmented education and training system. These important issues will be discussed in greater detail in the chapter to follow.

CHAPTER TWO – PART TWO

2.4 Introduction

This section attempts to show that Cosatu's proposals calling for active labour market policies and a unified education and training system through the adoption of a National Qualifications Framework (NQF) were influenced by Kraak's segmented-labour market thesis. These were critical components of a reconstruction programme which aimed, on the one hand, to create a South African version of a high-skills labour force, and, on the other, to achieve this through diluting South Africa's racially-segmented labour market and historically fragmented education and training system. This tends to support Cooper's earlier argument that Cosatu's endorsement of the education and training policy proposals cannot simply be collapsed into neo-liberalism. They constituted an attempt to balance the tension between equity and development.

In the main it attempts to highlight a central theme pertinent to this thesis.

This is that the criterion required for successful balancing of the equity/ development tension mentioned above, depended on effecting a deeper conceptual relationship between theory and practice as described in chapter one. This relevance must be seen in the context of this being the core objective and unit of analysis of this thesis.

The discussion thus far has revealed the presence of two oppositional discourses related to the government's new skills development policy with its integration of education and training. The first was a left-critical discourse that cautioned against its neo-liberal underpinnings. The second argued against collapsing it totally into neo-liberalism. It is this second strand of argument that this sub-section wishes to expand upon, especially because this was the official policy stance eventually adopted by the state.

As was briefly pointed out earlier in part one of this chapter, both Cosatu and early ANC policy proposals were strongly influenced by the social or macro-institutional perspective which has emanated from the process termed 'globalisation'. This process, which has already been briefly touched upon, arose as the outcome of a combination of developments in the advanced economies of the world related to the demise of Fordist production regimes and the onset of the global economic crisis in the mid-1970's. In addition, the process was fuelled by facilitation of the internationalisation of finance capital as a result of the advent of information technology in the early 1980's, and the rise in innovative forms of work organisation in the early 1980's, now referred to as 'flexible specialisation' or 'post-Fordism'.

These developments ushered in certain changes to prevailing economic systems characterised by high-quality export manufacture aimed at satisfying more sophisticated needs for specific consumer niche markets. As was argued in chapter one, the process of innovation became a central tenet of this new system – to continuously reinvent products and add value, information and knowledge about product and process. A central adjunct of globalisation has been its new education and training demands, such as the need for a highly skilled labour force that is able to employ the new technologies and add value to existing consumables. As a result of the need to adapt to volatile global product demands and rapid technological change, enterprises now need multi-skilled labour forces (Kraak 2004). The process of multi-skilling entails deeper cognitive skills to anticipate flaws in production, reprogram the computer-aided technological process if needed, as well as to repair, maintain and change over the equipment on which they work without the need to continuously summon the help of outside technicians. It is argued that this capacity to respond to breakdowns and unexpected situations on the shop floor is one of the factors contributing to greater flexibility in production (Dertouzos et al. 1989:89).

Globalisation, argues Kraak (2004), has imposed new conditions on competitiveness that have to do with attaining higher quality manufacture and higher productivity,

both on the basis of a more highly skilled workforce. The demand for innovation and rapid design reconfiguration needs has also placed an increasing demand for deepening workers cognitive and conceptual skills. Thus, this explains the increasing need to link the work of the hand to the work of the mind, separated historically through the development of capitalism and materialised through Taylorist and hierarchical demarcation of the work process.

The challenge of attaining these new demands on national economies led to long term research related to comparative studies between the nature of economies that were more successful in attaining these new conditions of economic competitiveness and those lagging behind. These studies led to the development of a social or macro-institutional perspective also referred to as the low or high-skills equilibrium theory. This body of literature had a great influence on ANC aligned economists, educationalists and trade unionists as well as on subsequent policy making processes related to the nature of education and training as envisaged within the National Skills Development Strategy (NSDS). It is for this reason that the following discussion will briefly detail the central components of this social-institutional perspective.

2.5 Interacting Dynamics: Work Organisation and Skill Formation

The leading contribution to this socio-institutional perspective emanated from Maurice, M, Sellier, F. & Silverstre, J.J.'s (1986) detailed case study of the interaction between work organisation and skill formation in (former) West Germany and France. They argue that there is a critical institutional dynamic between the form of labour process organisation and the acquisition of work-based skills. This study contrasts the conditions in Germany that have given rise to multi-skilling, with those in France. The outcomes of these differing interactions between "organisation-socialisation" are profound. The hierarchies within the work-process in Germany are less pronounced than in France because German jobs are directly linked to a high quality education and training system embedded in a qualification structure that has

strong social legitimacy and which provides opportunities for mobility across the occupational spectrum. Training is generic (broad based) and the qualifications system, which is nationally organised within a coherent institutional set of structures, sustains an external labour market which facilitates the mobility of trained workers. Occupations within key German industries remain closely linked because they are structured according to the qualification ladder (Maurice, et al, 1986:59-119).

Kraak (1994), drawing very strongly on Maurice *et al's* (1986) comparative study, and applying it to South African conditions, importantly points out the interactive dynamic between work organisation and the character of the qualifications structure, each in turn influencing the shape of the other. The work training process encompasses rotating workers across the different skill positions within a productive organisation. Such rotations are seen as crucial to developing a labour force with a wide spectrum of experience and capabilities and hence the capacity to deal flexibly with a varied set of production tasks with unpredictable problems and with changing technologies (Dertouzos, M. L. Lester, R.K and Solow R. M, 1989).

This job-rotational process entails a continuous process of enskilling workers and has important implications for polyvalent skill formation. Polyvalence is also associated with the reintegration of the mental and manual components of skills traditionally separated in Taylorist or hierarchical work contexts. Kraak (1994:94) writes, that in Germany it is precisely because of the cultural respect for the skilled production worker and because of polyvalent skill formation through job rotation, rigid job demarcations within separate departments never solidified as in America, Britain or indeed South Africa, where it is argued that quite the opposite trend is evident. Indeed, in Germany the tasks related to design, manufacture, quality control and maintenance are not the sole responsibility of separately trained workers and separate departments, but are respectively shared by all workers across differing work stations. In the German ideal system, little time is allocated to controlling labour and much more time is spent on hands-on dispensing of technical expertise. The *meister* (foreman) exemplifies the incorporation of technical expertise into the lines of managerial authority, unlike in France where hierarchical work relations act to

prevent this (Maurice *et al.* 1986:97). This is a feature distinctive of German industry, but absent in the British, American and South African contexts where financial cost-effectiveness is the first priority of these management systems strongly followed by control over labour (Kraak, 1994:94).

Maurice *et al.*'s (1986) study, alerts us to the fact that the position of design engineers in Germany is similar to the *meister*. Indeed, most engineers, many previously *meisters* themselves, have an intimate knowledge of industrial production pertinent to their firm. Thus the homogeneity of labour encouraged by the German training qualifications ladder reinforces the tendency of all skilled workers to collaborate together with design engineers in improving plant processes and product innovation. This process has strong implications for occupational mobility in the sense that articulation route from *facharbeiter* (skilled worker) to *meister* to the technical and engineering levels are ensured by a unified national qualifications system which links all these occupations along a skills ladder. These writers stress that the span of skill in German industry is relatively homogenous. This promotes broad co-operation between *facharbeiter*, *meister* and engineer based on their common background of theoretical and practical knowledge. According to them, such co-operation is found, not only within production departments, but also between production and engineering or other support departments that employ personnel sharing in this common fund of technical knowledge (Maurice *et al.*, 1986:91-101).

Commenting on this, analysts such as Kraak (1992) and Dertouzos (1989), note that it is the depth of this cross-departmental integration, and that the sharing of technical expertise and hands-on production knowledge among employees takes precedence over supervision and labour control functions, that accounts for Germany's economic success. According to these analysts employees function better within an environment that promotes technical expertise, encourages collegiality and rewards innovation. In contrast, the American, British and South African industrial training systems lack such practices, and the rigidity of job hierarchies within these contexts is a major determinant of their lack of economic competitiveness. As a result of their hierarchical nature, structured organisations become rigid, hamper vital

communication and co-ordination features and are unable to cope with change. (Kraak, 1994,95; Dertouzos *et al*, 1989:97).

In contrast, Maurice *et al*'s (1986) skill formation work organisation study found work organisational forms in France were quite different from those in former West Germany. In the first instance, France possesses no formalised national industrial training system as in Germany. It is argued that while general school education in France is more accessible, it is not as well articulated with training and the occupational structure as is in Germany (Maurice *et al* 1986:31).

As a result, French firms rarely rely on formal credentials, and they structure work in hierarchical and rigid forms within the the firm's internal organisation.. Labour in this instance tends to acquire specific training, and remains trapped within the the firm's internal labour market. Firm-specific 'in-house' credentials are awarded for seniority which moreover does not directly articulate with a national qualifications structure (Maurice *et al.*: 1986:68).

In this case the French model of work organisation, in contrast to Germany's 'qualification-led' model, is 'employer-driven'. As Kraak (1994:99) writes, a system of decision-making based on 'managerial prerogative' is associated with this form of hierarchical work organisation. The main focus of managers and supervisors in French firms lies in personal and administrative control, rather than on skill development as is the case with German managers. Within the French context of hierarchical work organisation, workers are seldom rotated to experience the different skill levels as in German industrial settings.

This, together with a lack of articulation between education and training, acts against the formation of any sort of polyvalent skilling sought after by the new knowledge economy. An additional constraint on polyvalence relates to the nature of work departments in the French industrial sector, which, unlike their German counterparts,

function in a separated and fragmented manner, negating any form of co-operative work and polyvalent skill development. As a result, product design engineers neglect manufacturing considerations in their design, unlike in Germany where design engineers co-operate with production workers in improving and innovating upon the product/process nexus of work. This contributes internationally towards German economic compatibility. As Kraak (1994:100) comments, the fragmented and divisible work organisational contexts of both France and America are quite the opposite from that applicable in Germany where technical departments are in the service of production shops, problems are resolved jointly, and suggestions from below are considered seriously. He also points out that the post-Fordist trend of sub-contracting parts of the larger process of production to smaller independent companies, as also happens in South Africa, has the potential to accentuate the constraints on polyvalent skill formation. Maurice *et al's* (1986) study shows that this is what has occurred in France, where maintenance work was being subcontracted, thereby reducing the in-house maintenance staff to a bare minimum. The decision has been driven by financial requirements and cost-cutting management and not a decision influenced by the wider need for broadly skilled workers. Consequently, in the various departments, design production and maintenance function relatively independently of each other, driven by their own narrowly defined responsibilities. This set of arrangements works against efficient management of the firm as a whole, management that would foster technological innovation and constant improvement in the production process (Maurice *et al.* 1986: 89, Kraak, 1994:101).

Drawing on Lane (1988:162), Kraak (1994) argues that the third constraint on polyvalency arises out of the manner in which the new computerised technologies have been implemented in hierarchical work organisational contexts. The trend has in general shown that employers have continued to use the new technologies to fragment and deskill work. Not unlike in South Africa, this has seen a neo-Fordist reassertion of Taylorism. Commenting on the nature of such managerial practices, Lane (1988:163) points out that they are all coupled to adversarial work relations where managements have seen the computer technologies as a new weapon to intensify control over labour. The lack of co-operation and the revival of Taylorism block the development of polyvalency, and subsequently limit the success of the

economic process as a whole. This is unlike the work process prevalent in countries such as Germany and Sweden, where the new technologies have been incorporated into the education, training and labour enskilling process. This interfusion of technology into education and labour-enskillling has created fertile conditions for meeting the labour and product demands of the new knowledge competitive economy.

Kraak, in relation to this, comments:

Technology is the pivotal issue. Technology mediates education's contribution to higher labour productivity. The mediation hinges on two factors: the social choices made with regard to the application of the new technologies and the form of work organisation which emerges as a consequence of these choices (Kraak, 1994: 89).

Finegold (1990:12) has highlighted the diverse impact on productivity and economic performance of different technology choices. He suggests that countries such as America and Britain, and indeed as the study by Natrass (1994) in South Africa has also shown, have used the new technologies to solidify managerial control over the production process by transferring skilled tasks from operators to white collar programmers. This deskills workers with the inevitable result that these countries have suffered a loss of international competitiveness.

In contrast, countries such as Japan, Germany and Sweden have achieved high productivity levels by turning greater control of the production process over to labour in co-operative work environments. Workers in these countries form relatively autonomous and multi-skilled work teams who maintain high levels of quality control in production, can spot and repair mistakes, and are well equipped to re-programme the new computerised technologies in response to rapidly changing product demands (Finegold, 1990:128, see also Dertouzos *et al.* 1989:88).

As was suggested through the discussion above and also the case in South Africa, hierarchical work organisation has negative implications for equity. The nature of job

design and the uses made of new technology have all had one purpose in mind, which is the establishment of supervision and control over labour (Kraak 1994: 10). Maurice *et al*'s (1986:115) study shows how social divisions within the hierarchical firm, typified by the distances created between various strata of personnel along the occupational ladder, reinforces class stratification that arises out of the social relations of capitalist production. In contrast, less class stratification in Germany's qualifications-led system of work organisation has had a homogenising effect on labour.

The analysis, which has drawn on Kraak's application of Maurice *et al*'s comparative study to South African conditions, has attempted to show through 'ideal-type' generalised argument, the interacting dynamics between participatory work organisation and polyvalence on the one hand, and hierarchical work and Taylorist task fragmentation on the other. As has been, shown the nexus of factors in the skill-formation work organisation interaction discussed above – such as France's acute social divisions within the work place and its poorly articulated ET system – are critical determinants of its weaker economic position in terms of labour productivity, product-innovation and economic performance *vis-à-vis* that of Germany's.

It is understandable for a study of this nature to evoke considerable international interest. It provides analytical understanding of the conditions needed to attain economic competitiveness. In particular, the suggestion that skill is a social construct implied that possibilities exist for it to be re-constructed in ways that could lead to a high-skills society. The challenge within this context of attaining these new conditions of economic competitiveness influenced educationalists to posit the theory of a low skills or high skills equilibrium (Kraak, 1994:89; Finegold *et al.* 1990; Young, 1992). A reading of this literature shows clearly the influence of Maurice *et al*'s (1986) study upon their work. Thus, in comparison to the divisive and fragmented work organisation and education and training system of the French model, it was noticed that attainment of high-quality manufacture through a highly skilled and highly productive workforce such as that of the German system cautioned against the commonly held perception of reinforcing education in isolation from its wider institutional context. Their study of the social democracies of Europe together with the German system quite clearly shows the need for educational reform to interlock with macro-economic, industrial and labour market reforms, such that their

interlinked impact has a better chance of meeting the new conditions of international economic competitiveness. The German system clearly shows the interacting dynamics between education and training and work organisation.

Kraak (1994:38) argues that the strength of Finegold's institutional approach is that it highlights the errors of previous ET policy reforms which have too easily attempted to copy individual institutional features without appreciation of the broader social, economic, technological and organisational contexts within which these institutions operate. In relation to this Finegold (1989) cautions:

... raising the skills of employees can improve productivity only if it occurs simultaneously with other changes within the firm – for example, new technology and reorganisation of work... To make the investment in training and the other components of an HSE pay off, a company must be able to organise the work process in a way that encourages continual innovation. It makes no sense, for example, to raise the competencies and expectations of a production worker if he/she is then given a narrowly defined job that consists of a series of repetitive tasks. (Finegold, 1989:15-25).

The section above has shown how in Germany the work-organisational process, which entails generic skilling articulated with a high-quality education and training system, accounts for their very successful qualifications framework. In contrast, within the French system, not unlike that in South Africa, the educational system is not as well articulated with training and the occupational structure. This results in a narrow, job-specific enskilling process, inhibits occupational mobility and development of polyvalence in terms of enskilling for the new skill needs of late industrial societies.

The section that follows attempts to discuss certain issues related to South Africa's racially segmented labour markets. In particular, this emphasises the manner in

which they mediated the relationship between the ET system, mobility within the occupational structure and economic performance. As has been shown, racially segmented labour markets played a key role in class formation by effectively excluding the large majority of South Africans from opportunities in the ET system as well as from occupational mobility. The interest in segmented labour markets has arisen as a result of the need to try to understand how societies such as Britain, America and in particular South Africa, which are characterised by hierarchical work organisation and acute labour market segmentation, can deepen their understanding of this phenomena so as to enable them to overcome some of its economic and socially debilitating effects. In particular, this concerns its effect in contributing to fragmented modes of education and training delivery, where each mode is associated with a distinct labour market segment. Such divisions as Kraak (1994) shows through his segmented labour market thesis gave rise to highly differentiated access routes and outcomes in education and training.

The international and South African interest in labour market analysis also stems from a desire to gravitate towards the German ideal system, wherein a state-regulated external labour market links jobs to a qualifications structure which provides opportunities for occupational mobility. Training is generic (broad-based) and the qualifications system sustains an external labour market which facilitates the mobility of trained workers. Work-based jobs along the occupational ladder remain closely linked because they are structured according to the qualifications ladder. In this instance the external labour market articulates with internal labour market through the process of active labour market policies and broad banding of the labour process. In this way divisive and hierarchal job formation systems are avoided through the process of generic and continuous training, progressively linked to occupations and a qualifications structure. In this way German workers are empowered both in terms of occupational mobility and an enskilling system that is sufficiently generic to meet new post-Fordist economic and technological demands.

The central thrust of Maurice *et al's* (1986) argument which the macro-institutionalist perspective has drawn upon, is that the process of skill formation is mediated by the

form of work organisation adopted. As a result of this, the pursuit of reforms in ET requires simultaneous reforms in the organisation of work and a restructuring of the form of interaction which occurs between the ET system and industrial organisation.

The macro-institutionalist perspective has also drawn on Japan's economically successful internal labour market (ILM), which is premised on two conditions. The first is a strong emphasis on high quality general education with high staying-on rates in secondary and post-secondary education. The second is a commitment by capital to broad generic in-house training. Kraak (1994:116) notes that within such an institutional context, employers can take for granted a high degree of cognitive ability inherited from the schooling system, and are therefore able to make the transition to broad in-house training much easier. Employers within the Japanese context also have strong economic incentives to provide life-long generic training and internal promotion procedures, which equip firms with highly motivated and innovative employees. In a continuation of his argument above, Kraak writes that each of the above examples have emphasised the centrality of the institutional environment within which successful ET systems operate, and the coherent articulation between external labour markets (ELMs) and internal labour markets (ILMs) as was pointed out to be the case in German and Swedish systems. According to Kraak, this approach contrasts sharply with the market-led approach adopted in the 80's by South Africa, which dogmatically emphasised privatisation, and the contracting out of training and employer voluntarism with regard to ET. He thus argues that what South Africa needs is a balanced ET system in which the external mode which refers to a public state-run institutional-based training system, sharing similarities to the German system, is dominant and which combines with internal enterprise based training. This would provide all young people with a broad based secondary school foundation of general education which, not unlike the Japanese model, would make generic enterprise training much easier to achieve. In this instance, institutional-based training also refers to a high quality post formal training system which would then to articulate with an internal enterprise-based training system. These were the challenges facing South Africa. The discussion will now turn to show that for South Africa to try to achieve any form of parity to the 'ideal' German or Swedish ET systems, it needed to overcome the problem of

racially-segmented labour markets and its related fragmentation of the education and training system. A second problem that was pointed out in an earlier sub-section and which also needed to be overcome was South Africa's neo-Fordist application of the new technologies and new managerial techniques. According to Kraak (1994:173) there was indeed no evidence to suggest that a more democratic variant of post-Fordist methods of production had emerged in South Africa. The local adaptation of the new disembodied technologies and managerial techniques were characterised by hierarchical authoritarian, racist and adversarial social relations as alluded to by Natrass in an earlier sub-section of this chapter. Labour, as Kraak (1994:172) informs us, continues to be viewed as a burdensome cost requiring continual enskilling. This acts to limit drastically the potential of the new forms of work organisation and the new technologies to transform South Africa from a low-skilled to a high-skilled oriented economy along the lines of German and Swedish industrial training systems. In these cases we have witnessed how an emphasis on the centrality of a state engineered educational institutional structure provided a high-quality theoretical knowledge coherently articulated with in-plant generic training in a wide spectrum of occupations related to well established internal paths of progression. More importantly, the Internal Labour Market played a critical role in linking one occupation with another along the span of qualifications. In this sense the ILM served to link what would otherwise be discrete and isolated occupations sustained by the External Labour Market. These were the challenges facing South Africa in the new competitive global market economy where export production underpinned by technology had become the central issue. This created the requirement of a highly skilled labour force that understood the theoretical underpinnings of the product/process nexus of their work practice. It was what gave Germany, Sweden and Japanese workers their innovative qualities, and gave their products the economic edge over those of their rivals.

The challenges facing South Africa were related first to an extremely narrow and vocationally oriented training programme, a work-organisational context that was extremely neo-Fordist in orientation, the inheritance of a racially-segmented labour market that created a fragmented and divisive education and training institutional structure – a formal educational system that has a very high drop-out rate at post-

secondary level with severe repercussions for learning subjects such as maths and science, which underpin the deeper understanding of technology.

As was also noted, students in South Africa have extreme difficulty in mastering the rigorous syntax of these formal discourses. Castle (1991) has also alluded to a study which shows how adult learners in general display a phobia about learning academic subjects and/or mathematics in particular which historically originates from their negative experiences of these subjects at school-level.

Two additional problems are stressed by Kraak (1994:7) who writes that the new training system adopted in the late 80's was characterised by certain levels of incoherence. These were related to an employer-led conception of the training process, the privileging of market forces over state intervention in the provision of training, which accounts for the narrow training system. There was also a state inability to coherently link the education and training departments. Importantly, the competency based modular education and training system (CBMET) adopted by South Africa's various industry-based accredited training boards was found to perpetuate narrow skilling, establish minimal articulation between education and training and was driven by a short-term "profit-led" perspective which sought to trim education and training down to its bare essentials (Kraak, 1994:7). He writes that the state ET proposals were clearly of a 'low skill equilibrium' variety, entailing an institutional framework, which was likely to perpetuate processes of low-skilling and low economic growth.

To enable South Africa to gravitate towards a higher skills base, among some of the most important issues, it would have to overcome the historically debilitating effects of racially-segmented labour markets and a fragmented and divisive education and training system. The sub-section that follows will try to show how South Africa's National Qualifications Framework was strongly influenced by the need to accommodate these issues. It will also try to show how the meaningful linkage between education and training, theory and practice, which is the main focus of this

thesis, was crucial to the success of this process and indeed of the National Qualifications Framework itself.

2.6 Segmented Labour Markets

This sub-section will start by giving a brief historical account of South Africa's racially segmented labour markets, and their influence on the formation of fragmented education and training systems. It will thereafter show how the labour federation Cosatu, as well as the ANC's labour-market and education and training proposals, were aimed at combating its debilitating effects in terms of enskilling historically disadvantaged black workers as well as positioning South Africa for a high-skills future. It will show how the NQF, with its stress on the meaningful integration of theory and practice, evolved from this context. This sub-section will also raise an important point in relation to the conceptual coherence of the new education and training policy. This will lay the groundwork for suggested alternatives to be taken up in the concluding chapter.

As has been alluded to, Kraak's (1994) segmented labour market thesis has very strongly influenced both Cosatu and ANC's labour market and education and training proposals. His work, which is an eclectic borrowing from the social or macro-institutionalist perspective, has drawn on both American segmented labour market theories as well as the Cambridge 'labour market studies' group to help him craft out his racially segmented labour market thesis. Its importance needs to be seen within the context of the labour market playing a mediating role in the relationship between education and the occupational structure primarily through the social processes of segmentation, discrimination, internalisation and exclusion (Kraak, 1994: 41). Drawing on these two labour market theories, he shows how segmented labour markets are those which have been institutionally divided into distinct and separate employment spheres. The three labour market segments, which historically merged within capitalist economies, are the independent primary market, the subordinate primary market and the secondary market. Most unskilled and non-unionised

workers form the make-up of the secondary market. A distinctive feature of this market is that workers have little protection from wider labour market competition and change. These workers also lack union-achieved worker rights, and can quite easily be dismissed. With no clear career paths, secondary employment is therefore very insecure. In South Africa this market segment constitutes up to 70 percent of the entire work-force. They also consist mostly of unskilled African workers. In terms of gender composition, the large majority of African women are located both within this market as well as in the informal sector (Kraak 1994:148). Employment security is minimal and workers are indeed very vulnerable during periods of economic recession. In South Africa, workers within this segment consist mostly of unskilled, insecure and non-unionised jobs.

The independent primary market entails those high-level manpower (HLM) jobs bureaucratically organised that offer long-term employment with considerable job security, clearly defined career paths and which are relatively well remunerated. It comprises professionals such as accountants and engineers, as well as other HLM employees such as technicians, managers, administrators, artisans, higher level supervisors and clerical workers. Most of these jobs require post-secondary educational qualifications.

In relation to the independent primary labour market, the subordinate primary labour market comprises jobs of the traditional unionised industrial working class. These would be the semi-skilled operative workers organised by Cosatu in manufacturing and other sectors. This market includes autoworkers, steelworkers and chemical workers, as well as, dock and railway workers. The distinguishing feature of the subordinate primary labour market from that of the secondary market, is that workers from this specific segment of the labour market are all unionised, and therefore benefit from the employment advantages won in union struggles against management. Thus their pay and working conditions are better than those in secondary market employment conditions. In periods of economic upswings, these jobs generally involve long-term employment security with prospects for pay rises based on seniority and increased responsibility. On the contrary, during recessionary

periods many of these workers are affected by large-scale layoffs (Kraak, 1994: 42-43).

An important consequence of this segmentation has been the development of only a limited number of technical occupations in the production sector with clearly defined educational entrance criteria. Kraak above also alerts us to the fact that the shielding dynamics of the internal labour market has resulted in craft apprenticeship being the only occupation at the skilled production level that has clearly defined entrance educational criteria. Occupations at the semi-skilled level are defined in the shadows of the apprenticeship route, being informal, unstructured, enterprise specific and non-transferable. Similarly, at the higher levels of technical skill, the independent ET mode channels individuals to two specific final destinations – Technikon-trained technicians and University-trained engineers. Indeed, because of the dynamics of labour market segmentation and ET fragmentation, all four levels of technical occupations are highly polarised in relation to each other. Thus, the operator, artisan, technician and engineer all fall within three distinct labour market segments and fragmented ET modes, each with distinct processes. In this sense, there is therefore very little occupational mobility for technical workers between such occupations, because a qualifications gap exists between each of these levels. This problem is exacerbated as a result of the increasing demands made of new technologies, which require a more flexible mix of the mental and manual skills traditionally held by these differing levels of workers Kraak (1992:109). The existence of these three distinct modes of ET delivery constrains movement within the total system. As a result, it becomes very difficult to coordinate and regulate such a diverse ET system. This is because no single mode predominates with uniform paths of access and a single structure of qualifications (Raffe 1990:16).

It is within the context of the above challenges that early Cosatu and ANC ET proposals evolved. Even here the influence of the macro-institutionalist perspective is quite evident. As the following brief discussion shows, these proposals entailed establishing both the dominance of the external mode and at the same time combining internal and external forms of ET provision. The macro-institutionalist

literature clearly favours the German and Swedish systems of ET delivery. Drawing on these systems, it is argued that the economic success of either Internal Labour Markets (ILMs) or External Labour Markets (ELMs) depends on the coherence of the institutional environment in which they are inserted. It is argued that successful ELMs are dependent on two conditions. The first is the existence of a strong institutional environment which, very similar to the German system, supports the maintenance of occupational labour markets, and which as Kraak (1994:111) points out, is a high quality apprenticeship system. Quality, in this sense, refers to a deeper theory/practice relationship between education and training, where the deeper conceptual underpinnings of practice are taught to apprentices through some form of institutional process.

In this regard, the German system is strongly cited within the macro-institutionalist perspective where the success of its ELM system is due largely to its highly legitimate apprenticeship system and its immersion within a well articulated set of supportive institutions. These include the 'dual system' of ET - a highly organised network of chambers of commerce and industry committed to high quality, generic skill training in a wide range of occupations; and co-determination rules which act to protect occupational categories and also act to incorporate capital's 'social partners' in a highly regulated system of labour market and ET governance (Kraak, 1994:115; Marsden, 1990:422:423). An additional feature of economically successful ELMs is that they do not substitute for ILMs, but in fact co-exist and articulate together. This is a very important point because the ILM in this context serves to link what would otherwise be discrete and isolated occupations sustained by the ELM. Again an excellent example quoted in the macro institutionalist literature is the case of Germany. Here again ILMs play a crucial role in linking one occupation with the other along the span of qualifications. This is also reflected within the Swedish labour market – predominantly an ELM, but with highly subsidised in-plant training and well established internal paths of progression (Kraak 1994:115; Standing 1988:105).

2.7 Labour Market Resegmentation

As the previous sub-section has shown, South Africa's historical unfolding of racial capitalism has led to formation of a racial division of labour and racially segmented labour markets. According to Webster (1985: 370), the role of the state has been decisive in their formation. This, it is argued, has occurred primarily through a complex web of legislation, which maintained control of labour movement and the homeland systems. Mechanisms such as these trapped black workers from the countryside into permanent secondary labour market employment. The state also intervened through the industrial council system, enabling white workers to demarcate the more privileged primary market jobs as their sole preserve. This interaction between the development of a capitalist labour process and the intervention of a racially exclusive state led Webster (1985: 350) to emphasise the interconnection between labour control within the firm, and control exercised outside in the historical formation of segmented-labour markets. The formation of South Africa's racially segmented labour markets prior to the mid-1970s was rigidly shaped by racial factors. During that period, the secondary market was dominated by African migrant workers doing low paid, unskilled and insecure work. In contrast to this, the subordinate primary labour market composed of an intermediate stratum of white, coloured and Indian semi-skilled workers. In relation to these, the independent primary labour market was predominantly white (Kraak 1994:146; Webster, 1985: 378).

Commenting on labour market resegmentation since the 1970s, Kraak (1994: 146) points out that mechanisation within industry and mass production techniques, hastened by the high degree of capital concentration and centralisation characteristic of this period, brought with it demands for new forms of labour power. There was, he says, a strong demand for large numbers of cheap semi-skilled workers which the existing system of labour reproduction was unable to meet. This necessitated the reconstitution of the racial division of labour and racially segmented labour markets so as to allow for a greater number of African semi-skilled workers (Kraak, 1987: 27; Webster, 1985: 369).

One of the most significant changes aimed at meeting these new labour requirements has been the rapid movement of African workers from unskilled secondary labour market jobs into semi-skilled operative positions in the subordinate primary labour market (Hindson, 1991: 2). According to his (1991: 239) analysis, the 1980s was a period characterised by a high degree of differentiation within the African working class. Semi-skilled workers within the urban terrain were increasingly benefiting from forms of secure labour employment associated with internal labour markets. They thus acquired greater access to promotion and training opportunities, were well paid in comparison with secondary workers and had access to housing and a relatively developed urban social infrastructure. (Kraak, 1994: 147).

He also brings to our notice the fact that outside the traditional apprenticeship system, and those professional occupations sponsored by capital, such as engineers and technicians, few formal linkages existed between ET institutions and the occupational structure. According to Kraak (1994: 150), race has been the determining factor in the allocation of people to jobs via the external labour market. The issue of qualifications has played a secondary role. In this instance many high-level management occupations were opened up to whites with low educational qualifications. He writes that features of South Africa's employment traditions most consistent with internal labour markets include the 'shielding' practices of white craft workers and the secure employment associated with white high-level management labour in primary market jobs. White employees benefited from privileged access to internal promotion paths, while most black workers have until recently been excluded from these privileges.

Abolition of the statutory mechanisms of job reservation and racial exclusion in the labour market in the early 1980's has had little effect for two reasons. The first is that in the occupational categories where blacks have historically been excluded, new forms of racial exclusion have emerged. Secondly, in those occupational categories where blacks dominate, such as operative labour, capital has attempted to reshape

the behavioural characteristics of these workers, with the aim of making them more sympathetic to free market values and submissive in the face of managerial authority. Both of these strategies, argues Kraak (1994 : 150), suggest that elements within the management structure in association with organised white craft labour are beginning to use internal labour market strategies more effectively to ensure their continued influence over labour market formation. Cosatu tends to agree with these revelations that 'racial discrimination' persists through recruitment practices, selection procedures, differential educational entry requirements and segregated training facilities (Cosatu, 1996 : 3). These internal labour market processes have placed strong constraints on the further mobility of black workers up the occupational structure.

In South Africa, according to Webster (1985:370), the racial state has complemented processes in production and the labour market in shaping a highly fragmented and racially differentiated system of ET. Middle class whites had historically dominated access to post-secondary education and privileged primary market jobs. The analysis will now turn to show how labour market segmentation in South Africa has influenced the development of three distinct 'ideal type' modes of educational provision.

2.8 South Africa's Fragmented Education and Training System

Kraak (1994) has drawn strongly on Raffe's (1990) work on differentiation within the British labour market and its impact on the development of a number of distinct and fragmented modes of ET delivery systems. He has adapted this analysis to the South African context, and shows how labour market segmentation in South Africa has influenced the development of three distinct 'ideal type' modes of educational provision. It is pointed out that they run parallel to the independent primary, subordinate primary and secondary labour market divides. He has also termed these separate modes the internal, independent and restricted modes of ET delivery.

Firstly there is the internal mode of ET delivery which emerges as a result of capital's promotion and recruitment of an internally stable and skilled work force. It also emerges as a result of the rigid job demarcational practices of craft workers, who restrict the access of less skilled workers to privileged jobs. As a result, this internal mode of delivery has been associated with the conditions of work in subordinate primary labour markets (Kraak, 1994:105; Raffe, 1990:15).

The educational and training requirements within this internal mode are employer determined. As a result workers do not require levels of general education above the minimum specified by employers. They do, however, require firm-specific vocational training acquired on the job. These workers benefit from reasonably secure employment, skills training and promotion opportunities based on seniority within the enterprise itself. This form and content of ET focuses on the existing technology in use, and rarely develops broad-based skills which are transferable on the external labour market to other firms and industries. Consequently these workers are often unable to adapt to rapid changes in technology. As a result, they face retrenchment and unemployment during times of recession and technological change (Kraak, 1994:106).

In South Africa, these workers would comprise union organised, semi-skilled operative jobs. These would constitute mostly Cosatu-organised black operative workers together with a segment of poor white workers. As regards gender orientation it would comprise mostly men with a small number of unionised black women operative workers (Kraak, 1994:106).

The independent mode of ET delivery, as was pointed out in sub-section 2.4, is defined by the fact that workers within it obtain the necessary ET qualifications prior to obtaining high level management jobs in the external labour market. In this instance, educational qualifications are acquired privately, independently of company sponsorship, and prior to obtaining company jobs. The agents within this mode have a class privileged access to higher education, which enables them to afford their own

education and training. This mode of ET delivery had emerged in association with the conditions of work in independent primary labour markets. Drawing on Poulantzas (1974:209), Kraak argues that the independent mode, more than any other mode of ET delivery, is shaped not only by the requirements of the independent primary labour market, but also at the level of the political terrain, emerging as a crucial instrument in the wider process of class formation within capitalist society. The Poulantzian argument is that educational credentials play a crucial role in the formation of the new petit bourgeoisie. His argument, which Kraak (1992:106) applies to his segmented labour market thesis, stresses that educational credentials are crucial to assigning this segment of working class among the various positions in the hierarchically ranked independent primary labour market. This is a consequence of the historical emergence of this labour market through the massive expansion of 'new petit bourgeois' non-productive white-collar occupations associated with the growth of monopoly capitalism. The control of labour in this market is not based on despotic supervision or routinised work, as is the case with the secondary and subordinate primary labour markets. Rather, it is based on 'bureaucratic control' firmly embedded in the organisational structure of the firm. This type of control is built into a highly stratified system of job categories, work rules, promotion procedures, discipline, wage scales, definition of responsibilities and systems of personalised productivity incentives (Edward, 1979:131; Kraak, 1994:107). These writers argue that such systems of labour control aim to elicit greater individual worker co-operation and compliance. Employees are thus encouraged to identify with company-defined workplace behavioural patterns.

Educational qualifications are crucial to the functioning of this labour market, since they assist in fostering an occupational consciousness among high-level-management employees. They also serve as a basis for differentiation in this highly stratified labour market. The sequential ordering of occupations creates differentiated educational job entrance requirements. This in turn serves to maintain the legitimacy of the hierarchically ranked independent primary labour market (Hussain, 1976:419; Kraak, 1994:107). In South Africa this labour market segment involves predominantly middle class whites. There has historically been a very small black middle class and

managerial layer. In terms of gender orientation this market contained mostly men, with a minority of high-level positions occupied by white women (Kraak 1994:148).

Finally, the third and by far the largest mode of ET delivery has been classified as the restricted mode. It comprises providing for the minimal education and training levels required of workers entering the many unskilled and insecure jobs within the secondary labour market. The jobs within this labour market segment require no formal education and training qualifications, and workers are not rewarded for having additional ET qualifications beyond the minimal levels required. As Kraak (1994; 107) above reports, work entails “dead-end” jobs with little chance of upward mobility. The following section will try to show how the ANC/Cosatu education and training (ET) proposals were geared towards undoing labour market segmentation and ET fragmentation. They were also geared towards trying to enskill workers for the new post-Fordist economy.

Trade union academics such as Bird and Elliot (1993:9) from the Cosatu think-tank identify four central problems related to the challenges of establishing a deeper relationship between education and training. The first being that:

... except in Germany, vocational training systems have traditionally been low status in comparison to the academic system... the second is that it doesn't solve the problem of those adults who have no general education. The solution that is offered is vocational education and training which is in no way considered equivalent to basic general education. The third is that mobility from one sector, or even one job to another is very limited since there is no underpinning for portability of skills in the form of generic knowledge. The fourth is that a range of academic/ vocational combinations appropriate to a wide range of political, economic and technological circumstances are excluded by definition (Bird and Elliot, 1993:9).

Speaking of the South African training dispensation, these writers note that many of the existing vocational courses are too narrowly defined and task specific, and exclude the broad knowledge constructs that today are increasingly required by the new technologies and new forms of work organisation. In contrast, they argue that most academic courses are abstracted from the economy and deny learners any knowledge of the world of work and social and economic consequences of changing technologies (Bird and Elliot, 1993:3).

2.9 Integrating ET to meet challenges

The section following will show how ANC/Cosatu ET proposals were geared towards meeting the demands of the new global competitive economy on the one hand, and on the other, reforming racially segmented labour markets. In this way it tried to balance an important aspect of the equity/development tension. The discussion will also show how the meaningful and deeper integration between education and training was pivotal to the successful balancing of this tension.

Cosatu affiliated academics such as Bird and Elliot (1993) suggested a 'unified, multi-path model' built around a nationally integrated curriculum with a single qualifications structure. Within this context learners were required to complete a given number of modules. Among these, some modules were to be made compulsory and 'core', whilst others were optional and could be selected from a bank of vocational and academic modules. The precise content of these core and optional modules was to be determined by the 'multi-path' context in which learning was to be undertaken, whether in the school-classroom, the factory training centre, or through correspondence courses. The essence of this approach, as stressed by unionists, was a vision of 'lifelong learning' for the majority of South Africans who were denied such opportunities in the past. Cosatu educationalists comment that this process of lifelong learning:

... is based on progressive learning in clear steps, where multiple entry and exit points make it feasible for a much larger number of learners to access the system through a wide range of delivery mechanisms (Bird & Elliot, 1993: 16).

Referring to this system's potential for occupational mobility, they argue that this approach also makes it possible for learners to progress through the acquisition of modular credits for courses at specific levels and situations to a single qualification (Bird & Elliot, 1993:16).

The nature of such a unified ET model has a number of critical features, among which the notion of articulation is the most significant. It implies learner mobility across previously fragmented modes of ET delivery. Articulation also has to do with skill portability. In this sense, a high degree of articulation implies that skills training of the kind envisaged would enable workers to move both up the occupational hierarchy within a single enterprise, as well as across other enterprises and industries. Within the context of the previously inherited training system, training received in one factory was often not recognised by other firms in the same industry, by other individual sectors, or by the ET system itself. The portability of skills was indeed a very important aspect of the ANC/Cosatu approach to maximum articulation (Cosatu, 1991; 21; Favish & Omar, 1992:16; Kraak 1994; 377).

The extent of articulation was also determined by the flexibility of access to the ET system. As Kraak has stressed in sub-section 2.7, access to the South African ET system was limited by the highly divisive character of the system itself, which was a historical product of racial, Taylorist and a class orientated nature of education and training.

Drawing on the British qualifications Framework, the ANC/Cosatu discussion document emphasised a 'high-participation' system based on maximum access to the ET system. They hoped to achieve this through introduction of multiple entry and

exit points to be embedded within the new system, and in particular through the creation of multiple ET delivery mechanisms that would provide access from the one to the other.

In following this up, Kraak (2004) writes that the focus on flexible access arises out of a concern that only the young have access to the ET system. However, only a minority of the young actually continue in the ET system after compulsory schooling. The Cosatu educationalists' concern was that the existing system did not cater for the needs of a larger contingent of marginalised society.

The majority of young people will leave school at the end of the compulsory period. Precisely where these young people will go is a serious economic and political issue which has major implications for the future ET system...Therefore, the majority of young people, together with the millions of others who were denied the opportunity to complete schooling have needs beyond those traditionally catered for by the general education system. The unified model proposes that a framework for learning be established which consists of a compulsory core of learning areas (such as communications, mathematics, social and physical sciences) together with a system of options. Courses should be designed in a modular fashion to allow maximum flexibility so that all learners regardless of their circumstances, will be able to pursue courses whenever and wherever possible and move incrementally towards getting a national certificate (Bird & Elliot, 1993:6).

The primary conception of articulation within the unified system stressed that it is therefore immaterial whether the learner is located in a school, a college, a company-training centre, a night school or in a correspondence course. The central concern and objective is that the unified model allows for flexible access, which balances the extent of academic and vocational modules needed in differing learner

contexts, and certificates the full range of learner pathways with the same national qualification. In this sense, access is in a range of locations; hence the emphasis on lifelong learning (Bird & Elliot, 1993:1).

As these writers above contend, rules of access to tertiary study would have changed profoundly under the unified model. Indeed, historically only students with school matric exemption and high marks in key subjects like mathematics and science gained admission to the historically white universities. Also, only school matriculants had generally gained access to the black universities. It is argued that these rules of admission have excluded large numbers of young blacks and black adults who have not completed school, but who have in many cases studied elsewhere in the post compulsory sector. It includes those, for example, who have enrolled in secretarial courses, apprenticeships and machine-operator training courses, such as those within this study. These academics argue that many of these adults have acquired considerable experience and know-how in the world of work. These internal labour market qualifications and experiences are currently not recognised by the tertiary sector, nor are they transferable into it. It is in this important respect that the changes envisaged by the unified system would open up access by putting in place accreditation mechanisms which recognise both prior experience and allow access to formal education.

Kraak (1994:381) writes that the changes envisaged above are radical in two ways. In the first instance they attempt to avoid the traditional divide within post-compulsory education, between a vocational and an academic track. In doing so, they dilute the processes of social class formation associated with highly divisive educational institutions by eradicating the divisions between an 'elite' academic and a 'low-class' vocational track. In the second instance such changes are regarded as 'radical' because they open up access to tertiary institutions far beyond that which is currently possible. The unified system is more equitable in terms of the distribution of publicly-owned tertiary resources to a much greater number of people.

2.10 Method of Unification

In this regard the organisational method of unification proposed by the ANC and Cosatu in the early 90's (subsequently adopted by the Government's Green Paper on ET) was to arrange curricular into 'core' and 'optional' modules. There are three important aspects related to the notion of 'core' modules. They are firstly regarded as generic in character and therefore held to provide a necessary foundation of general knowledge applicable in a range of contexts. In the second instance these writers hold the view that the generic nature of core modules could provide the facilitating mechanism for skill portability, whether across differing jobs, industries or ET sub-sectors. It must be noted that this issue of skill portability was regarded as important for unionists because it could empower workers in terms of employment versatility through the accreditation of experiential knowledge. It was also important in terms of the macro-institutionalist perspective because of the progressive movement up through higher technology oriented jobs. Finally core modules were regarded as important because it constituted national standards around which equivalence of degrees, certificates and modules could be ascertained. Its significance argues Kraak (1992:382) needs to be seen within the context of it enabling maximum articulation within the unified ET system. Both the ANC Curriculum Committee submissions on a draft curriculum (ANC, 1993) and the June draft of "A Framework for lifelong learning" (Bird & Elliot, 1993) recommended that 'core' modules entail communication skills such as English and one other language, mathematics, science and technology, social studies and a problem solving practical component termed 'applied skill and knowledge' (Bird & Elliot, 1993:22; ANC, 1993:10). Added to the core modules will be a range of more specialised options chosen from a bank of academic and vocational modules related to the specific vocational or job environment that the candidate finds himself in. Many of these core skills mentioned above are similar to those developed in Britain for their National Vocational Qualifications Framework. The key test for the ANC/ Cosatu approach says Kraak (1994:383) is to what extent these core modules will promote a broad-based knowledge context as opposed to the narrow variant, which is so typical of most

modularisation systems today. This he says will depend to a large degree on the conceptualisation of 'modularisation' and 'competency- based' learning systems.

The importance of the discussion above shows clearly the awareness among ANC and Cosatu aligned educationalists and economists of the need to move away from the narrow work specific and Taylorist oriented training systems of the past towards a deeper relationship between education and training. This is quite clearly captured in the change of language noticeable between earlier ANC/ Cosatu draft documents and the August 1993 draft of *A Framework for Lifelong Learning* (Bird & Elliot, 1993). This draft makes a significant departure from the earlier usage of the concepts 'competency-based ET' and 'competency standards', arguing that whilst a competency model refers to a particular form of outcome – usually the performance of a narrowly defined task in a work place – an outcomes approach, comment allows one to define a curriculum in terms of broader learning aims (Bird & Elliot, 1993: 27,28).

In this particular context outcomes refer to conceptual and intellectual skills and their applications – the principle goals of the learning experience. They are distinct, says Kraak (1994:387), from the competency model which refers to the performance of specific practical tasks, as in the case of traditional vocational programmes or the rote- learning reproductions of text book arguments, as in the case of many academic courses.

Both Spours (1988:13-14) and Kraak (1994:302) argue that Competency Based Modular ET systems (CBMET) often perpetuate a narrow Taylorist process of enskilling because they lend themselves to the development of discrete skill units based on employer-defined standards of competence. There is a tendency to standardise work-based competencies, resulting in the exclusion of many generic skills and knowledge essential for progression to higher levels of ET. It is in this context that these writers state that a broad approach to CBMET seeks to integrate the development of 'skill competencies' and the 'knowledge and understanding'

constructs which underpin such competencies. This approach is diametrically opposed to that of narrow CBMET, which seeks the development of discrete skills in isolation of knowledge and understanding. Broad competencies entail those skills which prepare workers to face the challenges posed by the new global economic context – adaptability in the face of rapidly changing technology, understanding and participation in the management of work roles and production systems, taking responsibilities for contingencies, quality control-innovation and flexible responses to new product demands. It is argued that these are competencies that are impossible to develop in narrow training systems (Kraak 1994: 304; Mansfield 1989: 28).

2.11 Active Labour Market Strategies and Skills Broad banding

An additional dimension of the ANC/Cosatu proposals drawn from the traditions of the consensual economies of Europe is 'active labour market policies'. The Cosatu trade unionist and academician, Bird (1992: 14), points out some central objectives of active labour market strategies. These are skills upgrading, reduction of unemployment through retraining and job replacement programmes, reduction of labour market segmentation and payment of unemployment benefits as a last resort (Bird, 1992: 14; Kraak, 1994: 389).

Bird (1992: 19), drawing on literature emanating from the Australian Congress of Trade Unions (ACTU), argues that the training undertaken tends to be generic and polyvalent. This training is underpinned by a work-organisational structure, which encourages career pathing – the movement of labour from one skill band to another – and rewards increased skills with an increase in wages. As a result, these policies result in a high degree of labour mobility both within the internal and external labour markets, Kraak argues (1994:389), adding that active labour market policies are also highly effective in dismantling labour market segmentation and eradicating specific forms of job discrimination. The literature from ACTU (which was very strongly influenced by the Swedish social-institutionalist perspective) argues that the position of women and youth in the Swedish labour market has been enormously

strengthened by active training and career path interventions. From this it can be seen that skill is a social construct, and as a result can consciously be re-arranged to serve the needs of equity. This aspect of active labour market policies, argues Kraak (1994 : 390), is of particular appeal in the South African labour market context, which is characterised by a high degree of racial and gender segmentation..(See also NUMSA, 1991: 36-43). Drawing on this literature, he writes that training and retraining are at the heart of an 'active' approach to labour market transformation. They are primarily concerned with creating labour mobility or 'flexibility' so as to bring about rapid structural change with minimal social cost. He defends his argument against accusations of neo-liberalist tendencies in this regard by stressing that the concept 'flexibility' in this context is not about lowering labour costs and weakening trade union power, as was the case with 'Thatcherite-style' market deregulation. Rather, this approach to flexibility is premised on the principles of continuous skill formation and full employment, even during periods of rapid industrial change. It is a flexibility achieved, he says, through consensus between labour, state and capital such as that practiced in the social democracies of Europe. These industrial training systems are characterised by continuous upskilling and labour markets highly regulated, yet sensitive to key market indicators, particularly those that suggest the need for rapid structural change. As such, it is an 'active' or 'proactive' instrument, and has, for example, assisted Sweden in its shift away from declining industries such as steel and ship-building to new higher value-added production via the redeployment and retraining of labour with minimum social disruption and unemployment (Kraak, 1994: 391; See also Actu, 1987: 105-107).

Kraak (1994: 392) says such an approach is in sharp contrast to the free-market 'deregulation' route currently being promoted by the South African state and employers. Bird and Schreiner (1992: 27) comment that the South African state has ironically moved from an active interventionist labour market role which historically privileged white workers, to a more passive market-led approach, at a time in history, when black workers have begun to assert demands for occupational advancement.

Active labour market policies we are told by Kraak (1994: 391) are normally achieved through the 'broadbanding' of skills and career paths. He defines 'broadbanding' as the re-integration of previously fragmented single tasks into one composite and broadened area of skill. It is interesting to note that this reintegration of the traditional capitalist division of labour has been a result of the introduction of the new computer-based technologies and a response to best-practice forms of work organisation, developed in the more advanced socio-democratic economies of Western Europe, as was noted much earlier in this discussion. As the Australian trade unionist Mathews (1989: 110) points out, production under post-Fordist conditions requires generic skilling so that teams of workers may be simultaneously responsible for manufacture, computer programming, quality control and maintenance functions.

Career pathing refers to the sequential structuring of these broad bands. Drawing on the Australian example, as Bird et al. (1990, 6-20) have done, shows that in Australia today, introduction of active labour market policies has entailed defining fourteen broadbands, sequentially ordered from unskilled worker (band one) to artisan (band five), and through to engineer (band fourteen). Through the required process of education and training each Australian worker now has the opportunity to progress along a clearly defined career path. Within the South African context NUMSA had led this initiative within Cosatu in promoting a policy of broadbanding. Their proposals were very similar to those developed in Australia. They indeed initiated negotiations with employers in the metal, engineering, auto and tyre sectors to reduce the number of grades required at artisan level to five, and to restructure the entire occupational structure into fourteen (14) broadbands (NUMSA, 1990; COSATU, 1991).

Kraak (1994: 393) warned at the time that such a 'wage-skill-grade' process of restructuring as envisaged in Australia and practiced in the Scandinavian countries would require some critical changes, particularly in the organisation of work and in existing payment structures. He argued that work responsibilities would need to be broadened and deepened (as within the German and Swedish systems and also as pointed out by Finegold in sub-section 2.3) so as to benefit from the increased knowledge and skill workers would bring to bear in production through increased ET.

Moreover, work would need to be restructured so as to enable a continuous process of skill formation. That, according to Kraak (1994:393), would require the elimination of craft demarcationism and all racially defined internal labour markets. In this way, implementing institutional features such as active labour market strategies and career pathing strategies through the process of 'broad branding' would combat segmentation and ET fragmentation.

The conclusion will now review some of the central points highlighted through this chapter. To reiterate an argument was made against a left-critical discourse that collapsed the union movement Cosatu's education and training and labour market proposals totally into neo-liberalism. It was shown how these proposals, which were strongly influenced by Kraak's Segmented Labour Market Thesis, were aimed at reducing some of the structural inequalities characteristic of the *apartheid* era. Kraak (1994), speaking of *apartheid* capitalism, has written that it was founded on a range of institutional mechanisms, which acted to solidify the primary class inequalities which have emerged historically. Two such institutional mechanisms, he writes, were racially segmented labour markets and racially fragmented ET institutions. According to him, these social institutions played a key role in class formation by effectively excluding the large majority of South Africans from further opportunities in the educational system and occupational structure.

In this sense Cosatu's proposals for active labour market policies and a unified ET system were critical components of a reconstruction programme which aimed to dismantle these structural features of *apartheid* capitalism. As Kraak argues, perhaps the most significant and far-reaching structural reforms will be those brought about by active labour market policies, which he says will act decisively to end the destructive 'craft' influence on labour markets and ET delivery. This is important because, as he has shown, the character of the South African labour process and industrial training system has been fundamentally shaped by this craft tradition within internal labour markets. The chapter has shown how white artisans have succeeded historically in demarcating certain jobs as their privileged preserve. The ANC/Cosatu education and training proposals were aimed at radically changing these 'shielding'

characteristics. Training, as has been shown throughout this discussion, will no longer be restricted to a privileged white labour aristocracy within racially defined internal labour markets. Nor, will such benefits be extended to a new labour aristocracy made up of privileged urban black workers. Such benefits will be made available to all workers via an external mode of ET provision such as the learnership programme within the industrial training dispensation. This will be co-ordinated by comprehensive state regulation of ET and labour markets. If implemented, all these reforms are likely to have considerable impact, as has been shown through earlier discussion, on the life chances of large numbers of working class people. These changes, it is contended, constitute substantial structural reform (Kraak, 1994: 408).

This chapter has also highlighted how important the successful integration of education and training is to the task of balancing the tension between equity and development. However, as problematised in the preceding chapter, the epistemological difficulty of bridging the tacit to the scientific is proving to be the achilles-heel of the new integration agenda. The importance of further problematisation of this issue in this chapter must be seen within the context that this is one of the central concerns that this thesis is trying to address.

The latter part of this chapter has noted how Cosatu and early ANC's labour market and education and training proposals have been very strongly influenced by Kraak's racially segmented labour-market thesis as well as emerging literature on macro-institutionalism. These proposals, it has been argued, could not simply be collapsed into neo-liberalism. They were aimed at trying to dismantle labour market segmentation and fragmentation of education and training. In relation to the issue of equity, there was a close correlation to the need for economic development to meet the challenges of new international economic conditions. The discussion has attempted to show how South Africa adapted the macro-institutionalist perspective to try to overcome the debilitating effects of labour-market segmentation and education and training fragmentation, and how it attempted to craft out a training system more in tandem with the consensual economies of Western Europe, especially those of Germany and Sweden where skills training, as the previous sub-section has shown,

tends to be more generic and polyvalent. More, importantly, underpinning this training is a work-organisational structure which encourages career pathing – the movement of labour from one skill band to another – and which is closely linked to a qualifications structure. In this sense, jobs along the occupational ladder remain closely linked because they are structured according to a qualifications ladder. This creates an interactive dynamic between work organisation and the character of the qualifications structure – each influencing the shape of the other. As Kraak (1994: 34- 35) writes, this interaction has important implications for polyvalent skill formation, as well as the integration of differing workstations such as design and production, and for co-operative work. His argument and that of the macro-institutionalist perspective is that this interaction between work-organisation and skill formation accounts in large part for the nature of German industry and its success in today's high-skill global economy. The previous sub-section has shown that countries such as France, and by extension South Africa, are typified by hierarchical work relations and Taylorist task fragmentation. Furthermore, this process of work organisation is not well articulated to their education and training systems. These factors are all critical determinants of their weaker economic performance. The challenge facing South Africa was the task of trying to effect the meaningful articulation of the external labour market supported by a national-qualifications framework with an internal labour market that has progressively linked skill bands within its work-organisational structure related to the qualifications structure. This is the requirement for the process of high-skilling and occupational mobility. However as this chapter has also shown, any successful attainment of the above goals crucially depends on the possibility of integrating working or tacit knowledge with the more formal theoretical knowledge domains. As the previous chapter has highlighted, this is proving to be exceedingly difficult. This is as a result of the epistemological difference between the two knowledge forms, and an implicative difference in their modes of learning. It has direct implications for any balancing of the tension between equity and development. This central concern that this thesis is trying to address will now be taken up in the following theoretical chapter which effects a synthesis between the two oppositional theoretical perspectives by meaningfully integrating the tacit or working knowledge to the more formal scientific knowledge domain.

CHAPTER 3

Theoretical Underpinnings of Study

This chapter provides the theoretical underpinnings of the study. It problematises a central research concern related to the epistemological problem of linking tacit or workplace knowledge to the more formal scientific and engineering knowledge domains. It does this within the context of two oppositional theoretical perspectives. The one derives from the neo-Bernsteinian theoretical perspective that insists that formal disciplinary discourses need to be learnt institutionally in their own right. The other emanates from newly developing social-cognitive theories of learning which take issue with the abstract decontextualisation of knowledge. This state of polarisation, also demonstrated in the previous chapters, has negative implications in terms of balancing the tension between equity and development because it concerns the enskilling process. .

As has been alluded to in chapter one, academics such as Gamble (2002), Breier (1998), Young (2003) and indeed even Muller (2001), as this chapter will show, have all adopted this neo- Bernsteinian theoretical stance in their critique of the failings of the National Qualifications Framework (NQF) which embodies South Africa's' new integration of education and training policy. These writers have drawn in particular on those aspects of Bernstein's theory related to the distinction between two discursive forms of knowledge characterised as horizontal and vertical discourse in the formulation of their key argument that the tacit or working knowledge which falls within horizontal discourse cannot meaningfully be linked to the more disciplinary knowledge forms characterised as vertical discourse. This is because of epistemological differences related to the internal structure of these respective knowledge forms. As a result, this chapter has concentrated on these specific aspects of Bernstein's theory.

The discussion that follows gradually draws on the neo-Bernsteinian elaboration of these differences in knowledge forms in order to deepen our understanding of the problem. According to Bernstein, vertical knowledge structures such as physics or mathematics are hierarchically organised in terms of principles of conceptual coherence so that each level of meaning is conceptually related to the next level. Vertical knowledge is also distributed through a re-contextualising principle and draws on 'un-common-sense' knowledge which can be generalised through a specific context only (Bernstein, 1996).

In contrast, horizontal discourse draws on common everyday knowledge, is context-dependent, distributed segmentally and has no overarching principle or knowledge structure relating or ordering different knowledge segments to one another. Muller (2001), drawing on this theoretical perspective, takes issue with a strong constructivist epistemology that has influenced educational reconstruction in post-*apartheid* South Africa and created the perception that because barriers of this sort are socially or discursively constructed, they can just as easily be dismantled by the same means:

The strategy of the constructivists is to reason that exclusion occurs because of an unwarranted disparity between curricular content and the sensuous content of the everyday lives of the children who must learn this foreign and hostile knowledge. This disparity constitutes an unnecessary barrier to the learners; it is a barrier arbitrarily constructed by agents of the *status quo* and it must therefore be removed in the interests of empowerment and emancipation (Muller. 2001:70).

In an attempt to achieve equality, the constructivists recontextualise everyday knowledge into the mathematics curriculum. Drawing on Dowling, he argues that this 'does violence' to the student in inculcating a view of mathematics as a series of specialised solutions to particular problems rather than as a connected set of axioms and theorems. Thus, in substituting procedure for discourse, constructivism obscures the interconnected and generalised nature of school mathematics. This, argues

Muller (2001), also precludes the induction of the student into the discipline of mathematics because the 'localising strategy' of indigenous examples induces the student to mistake 'algorithmic' solutions for generalisable principles, and in this way to mistake the nature of mathematical practices (Muller, 2001).

Although this specific case study shows that one cannot simply ignore Muller's argument, there still remains for me the dichotomy between contextualised and decontextualised knowledge. This is disquieting in the context of literature that suggests that in university undergraduate physics courses, studies have shown that even though students apparently master the (decontextualised) physics principles (as evidenced by good performance in traditional tests and examinations) they often, in fact, have poor conceptual understanding of the principles and are unable to apply these to real world, everyday contexts (see, for example, Arons, 1983; Hewitt, 1983; Mc Dermott, 1991). Furthermore, despite the hierarchical knowledge structure of physics (and the hierarchical structure of undergraduate physics curricula) the research suggests that students' knowledge about topics in undergraduate physics courses often tends to be fragmented, segmented and disjointed (see, for example, Hammer, 1994; McDermott, 1993; White et al, 1995). Unwin and Wellington's (1995) study of apprenticeship - in which an apprentice engineer interviewed in a car plant explained that she had never really understood mathematics until she became an apprentice where maths was taught in such a way as to be 'car-related' - supports the above finding. Moreover, this apprentice wanted to know why schools could not teach maths in such a stimulating way.

This debate needs to be seen within the context of the prominence given to mathematics and science in a new age of science and technology's relationship to global economic competitiveness. The concerns also relate to a situation where previously disadvantaged students struggle to master the curricular version of its rigorous language where proficiency is an entrance requirement for occupational mobility. In this way it constitutes symbolic capital, and confers symbolic power. It has thus been identified by concerned educationalists as an exclusionary mechanism needing radical reform. Muller does not exclude the possibility of

bridging the divide between the two knowledge forms, provided one does this with due respect for their 'boundaries', by which he refers to the horizontal/vertical divide.

Cautioning against simplistic correspondence between the boundaries, he does not preclude the possibility of trying to bridge the divide. Indeed he introduces us to Walkerdine (1998), who, although sharing the anger of the constructivists against the exclusivity of formal mathematics, advocates theorising the nature of the boundary:

...what happens when a set of signs which make sense in one discursive domain are transformed into a different set of meanings in another? How can this transformation be achieved so as to make the formal discourse accessible to a wider range of learners? And most important, how can the signs of mathematics be stripped of their power to pathologise and regulate and be imbued with a liberatory charge? (Muller & Taylor, 2000: 68).

In invoking this argument both Muller and Taylor (2001) take issue with the constructivist position, which for them has no theory of the boundary "as if, for example, the syntax of school mathematics could be perfectly aligned with that of ordinary everyday activity" They thus argue against this 'contrived realism', and stress the need to take cognisance of the internal structure of the domains that the border insulates.

The critical issue then is to try to understand the nature of the boundaries. This discussion will briefly turn its focus to this issue. However, before attempting to do this there is another important concern related to this epistemological divide that needs to be noted. As a result of the epistemological divide derived from the difference in the nature of the knowledge structures, it is argued that their modes of learning also differ (Breier, 1998; Young; 2003). By implication there can be no effective bridging of learning between the two knowledge forms. This again poses a very serious problem for attainment of occupational mobility and enskilling for

reflexive modernity. The following discussion attempts to achieve a synthesis between these oppositional theoretical perspectives. It entails briefly studying the nature of the boundaries, and attempts to establish an epistemological link between the knowledge forms under study. In this way it shifts the two polarised modes of learning into a state of collaboration.

My belief in the possibilities of establishing an epistemological link between technology related working-knowledge under this study and the more formal scientific knowledge domain emanates from a deepened theoretical understanding of my own anecdotal experience of technology-related working- knowledge. It was indeed this iterative process that has shaped some of the important theoretical features of this study. By 'iterative', I refer to the relationship between work-related anecdotal experience, and process and emerging theories of learning. It was also this practice and theory related experience that provided me with a deepened insight into the nature of the boundaries and their respective modes of learning. It is as a result of these factors that I feel the need to very briefly relate this experiential process, and show its role in informing a synthesis between the two polarised modes of learning.

During work-related experience in the early 1990s, I interacted with a small group of skilled wood craftsmen. This entailed engaging with machinery and familiarising myself with the fundamentals of machine minding. Difficult mechanical repair work was in general contracted out to a retired master technician. My acquaintance with this technician grew over time into a strong friendship. It was also then that I learned of his ability to replicate machines. He did this as a hobby. My fascination with this ability sparked an interest in finding out whether he could offer a theoretical explanation of his work. To my surprise he was unable to do this! My interest in his tacit working knowledge and a gut feeling that his work could clearly be placed within a theoretical framework influenced my decision to contact an engineer, an old student friend, who was able to provide a theoretical and conceptual framework, based upon a specific principle of physics related to force and angular rotation. This

principle was essential to the operationalising of the machine (which will be discussed later).

The engineer also gave us the algebraic equations symbolising the theoretical underpinnings that were applied in this replication. This alerted both the technician and me to the importance of extrapolation from the particularities of practice to the generalisation of theory. For me, this was an educative experience in terms of making sense of the relationship between science and technology. In my view, the experience evoked the concept of 'technological literacy', which stresses the importance of the deeper conceptual and theoretical underpinnings of technology as opposed to 'technological skill', a term associated with a more narrow focus on work-based skills acquisition (Gleeson, 1990:195).

It was within this context that the Bernsteinian-derived epistemological divide related to modes of learning continued to puzzle me – especially because technology related praxis was underpinned by principles of science. A reading of Bernstein's elaboration on the theoretical distinction between horizontal and vertical discourse, taken up in his later work, does not directly address or characterise praxis related to technology within the context of his distinction between these different knowledge forms. I however found a clue to the puzzle after reading Gamble's (2002) work on craft knowledge, where she innovatively applies Bernstein's theoretical principles to reposition craft knowledge within the horizontal/vertical divide. I draw on these insights and position technology as a modality of vertical discourse characterised by a horizontal knowledge structure which is tacitly transmitted.

Unlike the mass production system under Fordism where production of the whole is broken up into discrete parts and influences the mental/manual division of labour, in traditional craft work the relationship between part and whole is crucial, as the craft worker must be able to see how the parts fit into a whole and how the whole consists of a series of interlocking parts. What relates the discrete parts to the whole is an 'embodied principle of arrangement'. These principles operate at a general and non-

empirical level, but craft workers grasp the relationship between part and whole through the act of 'visualisation' (Gamble, 2002). They understand the principle in a practical manner and they pass on this knowledge predominantly through modelling rather than through verbal instruction. It is in this sense, she argues, that craft has something in common with general principled knowledge as we find it in the natural and social sciences. What is similar between the two kinds of knowledge, says Gamble (2002), is that both have an epistemic logic that interprets 'procedure through principle'. The difference lies in the nature of the principle involved. In craft, the principle is particular and embodied in the item that is being made. It is in this sense that she situates craft knowledge as a modality of vertical discourse, characterised by a horizontal knowledge structure and tacitly transmitted through the act of modelling. In the natural and social sciences, principles are abstract and non-empirical and can be grasped only through formal reasoning. However, she writes that progress in science knowledge has irrevocably affected the nature of vocational knowledge, and that a shift from particular to general scientific principles now characterises knowledge at intermediate and higher levels of technical and technological expertise.

There is certainly an implication here that current technology is underpinned by general principles of science. I believe this was why I was able to understand the scientific principles underpinning my technology related praxis, and why it was possible to make a meaningful theoretical link between the specific practice and more generalised scientific and basic engineering-related principles. This is what inspired my belief that this could be extended to the present case-study within which the product/process nexus of work was strongly underpinned by more general science and engineering-related principles.

By briefly drawing on the insights provided by Gamble's repositioning of craft knowledge the discussion will now briefly position the work related technology under study as a modality of vertical discourse characterised by a horizontal knowledge structure and tacitly transmitted. In this way it establishes an epistemological link between the tacit and the scientific, and argues that as a result of this, one can

meaningfully teach and learn from one mode to the other. I will in the following section go into the complex labour processes in the printing company where I did my preliminary research.

The lithographic process at this printing company starts at the Desktop Publishing (DTP) section where a print is designed in accordance with the client's specific tastes and needs. In many instances, images are scanned through light exposure and the feedback is then relayed to and read by a second computer, which is interfaced with an image setting machine to which it passes on this information. The image is reproduced on films through a process involving exposure to laser light in combination with sophisticated lens technology, which captures the image onto the films in terms of the different tones of colours and respective densities. In the entire process through the interface computer, light and lens technology sorts and reproduces the different tones and densities of colours onto the films in terms of three secondary colours better known in printing colour technology as cyan, magenta and yellow. These colours are reproduced in dot alignment structure on separate films. These films are then positioned by lithographers onto a grid and developed on an aluminium plate, which is coated by a light sensitive material and exposed to an ultraviolet light. This takes place within a plate-making machine where the ultraviolet light has to be regulated in terms of intensity so as not to affect the densities of the colours or create distortion of the image on the plate. The ultraviolet light apparently has light properties that induce the relevant wave frequency that enables reaction to photosensitive material. The plates are then removed and washed with another chemical enabling final development of the image onto the aluminum plate. The plates are finally mounted with clamps onto a roller. The printed image from these plates is then inverted and impressed onto this roller which has a rubber 'blanket' covering. This inverted image is then re-impressed onto the roller that has the printing paper embedded in it. The colours, cyan, magenta and yellow are each developed onto different plates and are separately run through the machines by these lithographers. The machine minders need to correctly align and load these plates onto their machines. In accordance with every 'new job' they have to adjust the pressure between the impression and blanket cylinders of their machine, as well as between the ink and damper rollers. They have to add the required levels of ink

and vary the acid levels in the water in accordance with the requirements of the new print. The correct size paper has to be loaded and its weight set to the correct pressure and suction process of the machine to effect correct 'registration' of the paper.

This process can generally be identified with tacit knowledge because it is structured in segments, and acquisition is equally segmented and context-specific. Within the context of Vygotsky's zone of proximal development, the learning process is generally taught by a more experienced lithographer through demonstration or exemplar modelling as well as through basic instruction which, in the Bernsteinian sense, could be described as a form of 'weak grammar'.

However, the possibility of extrapolating a range of disciplinary scientific principles underpinning both lithography and machine minding, as the empirical chapter five of the thesis shows, suggests that the product/process nexus of work in this instance shares some commonality with the vertical knowledge domain. In other words, workers' praxis is underpinned by general science principles. Moreover, in this case these technologies are operationalised procedurally through the principles themselves. Thus, within the context of the specific technologies involved in the lithographer-cum-machine minders work, the underpinning principles emanate from within the wider body of the science knowledge domain itself. In this way, lithography within the designated trade of machine minding can be positioned as a modality of vertical discourse characterised by a horizontal knowledge structure and tacitly transmitted. It is in this sense that I would like to argue that both lithography and machine minding technologies, which constitute the tacit knowledge in this study, share an epistemological link to the vertical form of disciplinary science knowledge. This epistemological link is possible because context in this case is relevant to concept. One could as a result of this, meaningfully teach or learn from one mode to the other. Repositioned in this manner, the two polarised modes of learning can now meaningfully collaborate with each other. This allows one to teach disciplinary science or engineering knowledge in social context, and is more in keeping with the new developing theories of learning that stress the situated nature of cognition. It

also tends to support the theoretical understanding emanating from researchers' anecdotal experience.

The anecdotal experience also identifies with emerging research that takes issue with the abstract decontextualisation of learning where the method of didactic education assumes a separation between 'knowing and doing, treating knowledge as an integral self-sufficient substance, theoretically independent of the situations in which it is learned and used' (Brown, Collins & Duguid, 1998). Brown, Collins and Duguid take issue with traditional schooling and the methodologies employed, arguing that its decontextualised nature of teaching defeats 'its own goal of providing useable robust knowledge'. Stressing the 'situated nature' of cognition, they challenge the separation 'of what is learned' from 'how it is learned'. Thus, the activity in which knowledge is developed and deployed is 'not separable from, or ancillary to, learning and cognition'. Neither is it neutral, they argue. It is indeed an integral part of what is learned. Essentially, their argument is that knowledge production is not theoretically independent of the situation in which it is learned and used. Arguing against many methods of didactic education that assume a separation between the two, they stress that theory related to 'authentic activity' can be deeply informative in a way that 'textbook examples and declarative explanations are not'. They identify strongly with Lave and Wenger's (1993) notion of a 'community of practice' that maintains that learning is in significant ways a process of enculturation. Thus, participation in 'communities of practice' is a critical aspect of developing 'knowledgeability' or working out the meaning of an idea in the context of its being used (Guile & Young, 1999).

Lave and Wenger expand on Cole's (1985) argument that culture and cognition create each other within the 'zone of proximal development' as it relates to the institution of apprenticeship or work-based learning. They do this by emphasising it as the site of dynamic interrelationships between social, cultural, technological and linguistic practices. This breakthrough was made possible because Lave and Wenger extended the zone of proximal development to highlight the social and cultural basis of learning (Guile and Young's (1999). The approach thus enabled them to highlight how social, cultural, technological and linguistic practices afford individuals and groups over a period of time opportunities to learn. However, whilst

acknowledging the importance of this emphasis upon the social character of the zone of proximal development, they show how Engestrom takes the debate further with his idea of 'transformative learning'. He retains a role for a theory of instruction which entails an explicit role for concepts and ideas which may be external to a community, but which could be the basis of frameworks for reconceptualising the felt dilemmas and contradictions within the community of practice.

The specific anecdotal experience identifies in important ways with some of the emerging theories on learning, expressed above, in particular the view that knowledge production is not theoretically independent of the situation in which it is learned and used. It also links to Lave's notion of 'knowledgeability' coupled with Engestrom's idea of 'transformative' learning, which retains a role for a theory of instruction entailing an explicit role for concepts and ideas which may be external to the community, but which may deepen the process of cognition. The importance of these ideas about learning needs to be seen in the context of the evolution from pre- to post-industrial societies characterised by the nature of rapidly changing technology and the demand it makes on education and training systems worldwide (Guile & Young, 1998). The notion of 'transformative' learning identifies strongly with the specific anecdotal experience in terms of the engineer's role in providing the underpinning concepts operationalising the machine that both the technician and I were constantly working with, and of which we became fully aware only through intervention in the form of instructive knowledge – i.e., knowledge outside the domain of our praxis!

As a result of the close proximity of her work to this study, the thesis draws conceptually on Scandinavian writer Mjelde's (1993) notion of a 'workshop pedagogy' in the grasping of scientific principles. This involves moving from the practical to the abstract (from practice to theory) through the medium of technology itself. Daly and Mjelde (2002) draw on Russian 'activity theory', with its stress on the sociality of people's learning and its suggestion that their knowledge and understanding can be further advanced in terms of expanding on their zone of proximal development through structured teaching and learning. The question – and I think, challenge – that both Muller as well as Mjelde and Daly pose, is whether one

can bridge the gap between horizontal knowledge or working class 'speech register' and vertical discourse or the more 'formal educational genres' such as science, for example.

Drawing on both Russian activity theory as well as Dorothy Smith's work related to the social relations embodied in the process of 'knowing', Daly's and Mjelde's (2002) point of departure is the assumption that meaning arises from social interaction, and that speech meaning is associated with this sociality. A person thus makes meaning, or sense, for another person, someone located outside her/himself, and the other takes that meaning in, sifts it, and makes it hers or his (verbally or in textual form): accepting, modifying, rejecting it (in relation both to the interlocutor and to common cultural values and varying personal experiences), and responding. This approach, she says, sees the commonality of culture and perceived reality as something continually internalised, sifted and questioned by all of us in society, through our 'inner speech'. This speech form is a medium through which we relate to the material world beyond our corporeal being.

This socially constructed inner speech develops in the course of childhood and creates the enabling conditions that allow us to relate to one another, to negotiate and build a common knowledge through learning, conforming to, criticising and elaborating what has gone on before, in the light of happening at present. This also allows for making social distinctions and hierarchic evaluations. In this way, knowledge as opposed to skills, expands and deepens the process of inner speech, and does so, it is stressed, more effectively through the process of group work and group learning. For both Daly and Mjelde (2002), this form of learning is especially effective in relation to vocational occupations that frequently involve much on-the-job social interaction in the course of "getting the job done". According to them, working and learning with others involves social skills of co-operation, competition and negotiation with peers, newcomers, and employers. They moreover see learning by emulation, and from the desire to be an effective member of the work group, to be one of the oldest and most effective forms of learning. Vygotsky (1978) proposed an inductive model of learning development. He argued that the learning child in its social context moves dialectically between spontaneous, self-referential learning and the more scientific and logically organised, socially established learning promoted by

the teacher. It was this process that he referred to as the 'zone of proximal development', and argued that the assessment of the child's ongoing performance in this zone was a more precise index of learning development than was the IQ test based upon already achieved knowledge.

Over a decade, even the profoundest thinkers never questioned the assumption; they never entertained the notion that what children can do with the assistance of others might be in some sense even more indicative of their mental development than what we can do alone (Vygotsky, 1978: 85).

Vygotsky argued that the learning child's acquisition of generalised and comparative meaning from words is highly dependent upon being particularised in a specific context. If the learner has not experienced a specific aspect of life, her or his understanding of the words that generalise that experience remain incomplete until everyday life introduces the specific experience that gives depth of comprehension to the generalising word. The process referred to above occurs in the 'zone of proximal development' – the necessary interplay between inductive, experiential learning of the subject, which gives rise to word sense, and the deductive generalising instruction of the teacher and the curriculum which helps expand the understanding of generalised and abstract word meaning. Daly and Mjelde (2002) write that without rich experience in the acquisition of the multi-faceted senses of a word, one does not learn to appreciate the full force of meaning that a word possesses in a culture and language. They argue that this process has parallels in many learning situations, particularly in workshop learning, and takes into account both learning about the material and technical environment, as well as the social and cultural human relations that adhere to our physical surroundings. Social relations, for them, imply the existence of different speech registers and forms of verbal expression. Thus, the relation between the learning subject and the speech registers or genres is always a dialogue where socially established meanings interact with the learner's immediate meaning of the moment, and with a different, more formal and/or inclusive speech genre of the instructor, mentor and educational system.

Formal educational genres tend to be of a textual nature: speech registers related to culturally standardised texts, diagrams, maps and charts. Speech genres, they write, can be considered essential components of both social stratification and the 'political economy of knowledge' (Daly & Mjelde, 2002:197). According to them, as one learns dialectically, moving between local 'hands-on' experience and wider, secondary experience that has its own socially formulated speech genres, the reflection on one's experience is constantly challenged and revised by the omnipresent learning process and the prevailing power relations.

Such processes, they argue, help the learner to establish her/his meaning socially, such that this meaning gains the status of a real object, a real thing recognised as such socially by many communicating actors.

These insights have been applied in chapter five of the study when faced with the daunting task of addressing some of our candidates' lack of English proficiency when teaching about the scientific principles underpinning their machinery. In South Africa at least, standardised scientific knowledge is generally signified through the medium of English. I drew on the work of Henning (1998), who stressed that under such circumstances it was best to draw on students' mother tongue, which contains the symbols that allow them to tap into their embedded cognitive models and schemas, and thereafter translate this into everyday English and finally to the English of discourse in the learning area. In this manner, one can activate understanding by invoking the first language as an extra resource. In this way we also introduced key concepts in the mother tongue within the context of their use, while simultaneously drawing on the specific scientific terminology. There was a conscious dialectical movement between practice and theory. This was in keeping with social activity theory that stresses working out the meaning of an idea within the context of its use. It needs to be pointed out that the students did possess some English proficiency.

For Mjelde, technology as praxis can provide an avenue through which one moves from the particularities of practice to the generalisation of theory. It is a process that entails extrapolating the deeper scientific principles underpinning the machine that the worker is personally engaged with, and, if I read her correctly, through a process of 'semiotic mediation' bringing it to the level of the worker's consciousness. This

means 'mediation by means of semiosis by means of language' (Hasan, 1996:178). This theoretical perspective suggests that language as well as concepts assume meaning within authentic practice, and can consciously be developed through it.

It is in terms of the above that this intervention in the form of an action research approach tries to bring to the level of the worker's (candidate's) consciousness the realisation of how the laws of science underpin and operationalise his/her vocation.

In conclusion this chapter has provided the theoretical underpinning of the study. It problematised a central research concern related to the epistemological problem of linking tacit workplace knowledge to the more formal scientific or engineering related knowledge domains. It did this within the context of two oppositional theoretical perspectives. The one theoretical stance emanates from the neo-Bernsteinian discourse that has come to be known as the Mulerian debate after the academic Johan Muller who very strongly advocates this perspective in his book, *Reclaiming Knowledge* (2001). Indeed, as the early part of this chapter has shown, many academics such as Gamble (2002) and Breier (1998), as well as Young (2003), have adopted this neo-Bernsteinian theoretical perspective in their critique of the failings of the National Qualifications Framework (NQF) - the embodiment of South Africa's new integration of education and training policy framework. Drawing on the neo-Bernsteinian theoretical distinction between vertical and horizontal knowledge forms, which characterises knowledge as differently structured within these respective forms, these writers take issue with the 'principle of equivalence' between disciplinary learning and workplace learning. In other words, because of their different knowledge structures, their modes of learning also differ. This implied that there can be no effective bridging of learning between the two knowledge forms.

The chapter argued that this was particularly problematic. The reason being that 'continuous innovation' and the ability to adapt and respond quickly to the rapidly changing nature of technology under the new competitive global economic conditions depends on the effective integration of tacit working knowledge to the more formal scientific and engineering knowledge domains. This was also

problematic in terms of being unable to bridge high and low status knowledge forms, and because it affected issues related to equity.

The chapter showed how, through a process of theorising the nature of the borders in this particular study, this researcher effected a synthesis between the two oppositional theoretical perspectives by meaningfully integrating the tacit to the scientific. This was done by positioning the technologies that form an integral part of the workers' tacit-working knowledge as a modality of vertical discourse characterised by a horizontal structure and tacitly transmitted. As the chapter showed, repositioned in this manner the different modes of learning collaborated with each other. This also bridged the stark polarization between contextualised and de-contextualised knowledge. This synthesising process allowed the study to draw on situated cognitive theories of learning to transmit or teach, and thus to bring the principles underpinning workers' practice to the level of their consciousness. The following chapter describes the research paradigm including a rationale for selecting an action research methodology.

CHAPTER FOUR

Research Design

4.1 Introduction

Whilst the previous chapter detailed the theoretical underpinning of the study, the purpose of this chapter is to describe the way in which the action research was planned and implemented. This includes a discussion of the following points:

- (a) the research paradigm;
- (b) the manner in which the sample emerged;
- (c) the nature and manner in which the pedagogical process was implemented;
- (d) data collection methods;
- (e) analysis and interpretation;
- (f) a consideration of the issues validity.

4.2 The research paradigm

The last few decades have witnessed a distinctive turn of the social sciences towards more interpretive, postmodern, and criticalist practices and theorising. The dominant approach, prior to this period, was characterised by the positivist paradigm which, in contrast to stressing the importance of the interpretation of actors' meanings in its analysis of the research phenomena, describes, predicts, controls and then explains a phenomena. In an attempt to constitute phenomena as neutral and objective, it employs a predominantly quantitative research methodology, which sets meanings apart from an individual's subjective interpretations, consciousness and intentions (Kelchtermans and Schratz, 1994). Drawing on Polkinghorne (1989)

phenomenological insights, Lincoln & Guba (2000) argue that objectivity derives from the Enlightenment prescription for knowledge of the physical world, i.e., that the physical world has a 'real' existence outside of human experience of it, and is therefore postulated to be separate from those who could have knowledge of it. Moreover, it is assumed that this reality can be approached only by using methods that prevent human contamination of its apprehension or comprehension. Thus for positivists in the empiricist tradition, the foundations of scientific truth and knowledge about reality reside in "rigorous application of testing phenomena against a template as much devoid of human bias, misperception, and other 'idols' as instrumentally possible" (Lincoln & Guba, 2000:176). The role of the researcher is also detached in order to minimise disturbance of the social phenomena under investigation, and as Osman (2003) points out, a method often used for data collection with human subjects is a questionnaire driven survey. It also draws on statistical language to draw conclusions.

Lincoln & Guba (2000) argue that if knowledge of the social (as opposed to the physical) world resides in meaning-making mechanisms of the social, mental, and linguistic worlds that individuals inhabit, then knowledge cannot be constituted as being separate from the knower, but is indeed rooted in his or her mental or linguistic designations of that world. Kemmis & McTaggart (2000) state that when quantitative researchers use questionnaires to convert participants' views into numerical data, they tacitly concede that they cannot understand practice without taking participants' views into account. It is further argued that researchers falling within the more critical and interpretive traditions will differ from one-sidedly quantitative researchers in the way they collect and use such data, because these latter researchers will regard the data as crude approximations to the way participants understand themselves, and not as quantitative researchers may assert, as more rigorous and hence, more valid or reliable simply because they are scaled (Kemmis & McTaggart, 2000:600).

Lincoln & Guba (2000) argue that at issue here is really not whether we shall have criteria, or whose criteria we as a scientific community might adopt, but what the nature of social enquiry or social research ought to be. These are indeed

epistemological questions about the nature of 'truth' in the human and social sciences. In this specific case the 'truth' is about research practice (Kemmis & McTaggart, 2000:575). This is strongly related to the issue of morality, or, as Lincoln & Guba (2000) more correctly put it, that branch of philosophy known as *axiology*, which deals with ethics, aesthetics and issues of morality. These should be the basic foundational philosophical-dimensions of paradigm proposal. They feel that values importantly feed into the enquiry process: choice of the problem, choice of paradigm to guide the problem, choice of theoretical framework, choice of major data-gathering and data-analytic methods, choice of context, treatment of values already resident within the context, and choice of format for presenting findings (Lincoln & Guba, 2000:169). Participatory action research, which has been the choice of paradigm proposal in this study, is in keeping with the sentiments and insights expressed above.

During the course of the initial chapter of this thesis the researcher proposed that critical education theory would provide the philosophical and methodological framework for this study. There it had been argued that critical adult education theory provides us with the tools for critical analysis, as it relates both to unravelling and attempting to overcome the unequal power relations that exist within our society. As Osman (2003) argues, it goes beyond interpretive aims to understand educational practices and instead proposes to change educational practices in a way that transforms the context of these practices. Any attempt towards conscious change implies *action*, and action has thus become a major controversy that informs the ongoing debates among practitioners of the various paradigms. According to Lincoln & Guba (2000), the mandate for social action, especially action intentionally designed and created by and for research participants with the aid and cooperation of researches, can be most sharply delineated between positivist and new paradigm enquirers, such as participatory action researchers. Many positivists or hard-line foundationalists, as Lincoln & Guba (2000:175) describe them, believe that the taint of action will interfere with, or indeed even negate, the objectivity that is presumed characteristic of rigorous scientific method of enquiry. Participatory enquirers understand action that is controlled by the local context members to be the aim of enquiry within the specific community of practice. For none of these paradigmatic

adherents, argue Lincoln & Guba (2000), is control an issue of advocacy, which they describe as a somewhat deceptive term usually used as a 'code within a metanarrative to attack an inquirer's rigor, objectivity, or fairness'. Drawing on both Heron & Reason (1997) participative inquiry paradigm they write that for researchers within the action research tradition action is a means of fostering emancipation, democracy, and community empowerment, and of redressing power imbalances such that those that were previously marginalised now achieve a voice or 'human flourishing' (In Lincoln & Guba, 2000:175). From the above it can be seen that action research shares spiritual and moral sentiments similar to critical adult education. Indeed, its abiding concern is to empower marginalised communities within the context of their practice.

The developing literature related to participatory action research seems also to complement the theoretical underpinnings of the thesis which is related to the situated (in contrast to the abstract) nature of cognition within the context of communities of practice, especially its stress that:

... action research concerns actual, not abstract, practices. It involves learning about the real material, concrete, particular practices of particular people in particular places.... action research differs from other forms of research in that it is more obstinate about changing particular practitioners' particular practices, rather than focusing on practices in the general or in the abstract (Kemmis & McTaggart, 2000:596).

The literature also argues for viewing participatory action research as a social process because it engages people in examining the social practices that link them with others in social interaction (Kemmis & McTaggart, 2000:597). They argue that the process entails people exploring their practices of communication, production, and social organisation, and they try to explore how to improve their interactions by changing the acts that constitute them. In so doing they try to reduce the extent to which participants experience these interactions as irrational, unproductive or inefficient, unjust or unsatisfying and alienating. Participatory action researchers thus

work collectively in reconstructing their social interactions by reconstructing the acts that constitute them (Kemmis & McTaggart, 2000:597). Whilst an important methodological aim of this study is to test theory related to the situated nature of cognition, the recursive nature of participatory action research as it relates to the relationship between theory and practice (as pointed out by these writers) tends to complement the theoretical underpinnings of the study which stresses the dialectical relationship between theory and practice.

Participatory action research thus involves “reaching out” from the specifics of particular situations, as understood by the people within them, to explore the potential of different perspectives, theories, and discourses that might help to illuminate particular practices and practical settings as a basis for developing critical insights and ideas about how things might be transformed. Equally, it involves “reaching in” from the standpoints provided by different perspectives, theories, and discourses to explore the extent to which these provide practitioners themselves with a critical grasp of the problems and issues they actually confront in specific local situations. Participatory action research thus aims to transform both practitioners’ theories and their practices and the theories and practices of others whose perspectives and practices may help to shape the conditions of life and work in particular local settings (Kemmis & McTaggart, 2000:598).

From the discussion above it is clear that the decision to embark upon action research depends on the unjust or oppressive conditions the researcher perceives on the ground. Indeed, as outlined in the initial chapter of this thesis, the researcher in this case embarked upon action research as a result of the unjust conditions perceived during the course of preliminary observations. It had been observed that the narrow enskilling process of the theory/practice relationship under the specific learnership programme was restrictive in both its redressive aims of occupational mobility and polyvalent skills, strongly articulated by the trade union movement. It argued the need for technological literacy or the notion of a more expansive enskilling process that related practice to theory by teaching the deeper conceptual underpinnings of practical skills. This, it was argued, was important for both worker

empowerment and broader developmental issues related to economic growth. Thus, by consciously creating such alternatives and possibilities, through this transformative learning programme, this research hopes to contribute towards balancing the discursive tensions between equity and growth. It was argued that by enhancing workers' capacity in terms of deepening their understanding and enabling them to access the exclusionary power discourse of science/technological language, it could provide for the capacity to bridge the social stratification divide maintained within the economy through high and low status knowledge forms. In this sense, it could make a meaningful contribution towards the political economy of knowledge debate so close to the heart of many critical educational theorists.

4.3 Site and sample generation criteria

The conceptual underpinnings of this study have strongly informed the sample selection process. To reiterate, the argument made by the Green Paper is that a newly transformed education and training relationship needs to create a well-educated and adaptable labour force. The narrow forms of industrial training, reminiscent of the past, are now obsolete. The demands of a more complex economy characterised by the increasing use of information, complex technologies and a general rise in the skill requirements of occupations, demand rising levels of 'applied competence' among its workers (SA Department of Labour, 1997:6).

This notion of 'applied competence' is defined as an overarching cognitive construct, which comprises 'practical' (performative), 'foundational' (general understanding) and 'reflexive' (the ability to connect and adapt to changing, but as yet unforeseen circumstances) competencies. It is argued that the need to equip workers with this multifunctional skill is critical to South Africa's future success in the global economy (Kraak, 1997: 18). This is to be realised through a newly constituted theory/practice relationship, and implemented through a learnership. The argument is that the new skill requirements in 'reflexive modernity' will be better served by an approach that is underpinned by the notion of 'technological literacy', as opposed to narrow vocational training based solely on work-specific theory.

The implication for my study was that I needed to identify a site with a well-established learnership. Secondly, workers needed to be involved with some form of technology, in particular within the manufacturing sector in keeping with the argument related to the competitive need of late industrial societies. I therefore approached a large Manufacturing, Engineering and Related Services SETA (MERSETA). After several meetings with experts in the materials development sector, such as Chris Vorwerk and in particular Zacharia Mazibuko, it became clear that the learnerships were still in their developmental stage at the time. Because of my personal background of machine minding in the furniture industry, I thereafter approached the furniture chamber of the Forest Industries Sector Education and Training Authority (FIETA). Once again I discovered that their learnership programme was underdeveloped. Having at the time learned from a colleague about a printing firm in close proximity, where a few learnerships were in stages of implementation, I decided to investigate the possibility of conducting research. I discovered that it was an officially accredited company in terms of training requirements, and had five well-established learnerships. Moreover, the candidates were doing their learnerships in lithography within the designated trade of machine minding. They were engaged within the learnership at artisan level two, which, in turn, fell within level three of the NQF. The minimum requirements for entry were language, maths and science at grade ten. The syllabus entailed doing a technical theoretical course related to lithography and printing machinery, as well as 'fundamental core specialised' courses, which in this instance entailed 'business studies' 'communication', 'science and technology'. This was in keeping with the notion of 'typicality' as it related to the interests of this case. The product/process nexus of their work constituted technology and science related work. In Stake's (2000) words: the phenomenon of interest observable in the case represents the phenomenon writ large. He argues:

The researcher examines various interests in the phenomenon, selecting a case of some typicality, but leaning towards those cases that seem to offer 'opportunity to learn'. My choice would be to examine that case from which we feel we can learn the most. That may mean taking the one most accessible,

the one we can spend the most time with. Potential for learning is a different and sometimes superior criterion to representativeness (Stake, 2000:446).

Within the general context of the difficulties encountered with learnership development at the time, I believed that this site would provide an interesting case for testing and observing whether the envisaged integration of education and training allowed the candidates to understand the deeper conceptual underpinnings of their product/process nexus of work. This meant providing the 'potential for learning' the requisite skills to cope with the rapidly changing nature of technology characteristic of the post-Fordist economy. Yin (1986:22-23) identifies the case study as any empirical enquiry that examines a recent or contemporary phenomenon within its real life context using multiple sources of evidence. It is thus appropriate when the phenomenon cannot be separated from the context in which it operates. This agrees with the theoretical underpinnings of the study which say that context is integral to learning. Merriam (1998: 26) writes that case studies 'especially qualitative case studies are prevalent throughout education' and are commonly used for investigating the implementation of innovative procedures or programmes, or the implementation of a particular policy.

4.4 Research method and procedure

The preliminary phase of research in early 2003 was more exploratory in nature. It comprised note taking on observations as well as short informal conversations with members of management, candidates under study and the official facilitator of the learnership. The purpose of these conversations was mainly to gather background material about implementation of the learnership programme in the printing industry. It did not involve the people under study in any penetrating dialogue, describing them rather from the perspective of an uninvolved observer. To some extent, it could be described in Carspecken's (1996) terms as being 'monological' in nature because the researcher 'speaks' alone when writing the primary record. This suited the sense-making nature of the research at the time.

During the course of preliminary research, modules related to the nature of outcomes-based education (OBE) and instruction provided to facilitators on assessment critique were also perused. It became clear that the outcome-based pedagogy specified predominantly work orientated learning outcomes, without reference to any of its underpinning science and technology concepts. This was explicitly stated as an important cross-critical outcome to be achieved by lithographers. There were also no 'fundamental core courses' offered to candidates. An example of this extreme trade and narrow vocationalist nature of outcomes specified for the technical theoretical module is detailed in the table below. These provided important pedagogical insights into the nature of outcomes based methodology.

THE MASTER CRAFTSMAN PROGRAMME (MCP) MODULE/MODULE ELEMENTS, CRITERIA AND EVALUATION STRATEGY						
Field: Method of Printing: Lithographic Process					Page 12	
Module Code	Module Title		Module Element		Module Element	Module Element
			Element Code	Objective	Criteria	How to Assess
MP4	Plate Making	The learning outcome for this module is to make a lithographic printing plate for a process colour job.	MP4a	Prioritising Jobs.	From given job cards prioritise the making of the plates against the latest production schedule.	Present job cards in random order and assess the process of prioritising against latest production schedule.
			MP4b	Interpret a Job Card.	Identify the plate type, plate size, deadlines and other important information from a given job card.	Assess the outcome of a made plate against the job card specifications.
			MP4c	To punch a plate for registration which conforms to the machine specification on which the plate is to be mounted.	- Select the correct punching system, e.g. Protocol or Bacher systems or specialised machine specific system. - Punch the plate and correctly form the lead and trail edge bend.	- Select from a number of punching systems the correct one for the machine in question. - Inspection of product against an industry standard.
			MP4d	To position the positive or negative onto the plate correctly with due regard for the facing being according to the correct emulsion surface side. (Emulsion to Emulsion).	- Select the correct pin register system for positioning the positive or negative onto the plate. - The attention to detail of ensuring dust free and clean vacuum frame. - Strip in a step wedge for determining the correct exposure time.	- The exposure frame should not be correctly cleaned. Observation of learner correcting the above to within acceptable industry standards. - From a variety of film punches the correct pin register system for the job specification is selected. - The step wedge should be positioned outside the working area. End product examination against industry standard.

In addition to this, readings of historical trade union literature on the intended aim of the enskilling process were also perused, and in general provided a background from which to contrast the enskilling process experienced on the ground

The broader literature related to macro-institutionalism and South Africa's segmented labour markets, which very strongly influenced the trade-union and early

ANC ET proposals, is detailed in chapter two also provided important information on the intended aim of the enskilling process in general. This provided a back-drop from which to contrast the enskilling process experienced on the ground.

The decision to embark upon participatory action research (outlined in the initial chapter) changed the nature of research and subsequent data gathering strategies. However, as was pointed out in the paragraphs above, data gathered from the earlier exploratory research stage provided vital background information. Even though the nature of research changed dramatically from being predominantly exploratory in nature to that of action research, the information gathered from the early phase informed many aspects of the action research methodology. An example is the important aspect of workers' tacit knowledge gleaned from the previous phase of the research, and around which some important aspects of the learning programme was planned. For example, observations of their product/process nexus of work gave me a much clearer insight into the nature of the science and engineering related concepts underpinning their practice. It also gave me an insight into the nature of the modelling process through which tacit knowledge was learnt, and how remarkably adept the worker candidates were in fixing the mechanical problems related to their machines. These insights proved invaluable in providing a platform from which to build the basic engineering and physics process-related principles in a manner related to their practices. The process of participatory action research involves in general a spiral for self-reflective cycles of:

- planning
- acting and observing the process and
- consequences of the change
- reflecting on these processes and consequences
- and then re-planning
- acting and observing
- reflecting and so on...

(Kemmis & McTaggart, 2000:595)

The process, according to Kemmis and McTaggart may not be as neat as the spiral of self-contained cycles of planning, acting and observing and reflecting suggests. My own experience in implementing the educational intervention through the action research methodology tends to support the above writers' views that the stages described above may overlap, and initial plans quickly become obsolete in the light of learning from experience. The process in reality is likely to be more:

...fluid, open and responsive. The criterion of success is not whether participants have followed the steps faithfully, but whether they have a strong and authentic sense of development and evolution in their practices, and the situations in which they practice (Kemmis & McTaggart, 2000:595).

From the nature of the methodology depicted above, we see the importance of constantly monitoring the effects of action research upon candidates' understanding of the phenomenon under study – in this case, the deeper conceptual underpinnings of their practice through the dialectical movement from practice to theory and back again. This required intensive observation, field notes, interviews and video recordings.

Observation can take different forms. Gamble (2004) citing Gold's (1958), typology of the participant observer identifies four different roles that researchers may play in this regard:

complete participant, where research subjects see the researcher only as a participant and not as a researcher;

participant-as-observer, where the researcher is a full participant but makes the research role explicit;

observer-as-participant, where the researcher interacts with research subjects in the social process, but does not pretend to participate in any way;

complete observer, where observation is so unobtrusive that research subjects are often not aware of being observed (Gamble 2004:48).

In accordance with this classification, the observational role adopted in this study can be described as that of participant-as-observer. The need to intensively study the operation of the machine and of lithography itself, so as to extrapolate the scientific principles underpinning them, brought with it the need for both the science facilitator and me to participate with the candidates in the product-process nexus of their work. This created an increased level of equity and rapport between the candidates and me as they taught me the tacit aspect of their knowledge. To supplement field notes, I have also videod some of these lessons.

Gamble (2000) is quite right in saying that in studies that heavily rely on observational evidence, systematic recording of observation through detailed field notes is essential. However, like both her and Milroy (1991:9), it was at times difficult to record events at the time they occurred. This is especially true in workshop situations, where noise levels from machines as well as unexpected disruptions resulting from production needs, severely hampers detailed note taking. I would then often fill in the background details later, when both the facilitator and I would recreate the day in detail and record observations and details. Often, when we noticed an interesting or enthusiastic response from students in class, we would eagerly follow it up by finding the time during breaks from their demanding production chores, to engage them in short informal interviews related to these responses.

This is also in keeping with Yin's (1986) view that interviews enable the researcher to access information that relates to the authentic feelings of the participants, which are generally not accessible through observation or the use of questionnaires. Whilst individual follow-up interviews were informal and of short duration, semi-structured interviews of a collective nature were taken under more relaxed circumstances, usually after work at the Oasis restaurant in town. Taylor and Bogdan (1984: 93) point out that in qualitative interviewing 'the interview is relaxed and conversational, since this is how people normally interact... it is only along the lines of natural interaction that the interviewer can tap into what is important to people'. It was within

this context that I tried to interpret participants' perceptions of their own learning. Semi-structured interviews were undertaken because they enable the interviewer to draw on a schedule of questions, pre-arranged in themes and consisting of broad areas to be covered , as pointed out by Jones (1991: 204). This allowed me the opportunity to probe and pursue other relevant areas that could emerge from individual interviews. Following Osman's (2003: 24) application of this strategy, the interviews were based on structured, open-ended questions revolving around the issues under discussion. Similar to her experience, these encouraged participants to elaborate on their experiences, and I intervened only to request further clarity or elaboration. In this way participants were 'allowed to speak freely as individual recipients and implementers of a process' (Osman, 2004: 25). The next chapter details students' presentations of the conceptual principles underpinning the operationalisation of their machines. The following extract, taped during the course of a collective interview, provides an example of the nature of some of the open-ended and semi-structured questions.

Even though I strived to keep within the objectives outlined above, it needs to be stressed that every different context seems to develop a dynamic of its own. However, I believe that the open-ended interview provided an insight into some of the key concerns, which could not be covered during the course of their official presentations. A major concern in this respect was to try to gain some insight into their perceptions of the new learning process in comparison to their previous learning experiences. Their changed understandings of their product/process nexus of work are captured through their official presentation in the next chapter.

4.5 Nature of Open- Minded Interview and student responses

The interview was conducted after a lovely lunch shared together with the candidates. They were told that they could express themselves in the language most comfortable to them. A key concern was to try to gain some insight into their perceptions of the new learning process and changed understandings, if any, of their product/process nexus of their work. This was to be especially in comparison to their

previous learning experience and understanding of their praxis. As has earlier been pointed out, Prins was the only candidate who had completed his theoretical component at the college, while the remaining students were conducting theirs at Dynasty Printers who were accredited in terms of ability to provide theory. It was because of this that I decided to initiate the discussion with a question put to Prins about the difference in the nature of the theory he experienced at the college, and the one conducted by this new learning programme, which as I have mentioned did not in any way interfere with the official learnership.

Prins answered that the theory at college was more trade related and not at all at the level of any underpinning science and engineering related concepts. He said that 'when Siddique came, we started opening the machine' and it was then that he learnt about the motor in his machine, and its relation to 'torque and diameters'. Probing his memory, I then asked him about a time in class when the issue of gas laws was being discussed and when he ran to me immediately after that workshop lesson exclaiming that, although he had done it in school, it was only now 'in my mind'. He said that it was as if it had remained dormant in his mind and that, after understanding the equality of $P_1V_1 = P_2V_2$ in context Boyle's Law, it suddenly came back to him. Both Alfred and Anand at this stage of the discussion strongly shared this sentiment, commenting that the theory in school was not related in any way to practice, with Prins at this moment of the conversation interjecting with the word 'meaningless'. Turning to Alfred, I asked his opinion on the difference in nature and learning of theory between the two different approaches he had been exposed to. His reply was that learning under the previous facilitator was basically about 'house-keeping'. I asked him what he meant by this, to which he replied that it was more about 'cleaning, inking' and basic setting of the 'machine'. There was an interjection at this point by Anand who, in relation to the learning process, also commented 'list three types of spanners', with either Prins or Alfred (could not tell clearly from the tape) joining the chorus by adding 'list two types of allen keys'. The conversation was immediately followed by a hearty banter from the group as a whole.

The conversation shifted to Alfred who said that the most interesting part of the course for him revolved around colours. Anand agreed, and said that for him to understand 'the science of colours' after having worked so many years prior to this

with was indeed a revelation. I decided to deepen this aspect of the discussion by questioning and eliciting Alfred's and Anand's response in respect of the issue of absorption, reflection and wavelengths in their interplay with the production of colour which entail their praxis. Moreover, we discussed how a spectacular array of colours could be created through combinations of the four basic colours of cyan, magenta, yellow and black applied in their printing work, to which the two of them enthusiastically contributed. Anand, at this juncture of the discussion, brought to our notice a related issue in the form of Siddique's (the science facilitator) challenging question that emanated during the course of that specific workshop lesson. He asked students if they thought it possible to print a 'full-colour job' (which in their work entailed applying the four colours referred to above) using only cyan, magenta and yellow. Anand said he had never, in his fifteen years of printing, come across such a machine. However through an acquired insight into the 'science of colour' he believed in its possibility. This would be achieved if a computer programme could be articulated to a three cylinder machine instead of the usual two or four so as to enable the proportionally required mixing of cyan, magenta and yellow to create the required black. He said he believed this would probably not be a very easy thing to do because of the difficulty of attaining 'true-black'. However, if this could be achieved, then he believed it could result in a 'twenty-percent reduction in cost', because this would mean much less time spent on your 'make-ready time', as well as the need to use 'one-plate' less. Moreover such a machine could do without 'one entire cylinder' and would thus cost less and could probably run on a single electric phase rather than the very huge four cylinders that can be run only on a three-phase current and which consume much more electricity. Though the aim of this thesis was not geared to concentrate on skills related to economic rationality, the logic displayed in this last particular conversation depicts the development of the kind of reflexive-enskillings actually needed in late modern societies that Guile & Young (1998), Fuller and Unwin (1998), Engestrom (1996) and many others writing within a similar research context refer to.

Finally, I decided to probe further Peter's comment about learning under Siddique being better than 'solving for x' in school. He said that he understood solving for 'x' much better through its working out in both the $P_1V_1 = P_2V_2$ and $n_1d_1 = n_2d_2$ principles

he was taught through his machinery. Some of the candidates' responses noted above have also been very briefly incorporated into the end of their official presentations detailed in the following chapter.

4.6 Analysis and interpretation

When asking how analysis and interpretation occurs, one is indeed actually asking how data can be systematised in a meaningful manner by means of analysis and interpretation. According to Mouton & Marais (1996), one could, depending on the nature of the enquiry, adopt either a deductive or an inductive strategy to answer such a question. Generally, in the deductive strategy, the researcher approaches the research project with a clear conceptual framework in mind. Adopting a framework of this nature governs the manner of conceptualisation, operationalisation and data collection, and will ultimately constitute the frame of reference for analysis and interpretation. This type of strategy is generally employed in hypothesis testing and in explanatory studies. By contrast, in an inductive strategy, the researcher embarks upon the project without an explicit conceptual framework, and merely uses general and vague hypotheses or guesses to guide the research. The nature of research is less structured. The researcher attempts to discover relationships or patterns by means of close scrutiny of the data. Analysis and interpretation are conducted by means of inductive abstraction and generalisation. This strategy is more appropriate to hypothesis-generating studies or to studies of an exploratory and descriptive nature (Mouton and Marais, 1996: 103).

Mouton and Marais stress that one should not conclude that these two strategies are mutually exclusive. It is quite possible that a researcher starts out by using an inductive approach and generates new hypotheses in the process. A deductive approach could then be applied in a testing of the hypothesis. This research began as exploratory in nature and subsequently adopted a deductive strategy. This necessitated the formulation of a clear conceptual framework. As a result, the 'theory in operation' played an important part in data collection as it sensitised the researchers to the relevant data categories. In this case the analysis of the data was

based on neo-Vygotskian theories of learning. It becomes evident that the interpretation of the data is also suggested by the theory, because the theory identifies the relevant variables as well. This however, as Gamble writes, brings with it the danger of encouraging the researcher to fit (or force) empirical evidence into pre-elaborated categories which are already available, and thus to be lulled into a misconception that no further theoretical labour is necessary other than to verify an already established theory. In this case the researcher avoids this dilemma by working and analysing data within the context of two opposing theoretical stances detailed in the previous chapter and related to the research phenomenon at issue.

4.7 Issues related to validity and ethics

As was pointed out in an earlier section of this paper, positivism generally adopts the stance that a reality exists independently of our representations of it. As a result, it insists on utilising a largely quantitative research methodology that sets meanings apart from an individual's subjective interpretations, consciousness and intentions. In such studies the role of the researcher is generally detached, in order to minimise disturbance of the phenomena under investigation. Such research also draws on neutral, objective or statistical language to generalise to wider populations.

In contrast, critical-action researchers, rather than locating foundational truth and knowledge in some external reality 'out there', tend to locate the foundations of truth in specific historical, economic, racial, and social infrastructures – e.g., of oppression, injustice and marginalisation. Moreover, social critique is tied in turn to raised consciousness of the possibility of positive and liberating social change (Lincoln and Guba, 2000:177). At issue here are fundamental epistemological questions related to the nature of social research. Epistemology (theory of knowledge) relates to the nature of truth and in this case the truth about social enquiry itself. The issue of validity or valid criteria is thus constituted differently by action researchers. Whilst for positivists any action on the part of the researcher or the candidates themselves would taint or violate their concerns of what would constitute objective research, for participatory action researchers conscious action

taken to give participants a voice in research, or to inculcate critical consciousness or emancipation from marginalisation would constitute valid criteria which, if neglected, would violate the morality of social research. The nature and quality of transformative work can be evaluated by checking whether participant's practices are eventually more efficacious,

... their understandings clearer, and the settings in which they practice are more rational, just and productive of the kinds of consequences they are intended to achieve. For participants, the point of collecting compelling evidence is to achieve these goals (Kemmis & McTaggart, 2000:592).

In relation to the ethical considerations raised, I would like to state that in 2003 there was no ethics committee. However, I did fulfil the requirements for an ethical approach by explaining the nature and aims of this study clearly to the participants. They volunteered for the study and were free to leave at any time. With regard to anonymity and confidentiality, the nature of this study did not pose a threat of any kind. In fact the participants were enthusiastic about having their progress recorded and published. I have provided retrospective proof to this effect in the form of a letter from the head of the company as well as one of the participants.

To conclude chapter four described the research paradigm, including a rationale for selecting an action research methodology. The chapter showed that this choice was strongly influenced by the fact that action research shared similar spiritual and moral sentiments as critical adult education theory, with its concern for empowering marginalised communities, within the context of their practice. In this sense, this meant sharing the trade union stance of providing high quality education and training to black youth and adults, who were previously denied this under *apartheid* education. These sentiments were shared by Cooper (1998:108), who held the view that the emphasis on raising workers' skills levels, and on formally accrediting workplace training, represented a response by unions to authenticate worker aspirations, and that this resonated deeply with workers' desire for recognition,

respect, greater equity and opportunities to progress. The chapter drawing on developing literature related to participant action research argued that it complemented the theoretical underpinnings of this thesis which was related to the situated, rather than abstract, nature of cognition within the context of communities of practice. This chapter drew on literature to suggest that participatory action research tends also to complement the theoretical underpinnings of this study, which stressed the dialectical relationship between theory and practice.

The chapter also showed how the sample selection process was strongly informed by the theoretical underpinnings of the study. In this sense, as identified within the chapter, the tacit work practices of the candidates in this study were strongly underpinned by science and technology concepts. The sample consisted of a group of workers engaged in a learnership in lithography, within the designated trade of machine minding. The research site was located within a specific printing company affiliated to the Media, Advertising, Publishing, Printing and Packaging (MAPP), Sector Education and Training Association (SETA). The following chapter will detail the nature of the action learning methodological process. It will indeed show how this learning process was strongly informed by both neo-Vygotskian and newly developing socio-cognitive theories of learning.

CHAPTER FIVE

An Empirical Chapter

5.1 Dynasty Printers – A brief introduction

The study is conducted at Dynasty Printers in Mokopane within the Limpopo Province of South Africa. It is a young and emerging printing company employing a permanent staff of twenty. During peak production periods this number rises to thirty-five. It has a design and layout section where graphic artwork is computer conducted and related to the image setter. This section has a predominantly female staff. The plate making, stripping and lithography sections are predominantly male staffed. Whilst most of the staff in the above categories is employed on a permanent basis, the binding and packaging sector has a mixed staff ratio which varies in relation to production needs. In keeping with the government's affirmative action policy, the company is concerned about achieving a more equitable racial mix across its structure. It is also keen to support training and development programmes for its employees. Dynasty Printers has been accredited by the South African College of Printing to offer them a theoretical component.

5.2 Profile of the participants

Classification of the candidates within racial categories below is only for analytical purposes and needs to be seen within the context of the legacy of South Africa's *apartheid* education. This is the reason for its application below. All the participants in the study are involved in learning lithography within the designated trade of machine minding. This is conducted through the government's new education and training programme, either by means of the 'recognition of prior learning' (RPL) or a learnership, both of which constitute integrating theory within practice. The science facilitator, Siddique, is a middle class Asian male and a computer technician by trade, with skills in the science knowledge domain.

Prins is a 23-year-old black male and the only participant who has done maths and science at matric level (Grade 12). He comes from a middle class background and attended a private school in the city of Tshwane. He had completed a six-month theory course at the South African Printing College and was at the time serving his second year of apprenticeship at Dynasty Printers. His tacit knowledge was predominantly learnt through practical experience and through trial and error working under more experienced lithographers at Dynasty Printers.

Anand is a thirty nine year old Indian male. He completed his matric in 1986 in Stanger in KwaZulu province. He comes from a working class background. His father was a mechanic by trade and committed suicide while Anand was still in grade eleven. He completed his matric with maths and biology. It must be noted that he did not take science at this level. Being the eldest in the family, Anand was forced to find employment immediately after completing his grade twelve. He was fortunate to find work at a very small printing company in Stanger where he 'could earn and learn' at the same time. Eventually migrating to Transvaal in search of better paying prospects he managed to find employment at Dynasty Printers. He worked overtime for more than a decade within the printing industry and it was his third year at Dynasty. His tacit and experiential knowledge was gradually learnt through 'hands-on work', and, as he put it, 'stealing with the eyes'. Anand prides himself in terms of the quality of his work, and he indeed comes across as very professional when engaged in it. Having had the privilege on several occasions of being able to observe Anand and his co-workers at work, I am reminded of a description in Daly and Mjelde's (2002), study of workers in their process of production. Inspired by a Goffmanesque critique, they write:

Having a feel for the machine and the teamwork, and operating with ease and without stress, is the basis of self-respect and self-image in the workplace ... where one works under the product discipline, but without straining, and

retains a modicum of remove and self-identity which signals one is not owned by the employer (Daly & Mjelde, 2002: 205 - 206).

Pieter is a 23 year old black male. He attended high school in a village near the town of Mokopane in the Limpopo Province. Coming from a rural background, he completed grade ten and due to financial constraints experienced at home, left school during the course of attempting grade eleven to look for employment. He did General Science and Mathematics at the standard grade at this level. He was working during the course of the research at Dynasty Printers for the third year. The theoretical component of his course was also being completed there. He started working at Dynasty initially cleaning the machines, then later, as a bookbinder, collating and numbering books. He gradually moved into printing tasks through the process of initially assisting the experienced lithographer and machine minder operators loading paper and filling ink into their printing machines. In this way he slowly learnt his tacit skills through observation, emulation and hands-on, experiencing the different aspects of printing from the operators. He thus started first to print 'one-colour jobs' to being able eventually to print in 'full-colour' over a period of three years. This also gave him a sense of pride and identity because of its better occupational status and remuneration. Pieter's experience reminds one very much of Lave and Wenger's (1991) notion of 'peripheral' participation in 'communities of practice'.

Alfred is a 30 year old black male. Also coming from a rural, working class background, he attended high school in the village Sekgakgapeng, where he completed his grade eleven with maths and science at the standard grade level. He also alluded to the difficulties which he and his friends had had in understanding subjects such as maths and science. This, coupled with the lack of qualified maths and science teachers as well as any adequate laboratory, was a cause for many of his friends and himself either 'dropping' these subjects or choosing softer options such as biblical studies and home economics. Not unlike Pieter, and Anand, Alfred was also compelled to find employment immediately after schooling due in large measure to the family's financial standing. He feels he was 'fortunate to find

employment at Dynasty because his father was already working there as a book-binder. Finding work initially as an assistant to his father, he was also gradually absorbed into the company's printing division. He was initially assigned as an assistant to Danie, Dynasty's chief machine minder and lithography operator at the time. According to Alfred he learnt 'a lot from observing' and sharing work-tasks with 'Daan'. It was his third year at Dynasty Printers.

Fred is a white male in his late 20s. He withdrew early in the programme because of a serious road accident and had to be hospitalised for a long period of time. It was hoped that he would rejoin the programme after recovering but unfortunately he was unable to continue working and subsequently left Dynasty Printers. However, there is videoed material of his brief participation in the course.

5.3 The learning process

To draw on Vygotsky's notion of the 'zone of proximal development', the learning process involved ongoing relations between the novice and more experienced workers, between the worker and the machines, between the worker and related elements of the lithographic process as described in the previous sub-section, and between the work team and management. As was noted in Anand's case above, in relation to the machines the worker 'comes to know the machines, their rhythms and their specific tendencies towards inertia' (Daly & Mjelde, 2002). The challenge, as the following discussion will attempt to demonstrate, was thus to try to expand on the candidates' zones of proximal development through the application of theoretical insights drawn from developing situated cognitive theories of learning (detailed earlier in chapter three). The candidates described within the context above seem also to resemble Lave and Wenger's (1991) notion of learning as peripheral participation in socially situated communities of practice, related to the process of identity formation, which in this case was noted through their expressed interest in acquiring an occupation. The theoretical chapter (ch.3) has detailed Lave's important work in alerting us to sociocultural perspectives on learning, which view learning as a

social collective phenomenon. This is in contrast to a mentalist and behaviourist view of learning as an individual psychological process. However, the conceptual chapter has also shown that these theoretical insights had still to be taken forward (Guile & Young, 1998) to try and further our understanding of how to create the requisite skills needed in 'reflexive modernity' or late industrial societies. This work attempts to contribute towards these developing theories of learning. Since the study is small, the intention is not to generalise the results to larger groups but rather to deepen our understanding of situated workplace learning that can contribute to this developing body of theory. The study does however raise the possibility of probing a theoretical generalisability related to an epistemological link between tacit working knowledge and certain more formal disciplinary knowledge domains.

The course we presented did not interfere with the official learnership programme. Due to budget constraints, which included the science facilitator's fees, as well as production time, this course had to be completed in four months. Initially we began with one hour every morning before production. Later, production requirements and travelling distances for participants limited our time and participants' attendance. After the high production period of Christmas and the New Year I continued with revision, interviews and video taping presentations. Data has been generated from video and tape recordings of the lessons themselves as well as from observations noted during the duration of the course. Following Marshall and Rossman's (1989) comments about stating explicitly one's role as a researcher in action research, I need to state that my role was student, researcher and facilitator as the need arose.

After careful observation of the product/process nexus of our candidates' work, which entailed lithography and machine minding respectively, the science facilitator and I realised that a machine can have embedded within it a compact of technologies. In keeping with the theoretical underpinnings of our study, which entailed teaching from practice to theory, we eventually decided to extrapolate and teach those science principles underpinning the technologies that were more openly observable, and with which the candidates were more closely engaged in terms of their praxis. These were physics principles related to mechanical engineering such

as angular acceleration and forces; light, colour and lenses; pressure and volume related to the laws of gases; electrostatics and magnetic fields (briefly). We included a basic historical overview of the atom to deepen their understanding of the nature of gases and the behaviour of an electron within electric current. This was done in a period of four and a half months with an average of 40 minutes every morning.

5.4 The learning programme

The range of the scientific principles taught during the learning programme cannot be discussed in detail in this chapter. Instead, in this section, I have chosen to present vignettes of three broad physics topics that were taught to the students through our specific theoretical framework. The first vignette is the most detailed of the three, and in general reflects the nature of our methodology throughout the intervention process. In the next section, students' own formal presentations of the remaining principles will be discussed to ascertain whether they had understood the deeper conceptual underpinnings of their praxis. However, I will draw on the emerging trends emanating from the work as a whole, referring briefly to the other principles as they were taught within the context of this specific methodology.

5.5 Vignette 1: Talking about torque

We began by pursuing the physics-related engineering principles which operationalise the central mechanical aspects of their machine. This meant that we needed to develop participants' understanding of angular rotation and velocity as well as force related to the concept of torque. To define it further, we had to show how and why this principle worked through their machines, and that its possibility could be achieved only as a result of both the angular and circumference/diameter ratio equality of circles in general. The challenge was to teach sequentially from practice to theory. Prior observational knowledge¹ revealed to me that most of the candidates were relatively adept at fixing the basic mechanical problems in their

machines. This informed the manner and nature of teaching the initial concept of torque within the context of circular rotation.

To show that variation in the radius or diameter of a circle (in the form of a gear or the main driving cog in a motor which were both manifest in their machines) was directly related to torque (generally defined as a 'twisting force' – determined by the magnitude of the applied force and the distance from the turning point), we used the socket wrench, a tool commonly used by them. We drew on the students' prior knowledge that by increasing and decreasing the length of the wrench in its motion of tightening a bolt, they could effect change in torque. From the circular nature of this motion we were able to show them how the different diameters of the gears, with subsequently different radii driving the rollers in their machines, similarly created different levels of torque. We did this by measuring the diameters of the different gears. The students could, in this way, clearly see that the gears driving the bigger cylinders used for different processes of printing (for example, inking rollers had smaller gears while image transfer and blanket cylinders were driven by much larger ones, etc.) had a greater diameter which, in turn, implied a longer radius and therefore greater torque to drive it. At this stage of the demonstration, the facilitator in a dialectical process diagrammatically represented a diameter and radius within circles graphically showing the opposite but parallel directed forces. Simultaneously we needed to demonstrate how the same principle affected the different speeds in terms of angular velocity in their machines. In this instance, varying diameters between two or more circles connected either by means of a pulley or interlocked through gears directly affects angular velocity. To explain this through their machine, I used the manual drive to demonstrate that the primary pulley connected to the larger pulley in both sections of the machine rotates faster, making more revolutions in proportion to the larger one in a given time period. When the diameter of the larger one is increased, the number of revolutions of the smaller one proportionally increases, thereby reducing the speed of the larger one. Having access to a redundant machine in the workshop, we were able to take this process one step further. We removed the cylinders from it, marked them and rolled them on a level surface simultaneously, the students marking the revolutions as they occurred, to test the principle. We then asked the students to measure the markings as the

circumference of each cylinder completed a revolution and divide this by their respective diameters. In this way we were able to show the general equality of the circles in terms of their δ value. They were thereafter asked to run their machines at different speeds and each time we showed them how the relationship between diameters changed in this process. At this stage the students expressed surprise, and Prins agreed with Anand that they had initially thought that the two cogs – the motor cog and the central driving cog (connected through the pulley) – ‘were moving at the same speed’².

After having established this base we were able to extrapolate the formula related to revolutions and diameter, which in scientific syntax is presented as $n_1 d_1 = n_2 d_2$, where n denotes the number of revolutions per second and d denotes the diameter of the circle. It is this equality, which allows the cogs or gears to move simultaneously without slippage. In contrast to the fragmented and atomised nature of the unit standard approach to learning observed during the course of preliminary research, this approach built up students’ conceptual knowledge in a progressive and integrated manner, applying their function to the machine. Moreover this knowledge emanated from the broader theoretical body of knowledge.

Because the motor power (in kilowatts) controls the number of revolutions per minute, we were able to show how electrical energy is transformed into mechanical energy. The formula for the power of the motor is given as $P = 2\delta n$ where 2δ represents one revolution in units of radians (a mathematical representation of angular displacement), n denotes the revolutions per second and represents torque. Since P (the power of the motor) is generally constant we are thus able, by means of these principles, to change speed and torque through by varying the relationship between the diameters of different circles. This allows the machine to perform various functions simultaneously and in one motion. Whilst most of the candidates grasped these principles as is reflected later in their presentations, Prins was the only candidate who understood the deeper mathematical derivation because it was closely related to geometry, which the facilitator and the two of us had covered

in school. I shared his view that the mathematical derivation of angular displacement within context was more meaningful than 'learning about angles at school' ³. Even at these early stages of the workshop lessons, learning the syntax of science through the context of its use above decoded the formulae and became much more meaningful than learning the formulas in a decontextualised way at school. This process shares affinities with the developing social activity theories of learning, which stress the learning of an idea or a concept within the context of its use.

From this position, drawing on my anecdotal experience (outlined in chapter 4) we were able to expand on this formula, in order to relate the torque on two connected pulleys. We derived $n_1 r_1 = n_2 r_2$ where n refers to number of revolutions and r to torque which could further be substituted by $r_1 r_1 = r_2 r_2$ where r denotes radius and r denotes torque. From these it was possible through some basic algebraic applications to derive torque on the second pulley (where the motor's power is a general given) because you would have an indication of the number of revolutions of the primary pulley. This implies that if one has an idea of the magnitude of workload, it is possible to work out the power (P), which I recalled was how we were able to change the motor for the requirements of my woodworking machine. I was excited by the capability of such a learning process because the concepts of torque and angular velocity are foundation principles, generally introduced at first year engineering level.

A concern we had to address was that, apart from Anand and Prins, the candidates lacked English proficiency. This posed a challenge because standardised scientific knowledge is generally signified through the medium of English. I drew on the work of Elizabeth Henning, who stressed that under such circumstances it was best to draw on students' mother tongue, which contains the symbols that allow one to tap into their embedded cognitive models and schemas, and thereafter translate this into everyday English and finally to the English of discourse in the learning area. In this way one can activate understanding by invoking the first language as an extra resource. To give the students a sense of circularity, rotation and angular acceleration in the mother tongue we used the following phrases:

Selo sa nkgokolo se a dukuluga – this round thing is turning;
Selo sa nkgokolo se dukuluga ka lebelo – this round thing is turning faster;
Go namelela godimo go nyakega maatla – to climb up it needs force.

In this way we introduced key concepts in the mother tongue within the context of its use while simultaneously drawing on the specific scientific terminology. We were pleasantly surprised that, as the course progressed, they began to use the basic scientific terminology drawn upon by the facilitator ⁴. This is supported by Henning's study. She writes:

This approach defies the notion that African languages cannot signify the meaning of high technology-words and phrases... linked with cognitive models and schemas, they will find some way to express and encapsulate meaning (Henning; 1998: 58).

However, despite Henning's comments above, we had struggled to find adequately correlating seSotho terminology for some of the other principles. I believe the fact that we achieved a strong degree of success in this regard was due rather to the fact that many basic building concepts in the field of Physics are related to natural phenomena, and can in many instances be located within other languages. Secondly, many people have directly experienced technology, both through their tacit work experiences and also because of its pervasiveness in society as a whole. It needs also to be pointed out that the students did possess some English proficiency. This brought to mind Daly and Mjelde's (2002:198) insights drawn from Smith (1996).

When the learner struggles to give "discursive shape" to experience, this is, of necessity, a social and communicative act. It involves hooking a local sequence of action and experience into a wider discourse...that the mediation of meaning between the individual learner and the "real" environment is a

social act, which, through language, abstracts the “universal character”... (Smith, 1996:189).

The term ‘universal character’ above, if interpreted within a neo-Vygotskian conceptual framework, would tend to mean the deductive generalising instruction of the teacher and the curriculum, which helps to expand understanding of generalised and abstract word meaning. We strove to engineer our methodological approach in terms of this understanding.

Later in the week, while the discussion focused on gears in machines, someone from management who often travelled through very sandy roads, commented that he usually had to change to a lower gear and asked if this was related to torque as speed is reduced in this process ⁵. The supervisor responded that this was a classic example of the relationship between diameter, torque and speed because a lower gear means engaging a higher diameter resulting in increased traction torque. Similarly a car driving up a steep incline had to change into a bigger diameter gear to exert more force. Because the smaller gear now has to drive a bigger diameter gear, this results in decreased speed as well. During the course of the following week, Peter and Prins were found one morning having an animated discussion about gears in relation to Peter’s bicycle. They seemed to disagree with the example about engaging a bigger diameter gear to cycle up a steep incline. They argued that, in relation to their bicycles, they would always switch to a smaller diameter gear when cycling up a hill. The facilitator was not in on the day and I was forced to try and think the problem through. Since I had not ridden a bicycle in years and so had little practical experience of bicycle gears to draw on, I felt rather nervous in trying to address the problem. However, the students’ questions excited me because of the fact that they were beginning to apply the principles to a different technology and context. I told them that I would think the problem through.

Reflecting on the pedagogical process, the students’ experience of bicycle gears continued to puzzle me: why was the easiest gear the smallest diameter in the

bicycle rather than the largest diameter? This prompted me to revisit the problem. After I had discussed the problem with a physics lecturer I realised that the students had been confusing the diameter at the front chain wheel with the diameter at the rear wheel. So, we revisited the problem together. We brought a bicycle in the workshop and noted how torque was transmitted from the main driving gear (connected in this instance to the pedal) to the other gears through the interconnecting chain. We confirmed that the maximum torque driving the rear wheel was indeed when the diameter was largest. Then we looked at the set of gears at the front chain wheel. At this point we realised why the students had earlier said that the 'smaller diameter was easier in a bicycle'. When the smallest diameter of the front chain wheel is connected to the largest rear gear, the gear ratio is greatest and so it is indeed easiest to turn the rear wheel. We watched how the front chain wheel made several revolutions for each rear wheel revolution. Prins and Peter then reflected that if they were to race on a gentle incline they would choose a somewhat larger diameter of the front chain wheel, but that on a leisurely ride they would not do this, as this would tire them out too quickly. Through discussion we explored how the $n_1d_1=n_2d_2$ principle operated in their bicycle: apart from being able to alter torque and speed, one could also explain a cyclist's rate of energy expenditure. Racing up a hill required more 'power', i.e., more energy expended in a shorter time than riding leisurely up the hill.

In a dialectical process, I referred on the chalkboard to our earlier discussion about energy and power. Here, I made the link between 'human power' riding a bicycle and the electrical power of a motor, and how in both cases the principle of energy used per unit time applied. In my woodworking experience, I recalled that if I were working with a particularly hard wood, then I would need a larger diameter in order to have sufficient torque. If the diameter was not made larger (i.e., the angular speed smaller), then the motor would overheat. Prins' suggestion of nicknaming Peter's bicycle 'NIDI' – referring to the $n_1d_1=n_2d_2$ relationship - was enthusiastically adopted by all students. This was probably because of their direct experience of this phenomenon through the bicycle. Here one notes the dynamic interplay between cognition, context and practice stressed in social cognitive literature and consciously strived for in our methodological process.

According to Kemmis and McTaggart (2000), the research process may not be as neat as the spiral of self-contained cycles of planning, acting and observing and reflecting suggests. My own experience in implementing the educational intervention through the action research methodology, as noted above and in the paragraphs that follow, tends to support the above writers' views that the stages described above may overlap and initial plans quickly become obsolete in the light of learning from experience. The process in reality is likely to be more:

...fluid, open and responsive. The criterion of success is not whether participants have followed the steps faithfully, but whether they have a strong and authentic sense of development and evolution in their practices, and the situations in which they practice (Kemmis & McTaggart, 2000:595).

5.6 Vignette 2: Boyle's Law

The next principle we attempted was Boyle's law, $P_1 V_1 = P_2 V_2$, which relates to the behaviour of gases under conditions of pressure. This was an important principle underlying the correct registration (feeding) of paper to the machine. The methodology closely followed that in the first detailed vignette. In order to deepen the participants' understanding of the possibility of compressing gases, one needed to have at least a basic understanding of the behaviour of atoms. The equality of the different volumes could be understood only in terms of an understanding of mass as it relates to atoms and molecules. Apart from Prins, the other students lacked this background and we decided to return to this section after including a basic historical overview of the atom. This, to some extent, seems to support Muller's (2002) argument (derived from Bernstein's distinction between the vertical and horizontal knowledge structures) about disciplinary science knowledge preceding application. However, Prins' response is worth noting as it again reflects the tension between the two. He ran to me after one of the demonstrations and exclaimed that though he had

done this at school, it was only now that, “It’s in my head!” ⁶. For the first time he could perceive how V_2 though greater, was balanced by P_2 , which was smaller, thus he understood the equality in context. This equality is possible because of the inverse relationship between pressure and volume, where increased pressure at input reduces volume by compression and decreased pressure at output increases volume. Peter’s explanation of these concepts is included in section 5.10 below.

5.7 Vignette 3: Light and colour

In the next phase we worked with principles of light, colour and lenses, underpinning the reproduction of image, which is a central factor of the printing industry. Because mirrors reflect light accurately they are used in many industrial machines. Thus we were initially able to draw on the everyday experience of light reflection in students’ lives. The image-setting machine and plate-making machines related to the reproduction of images were inaccessible in terms of dismantling. Since they could not be dismantled we used a redundant photocopying machine, which represented a simpler construction of the same principles and with which students were familiar. Through a dialectical process, which entailed moving from the machine to the board and back again, we were able to show the students how an image is created. We were amazed at the interest of the students, who traced on paper the entire path of light depicting the correct angles of incidence and reflection. This they did of their own volition, working collectively and corroborating with each other. I remember vividly the facilitator’s comment that they were doing this “unasked for” ⁷. Here we note, not only the display of elements of learner-centeredness which is discussed later, but also the natural collective nature of learning typical of workers in communities of practice so often noted in literature related to worker education as well as to social cognition. We have captured videotape material of the interactive process between facilitator and students during the course of this lesson.

In relation to principles governing colour, the facilitator, with constant reference to the students’ personal prints, showed how the different colours in their printing were

derived from the light spectrum. By means of a prism they were first shown the dispersion of colours, which occurred as a product of different wavelengths. From here the facilitator explained how white light was a combination of the primary light colours (red, green and blue) and finally how the secondary colours - cyan, magenta and yellow - used in the printing industry, were derivations of these primary colours. Unlike painters' mixing of colours, printers' colours are laid out in terms of dots per square inch ('density'). They were shown how the three colours in varying percentages reflect different wavelengths, which, through a process of absorption and reflection, result in the desired colour/s. The facilitator referred to the word 'opacity' to describe an object's tendency to reflect a specific colour light. At this point both Alfred and Anand immediately brought to his attention the tins of pigment which were labelled 'opaque' and 'transparent', and asked about their relationship to 'opacity'. This invoked an animated discussion in class⁸. Density was defined as: $d = m / v$ where for the case of the 2-dimensional printed page, m was taken to reflect the number of inked dots and v the area in terms of square inches. The students had previously simply added more pigment when the picture required a darker shade. Now they understood the concept 'density' as in dots per square- inch.

As mentioned earlier, to expand on their understanding of the nature of gas and the behaviour of electrons, we taught a basic course on 'the atom', choosing an historical approach. Interestingly the students identified with Rutherford's experiential approach, which lends itself to graphic illustration. Both Alfred and Prins raised questions about the 'reflected' and 'refracted' nature of the alpha particles emanating from the isotopes, and which were projected towards the gold foil used in the experiment.⁹ This seems to suggest their identification with a contextual approach, which is important because the atom is an abstract concept. After the course on 'the atom' and electrostatics, we returned in a dialectical manner to the machine. Here, we examined the organic photo-conducting drum, an important part of image reproduction in the photocopying machine. This is an exciting application of the principles of electrostatics, which required the participants to have a basic understanding of the atom and electrons.

Participants' presentations of principles underpinning their praxis

As a result of historical disadvantage, some of the participants in this study were not very proficient at expressing themselves in standardised English. It was, however, felt by my supervisor and myself that the participants had the right to be fairly represented in a dignified manner. It is in keeping with this that I transcribed participants' representations (reflected below), without deviating from their core arguments. It needs to be stated also that the transcriptions have kept intact the science syntax directly articulated by the participants themselves. This was deemed important because of the fact that one of the objects of the study was to demystify disciplinary science syntax.

5.8 Anand's presentation – optics and electrostatics in application to the machine

Anand presented his work through a slow dissection of a redundant photocopier machine. He started with a description of the process of image creation. This entailed the interplay between reflection and absorption of light, which was initially emitted through a slit resulting in an 'incident ray'. This in turn was processed through a range of 'reflected' rays at the correct angles towards a unit of lenses constituting converging, diverging and inverting lenses.

A: "... when the incident ray meets the point of incident on the mirror, it is reflected. The point at which it is reflected it exactly equal to the incident ray, therefore we can say that the incident angle is equal to the reflected angle – and because of this property we can build our photocopier much easier. The photocopier works on these principles of reflection of light..."

Pointing at, and carefully dislodging the mirrors in the photocopier, Anand commented:

"...these mirrors are set at 45 degrees to pass the light at right angles to its destination at the last mirror near the top part of the machine known as the optical section. The mirrors, the lights and lens all work through the optics of the machine."

After carefully removing each and every lens Anand detailed how 'propagation' through the correct focal lenses and 'focal points' played an important part in the process. Through a process of convergence, divergence and inversion, the light travels through onto a 'photo-conducting drum'. When he finally removed the last mirror, he stressed its 45 degree angle position to the drum, which he said enabled it to transfer the image at 90 degrees to the drum. According to Anand, the 'photo-conducting drum', which is mildly charged, becomes light sensitive.

When the facilitator asked him to explain how the drum itself gets charged, he replied:

A: "The drum gets charged by a mild electrostatic charge through very thin wires lodged onto the drum itself. I'm going to take out the wires that actually charge the drum."

F: "I can see this is a very, very mild charge."

A: "Very mild. If you look inside you can see a very thin wire."

F: "Yes, I can see, actually there are two wires, am I right?"

A: "No, those two wires are on the grid, if you take this grid out – there's a thin wire."

He removes the grid.

F: "Oh there you are – it is such a thin wire, you can hardly see it."

A: "Now, the machine regulates the wire at a very low voltage to create a static charge. It doesn't have one, it has two."

F: "I see."

A: "It has two wires, to induce a very uniform charge."

F: "I see, what passes on this uniformity?"

A: "The grid."

F: "This particular grid?"

A: "This grid assists in effecting uniformity of charge across the entire length of the drum."

F: "So the grid does that of uniformly distributing."

A: "Very uniformly."

F: "Is that the relationship between science and technology?"

Following this elaboration on the properties of the photo-conducting nature of the drum, he goes on to explain further how those parts upon the drum where light is incident become conducting, and therefore the electric charge is discharged. The parts of the drum that light does not strike (because the light has been absorbed by the dark printing on the paper) remains charged and form a 'latent image' on the 'electrostatic charged' drum. As the dialogical process below will show, Anand draws on principles of electrostatics to show how these charged parts of the drum attract the grains of toner powder, which are also charged. Finally the toner gets melted on to the paper. Referring to an example of scanning a paper with blue writing on it he explains that,

A: "...this image will be passed onto the drum. As a result of the properties of light related to absorption and reflection, the light is absorbed on the blue and reflected on the white. Now when the light is travelling from the top to the bottom, the reflected light will be the only light coming through onto the drum and because of the photo-conducting material, the light erases that part which is reflected and will leave the absorbed part."

F: "Is that the image that was there, the latent image you were talking about earlier on?"

A: "That latent image is actually the absorbed part of the image off the top."

F: "Which light cannot prevent?"

A: "No, so when ever the light is reflecting it is going to erase a charge on the drum and when the drum turns, whenever it is charged it will pick up the toner. Remember the toner is also charged."

...

F: "I see, that's amazing. (Remembering Anand's opening statements about how the principle of electrostatics works through the drum.) So it's almost the electro-static principle that is working."

A: "The reason being that the drum does not even touch the toner. It is a millimetre of a fraction away from the toner. It just passes over the toner."

A: "So if you place the toner against the drum, both charged in opposites to each other, what do you think will happen?"

F: "It will attract."

A: "Through this process of attraction the toner is drawn to the drum, which in turn transfers it onto the paper and is subsequently dried out through heat."

F: "That's amazing."

From excerpts of his presentation above one can see that Anand was able to explain the scientific principles related to the properties of light operating through his machine and also to reflect on its relationship to aspects of the technology in that specific machine, for example, between the design of a specific grid to distribute the electrostatic charge evenly across the photo conducting drum.

He was also able to draw quite effectively on the scientific syntax to articulate these principles. As was also clearly depicted in the collective interview in sub-section 4.5, Anand's thinking also clearly showed his ability to apply the principles to a different

technology and context signifying the take-up of technological literacy. When asked about his feelings about the nature of the type of pedagogical process they had undergone he said that for him to understand 'the science of colours' after having worked with it for so many years prior to this was indeed a 'revelation', particularly the 'issue of absorption, reflection and wavelengths', in their interplay with the production of colour which entails their praxis. He also mentioned how 'a spectacular array of colours could be created through the combinations of the four colours of cyan, magenta, yellow and black' applied in their printing work.

During the course of the presentation he stated that he had "learnt a lot from this course" and hoped they may have time to continue learning additional aspects of their work process within the context of such a pedagogical process.¹¹

5.9 Prins on colour and light

The subject of colour according to Prins was introduced only after the science tutor covered a more basic course on light, wherein incident, reflected and refracted rays were all taught in relation to their application within the context of their photocopy machine. It was against this background that the course on colour and light-wavelengths were deepened and 'taught in its application to the colour prints' they constantly produced. This description by Prins of their pedagogical process seemed to be in keeping with the theoretical underpinnings of this study, which had drawn on developing socio-cognitive theories of learning, with its stress on learning in social context. The facilitator also tried to take into consideration curriculum process questions (as raised within the context of the Mullerian debate) such as the sequential process of learning, which alludes to the concern that certain concepts (especially within formal knowledge discourses) need to be learnt prior to others because of the logically related nature of their structure. It was within this context that the researcher, Faizul (F) asked Prins (P) if the brief course they did on light helped him in any way to understand the nature of 'secondary- colours' as used in their print-making process.

P: Yes, because the secondary colours known as cyan, magenta and yellow which were used in our printing work are derived from the primary colours red, green and blue. These basic primary colours are derived from the seven visible spectral colours that are contained in white light.

F: Do you mean the light that we can see through this window has contained within it several other colours of light?

P: Yes, we were shown how passing a beam of white light through a prism separated in order a range of colours that made up white light. From this we learnt that the distinct order and range of colours denoted the different wavelengths, each with its own frequency.

In order to show 'F' how the primary colours red, green and blue were derived from the other seven visible spectral colours he physically mixed small quantities of red and orange to give us 'primary' red, green and yellow to give us 'primary' green and blue, violet and indigo to give us 'primary' blue. He followed a similar process to show the researcher how 'secondary colours' (more commonly known as cyan, magenta and yellow) used in their printing work, were derived from the primary colours, red, green and blue. Mixing blue and green dots produces cyan, while red and blue dots gives magenta and finally red and green dots produces yellow. The researcher, to understand if Prins understood some of the scientific principles underpinning the production of these colours, interjected with the following questions:

F: You mentioned much earlier that the distinct order and range of colours denoted different wavelengths, each with its own frequency. Could you

explain how this plays a part in your print work, especially in regard to the varied colour ranges in your printed pictures?

P: Yes, mixing the three colours in different proportions initiates a process of absorption and reflection to produce new colours. If you remember, I said that different colours denote different wavelengths. Each colour absorbs some light wavelengths from white light but reflects others. It will reflect light wavelengths from a like colour and absorb light wavelengths from an unlike colour.

F: I am still not so clear; perhaps because light wavelengths are still abstract to me, I cannot understand the process of absorption and reflection and its effect in the formation of new colours.

Prins answered that he was also a little confused at first because he could also not really see wavelengths, but the interplay between wavelengths, absorption and reflection became much clearer to him when they were shown how the mixing of the three colours produced black.

Following from his earlier description of colour mixing he explained:

P: when you mix cyan, magenta and yellow, you are actually mixing a combination of blue-green, red-blue and red-green which in turn is a combination of blue-violet-indigo/yellow-green; red-orange/blue-violet- indigo; red-orange/yellow-green. Are you following me?

F: Yes, you are saying that you are mixing the 'secondary' derivatives from the 'primary' colours you described earlier on.

P: Yes, and when these combinations are exposed to white light which contains all the spectral colours, then in the first combination blue, violet, indigo, yellow and green are actually reflected, while red and orange wavelengths are absorbed.

The researcher interjected with the question:

F: To read you correctly, are these colours in this combination repelling colours of a like nature being emitted from white light?

P: Yes, but it may also be that common wavelengths repel each other, and if you can remember, I said that white light contains all these seven visible spectral colours. These are the colours you can observe in a rainbow like red, orange, yellow, green, blue, violet and indigo.

F: You can proceed.

P: In the second combination red, orange, blue, violet and indigo are reflected, while yellow and green are totally absorbed. The final combination follows a similar rule, wherein red, orange, yellow and green are reflected, while blue, violet and indigo are absorbed. What happens is that whatever one combination reflects is then absorbed by the other, which results in the total absorption of all the colours or light wavelengths giving us the colour black.

F: Are you saying that black absorbs all the colours, not allowing any light to be reflected?

P: Yes

F: That's amazing!

In this way, even though he could still not actually see light wavelengths, he was 'better able to understand it through its effect in the process of absorption and reflection' that was pointed out above.

Prins also mentioned how they were taken on organised visits to both Nashua and a painter's studio to study the different picture-creating technologies of an advanced photocopying machine, and a painter's paint-making process respectively. By drawing comparisons with their printing process, they learnt how different technologies 'seemed to draw on similar science principles to create a colourful picture'. In contrast to the actual mixing of different colour paints, according to Prins, their printing paper contained thousands of dots divided per square-inch independently filled with either cyan, magenta or yellow ink and aligned in different configurations and in different densities to eventually produce a very colourful picture. Although in ways a little different to the painter's or photocopying technology of colour mixing, he says that similar science principles are drawn upon where 'each colour absorbs some light wavelengths from white light but reflects others'.

According to Prins:

"If you look at our full colour prints through a magnifying glass you will notice that the ink colours are not organically mixed, but separately aligned closely to each other. However, through the same principle of absorption and reflection

a colourful picture is perceived by the human eye which sees it almost as an organic-mix.”

Picking up the magnifying glass that Prins brought with him, ‘F’ started to look at the prints through it and exclaimed that he was totally “unaware of this”.

‘F’ thereafter asked him if he had studied the subject of colour at school. Prins replied that he did, but could ‘hardly’ remember any of it. Moreover, he didn’t enjoy doing science at school as much as he had enjoyed it in these workshop lessons.

When the researcher asked Prins during the course of a collective interview about the difference in the nature of the theory he experienced at the college and the one conducted through this workshop learning programme, he answered that the theory at college was more trade related and not at all at the level of any underpinning science and engineering related concepts. He said ‘that when Siddique (the science facilitator) came, we started opening the machine’ and it was then that he learnt about the motor in his machine and its relation to ‘torque and diameters’. The researcher then asked him about a time in class when the issue of gas laws were being discussed and when he ran to him immediately after that workshop lesson, exclaiming that though he had done it in school, it was only now ‘in my mind’. He said that it was as if it had remained dormant in his mind and after understanding the equality of $P_1V_1 = P_2V_2$ in context, ‘Boyles Law suddenly came back to mind.’¹²

Both Alfred and Anand at this stage of the discussion (in the collective interview) strongly shared Prins’ sentiment, commenting that the theory in school was not related in any way to practice. Prins at this moment of the discussion interjected with the word ‘meaningless’.¹³

To try and achieve a degree of equity between researcher and candidate, the researcher tried to conduct his questioning within the context of a dialogical process. The questions were consistent with the research objectives which, in the first instance, were to try to find out if Prins understood the deeper conceptual underpinnings of his practice. In the second instance, they were to see if he could explain this, using the correct science syntax and thirdly to, gauge his opinion about the nature of this type of learning in contrast to his previous learning experiences.

From the discussion between Prins and the researcher about colour printing it becomes quite clear that Prins was able not only to understand the principles of science underpinning his colour printing, but also to teach the researcher in a dialogical way about his subject material. His ability to articulate his explanation through the use of science syntax could be attributed in this case not only to learning syntax in context but also to the fact that he had studied science at school right up to matric.

However what also becomes clear is his insistence that learning within context as the discussion has shown, was not only much more understandable, but also much more *enjoyable*.

Finally, the fact that his understanding extended beyond the issue of colour, as was shown through his comments related to general science and engineering related concepts underpinning motors in his machines in the discussion, clearly shows that Prins had achieved a level of technological literacy. This has shown the possibility of achieving the epistemological link described above between the tacit and the scientific through the process of explicit transmission in the form of conscious intervention. Whilst a link between science and technology has always been acknowledged, I don't believe the possibility of seeing it in the form of praxis that could innovatively be linked to theory or disciplinary knowledge in the form of science has been perceived and thus its potential for linking theory to practice realised.

Indeed, its relevance must be seen within the context that thousands of workers are engaged with technology as praxis.

It needs to be noted that some of the students, namely Peter and Alfred, used a mix of seSotho and English to explain their principles. However, the science terminology recorded in these presentations was kept intact as the students themselves articulated them.

5.10 Peter's presentation on gas laws in application to machine

Peter decided to present the principle related to the behaviour of gases under conditions of pressure, and how this is an important function of the correct “registration” (feeding) of paper to the machine. He drew on the principle of Boyle's Law that we had collectively worked through in the workshop where the input product of pressure and volume generated is equal to the output product of pressure and volume denoted by the formula $P_1V_1 = P_2V_2$, providing that temperature remains constant.

This equality is possible because of the inverse relationship between pressure and volume, where increased pressure at input reduces volume by compression, and decreased pressure at output increases volume. In the initial part of this presentation, certain excerpts of which will follow, he demonstrated how the piston in the compressor attached to their machine generated input pressure on the gas, which was released into the pressure bar through nozzles separating the paper evenly, which was a very important function of the process of “registration”, which entails adjusting the pressure and vacuum elements on one's machine to separate, pick-up and distribute with precision the stack of papers evenly through one's printing machine.

F : You spoke about how the separation of your print sheets takes place through the relationship between pressure and volume, but where does this relationship between pressure and volume all start from in this machine of yours?

Peter, moving towards the one side of the machine, points to a cylindrical object that has attached to it a piston, and states that:

P: It starts here with this compressor. This is where the process of high pressure and low volume takes place.

F: But how does this volume get compressed here in your machine?

P: It is compressed through this piston being pushed down within the compressor.

Peter, pointing to the front top-end of the machine where the pressure blowers and vacuum suckers are located, stated that the process of pressure and vacuum that operated in this instance followed the principle of high to low pressure as found in gas laws. In reply, the researcher asked him if he could show him exactly how this process of high to low pressure operates in this machine.

Peter, pointing to the piston leant down and replied:

P: This is where, through the compressor, high pressure is created and flows through to the multiple blowers where it separates the papers. The compressor, having pumped the gas out, immediately moves into a state of vacuum creating in it a state of very low pressure. Through

the suction nozzles, which pick up the papers through a process of vacuum sucking, gas is quickly redrawn into the compressor and in this way moves from high to low pressure.

Knowing that in this instance high-pressure is not created by the machine, the facilitator questions Peter further by asking him where the high pressure in this instance emanates from. Peter replied:

P: It emerges from the atmosphere which has a much higher pressure than the compressor, which as I have mentioned after pumping out all the gas moves into a state of low pressure.

Addressing Peter, the camera crew and the other students attending the presentation, 'F' answers:

F: I believe this is generally correct because when the gas is pumped through from the compressor, it is momentarily in a state of vacuum which indicates lower pressure than the atmospheric pressure at that moment outside it.

The nature of gas is such that it moves from high to low pressure. Drawing theoretically on this additional aspect of the principles of gas behaviour, Peter as the excerpts above have shown, demonstrated how the low pressure created after release of the gas from the high pressure in the compressor is quickly filled by gas moving into the resultant low pressure within the compressor. This happens because atmospheric pressure is higher than the pressure within the compressor at that specific moment. Capturing the interplay between science and technology (which I vividly remember the facilitator bringing to the attention of the students in class) Peter was able to show how the machine manipulates this condition to draw up

paper through its “suction bar”, which aids the process of “registration”, or evenly distributing paper through the machine.

Since Boyle’s law refers specifically to gases wherein the nature of molecules differ from those in more solid states, F’s following question was intended to see if Peter understood it at this slightly more complex level.

F: Could the piston compress water or ice in the same manner as it does gas?

P: No, it will not work because the molecules that are in motion within gas are not the same as those in water or ice.

Recalling how the science facilitator had illustrated this in a previous workshop lesson, F asked Peter the following question:

F: Can you in some way show me the difference between these molecules within gas and a solid such as ice?

(Referring to diagrams from his workshop lesson sheets Peter replied):

P: Here, as you can see, the molecules of gases have spaces between them, while molecules in ice are closely packed together.

F: I believe you are trying to tell me that the spaces between the gas molecules make it possible for it to be compressed in order to create pressure. If this is so can you show me how this operates through your machine.

Peter led ‘F’ to the compressor section of the machine and argued that:

P: Within the compressor you have pressure, volume and molecules in combination with the piston. I can turn the machine to show you how the piston goes in and pressurises the gas inside the container. I am now turning it slowly just to show you, but if I turn it faster it will begin to pressurise the gas, and the molecules within it will begin to move faster as they bounce off the container, increasing pressure. If one puts in a solid such as ice, the piston will stop at a certain point as a result of the compactness of the molecules within ice.

F: You have mentioned that the molecules within the gas under piston pressure will move much faster as they collide with the insides of the compressor and create greater pressure. What kind of energy would this create?

P: Kinetic energy because it is moving.

F: So kinetic energy would be energy created by motion?

P: Yes.

F: Just for clarification, you said that the molecules within gas, which are condensed under pressure constantly, hit against something?

P: Yes, against the inside of this container – faster as the piston pushes into the container.

F: You said that this creates pressure?

P: Yes.

F: Thank you.

This probing of the nature of gas and process of pressure was important because I wanted to see if Peter understood it at a level deeper than simply 'piston force' which was the answer the students had initially given to the facilitator during earlier workshop lessons.

The concept of 'fixed mass gas' is rather important because the principle can only hold within the context of a fixed volume of gas. It was for this reason that F asked P to show him where 'fixed mass-gas' resides within his machine, to which P immediately pointed out the compressor container.

At this point F asked P that if for some reason the temperature did not remain constant, would it affect the process. P replied that it would. F then asked him why. P hesitated, at this moment and the discussion was interjected by Prins who explained that the volume could either go up or down if there was any rapid temperature change in either direction. They both agreed that this would affect the smooth functioning of the process.

Peter, as the excerpt above has shown, understood an important aspect of Boyle's Law when he pointed out the compressor as being the container containing 'fixed-mass gas'. However, I was not very pleased with the fact that he could not answer the question related to the impact of temperature rise upon the 'fixed-mass gas'. I deemed this important, because the efficient working out of Boyle's Law depended upon the importance of temperature remaining constant. However, his explanation of certain other aspects of Boyle's Law below show that one cannot simply ignore or rule out the potential of this type of contextualised learning.

Through earlier observations of how this principle of gas laws operates through the printing machine, the science facilitator realised that even though the principles are operationalised through these machines, they are in certain ways adapted by these technologies to suit the tasks of the purposes at hand. This was also the case in this machine, and the facilitator had adapted the formula somewhat and had worked through this adaptation in relation to the machine with the students during the course of their workshop related lessons. The next question 'F' put to Peter was related to this adaptation of the science principle and I believed his answer would give me an indication of the level of his understanding of this adapted principle.

Indicating through his body and hand movement, Peter first showed us the piston followed by the pressure blowers and finally the release valve, arguing through this motion that:

P: In Boyles law P_1V_1 is supposed to be equal to P_2V_2 ; however, here in our machine P_1V_1 which first starts here in the compressor and moves through to P_2V_2 here at the pressure blowers (as was earlier shown) is always higher than what is required to shift the weight of our papers. An example is carbon, which is lighter in grammage than other papers. To solve this problem, the machine has an additional release valve to allow us to release the extra product of pressure and volume. This extra product pressure and volume that is released through this valve originates from the initial P_1V_1 that emanates from the compressor and must therefore be added to P_2V_2 to create the equality between P_1V_1 and P_2V_2 as it works in our machine.

Peter demonstrated through his machine how he changes the settings on the release valve to create different pressures required of different workloads.

In contrast to an earlier concern raised about Peter not being able to answer a question about the impact of temperature change upon 'fixed mass-gas', the

excerpts above show that he was able to grasp the other important aspects of Boyle's Law, even at its adapted level. As the discussion has shown, Peter was also able to distinguish between the nature of different states of gases in relation to their effect in creating pressure within his machine. He was also able to draw on the science syntax in his explanation of the principle.

Through his presentation we were able to witness how technology in the form of the release valve operationalises this principle in its adapted form to suit the task at hand. This is also an instance where one can see the interplay between science and technology.

When asked to elaborate on a noted comment he had made about this type of learning being better than the sums he did in school, Peter replied that in both instances of formula application, such as the $n_1d_1 = n_2d_2$ as well as the $P_1V_1 = P_2V_2$ principles he did in these workshop lessons, were much more interesting and understandable than 'solving for x' in school. Referring to the $n_1d_1 = n_2d_2$ principle, he said that he could, in this instance through its application in his bicycle, see and solve for x in terms of the number of both revolutions as well as in the diameters spoken about. He also said that 'for the first time [he] feels confident enough to attempt maths and science at the matric level'. Alfred sharing this sentiment added, 'at higher level'.¹⁴

Not only did Peter express his preference for the contextual nature of this type of learning in contrast to his experience at school, but, as the earlier narrative in chapter five had shown, both he and Prins were able to transfer their learning of these principles to other technologies and contexts.

5.11 Alfred's presentation-Transformation of Common-Sense Understanding

Alfred's presentation differed from those of the other candidates in the sense that he sought to explain the process of his learning of certain engineering principles in relation to the functioning of his bicycle. His reason for this was about the surprise he had felt at the deepening of a common sense understanding he had of his bicycle prior to seeing its functioning in terms of these principles. I decided in this instance to stand back and intervened only when clarification was needed.

He said that as a result of his absence from some of the workshop lessons that dealt with angular acceleration, force and torque, he remained confused about its relation to his bicycle, and sought an explanation from the facilitator in regard to this.

According to Alfred, the facilitator graphically drew a scenario depicting a cyclist riding up an incline. He asked him about the specific gear combinations he would select when riding up such an incline. Alfred, drawing on years of experience, said he would engage a larger diameter gear at the rear-end of his bicycle while leaving the gear at the pedal-end unchanged. In reply to his explanation, the facilitator asked him a reason for these changes. Alfred, giving an answer that made common sense, replied that even though his speed would drop, he would not tire so quickly with this gear combination on the up-hill. Alfred said that he was quite confused when the facilitator acknowledged that he was correct, but said that he had still not explained why the change of gearing allowed him not to tire so quickly.

In a similar methodological process applied to effect understanding of students' machines, described earlier in this chapter, the facilitator drew on Alfred's prior knowledge that by increasing or decreasing the length of the 'wrench' in its motion of tightening a bolt, change could be effected in terms of force or torque.

According to Alfred, from the circular nature of this motion:

I was able to learn how the different diameters of the gears similar to the differing lengths of the wrench created in a similar way different levels of torque and force.

The distinction between torque and force is subtle and can be confusing. Its distinction, however, is rather important to this principle of 'mechanical advantage', and it was for this reason that I asked him if a larger diameter gear implies greater or lesser torque. He replied:

"More torque and less strain on the rider."

By implication, this was correct because it meant that greater torque could be effected through either the same or lesser force to be exerted from the rider. This is also the reason why he would not tire so quickly. In an explanation of his understanding of why his speed dropped on the up-hill he said that:

"When you change to a bigger diameter gear, not only are you increasing torque, but also the circumference of the gear that is now in operation is much larger. This means that its number of revolutions would take longer in time than the smaller diameter gear, which because of its smaller circumference would turn faster. "

Alfred's common-sense understanding through this process, was transformed when he learnt why the gear combination that he applied for years before on the up-hills, while reducing the speed of his bicycle, made it easier for him to climb. This understanding was in keeping with the more general principle of varying diameters between two or more circles which when connected either by means of a chain or

interlocked through gears directly affects angular acceleration as well as both force and torque.

Finally, demonstrating through a process of very slowly walking his bicycle between two points in the workshop, Alfred carefully counted the number of revolutions that both the pedal-gear and the rear-end gear made between these points. He thereafter respectively multiplied this by the diameters of each gear, and showed the working out of the formula $n_1d_1 = n_2d_2$, where 'n' denotes the number of revolutions and 'd' the diameter. When connected through a chain, and moving within the same time period, the product of the number of revolutions and the diameter of each connecting gear would be respectively equal. He was thus able to extrapolate a more general formula from this particular practice. It is in this context that one can understand his shared sentiment with Prins about the difficulty of abstract learning of formulas in school as compared to the way they have learnt it here through their practice.¹⁵

When asked about his opinion of the difference between the two approaches to learning he had been exposed to, he replied that learning under the previous facilitator was basically about 'house-keeping'. I asked him what he meant by this, to which he replied it was more about 'cleaning, inking and basic' setting of the machine. Anand interjected at this point in the collective interview and characterised the learning process through the remark 'list three types of spanners', with Alfred rejoining the conversation by adding 'list two types of allen keys'. The conversation was immediately followed by a hearty banter from the group as a whole.

To summarise some of the conclusions already outlined during the course of this discussion, the excerpts from Alfred's presentation quite clearly show that the nature of this type of contextualised learning enabled him, not only to understand the deeper conceptual underpinnings of his practice, but also at the level of principle to generalise from the specifics of his practice. He was also able to articulate himself through relevant science syntax. He also displayed an awareness about the generalisability of this principle to different technologies when he explicitly stated that

he had chosen to speak about its learning because of the fact that it was this very principle that had enabled him to learn, not only about the deeper workings of the machine, but also of his bicycle as witnessed above.

5.12. Different knowledge forms – contextualised and decontextualised

In this study, the central tension between contextualised and decontextualised knowledge manifests itself between disciplinary and applied science knowledge. For Prins and me, with prior experience of disciplinary knowledge, the science syntax became meaningful only within context. However, for the students without a solid grounding in the science knowledge domain, this syntax proved to be more challenging. We could deepen their understanding of certain characteristics related to the nature of gas and the basic behaviour of an electron within electrical current only through prior induction into the nature of the atom. This is why Muller believes that prior disciplinary science as taught in institutions should precede science in application. Although this specific case study shows that one cannot simply ignore Muller's argument, there still remains for me the dichotomy between contextualised and decontextualised knowledge. The fact that our candidates were able to express this deepened understanding, as their presentations above have shown, seems in general to suggest that a synthesis could be effected through the dialectical movement between the two. Importantly, the students were able to articulate the principles' functionality to their machine.

Other research on science learning echoes Prins' and my own experiences of learning science at school. As was noted in chapter 3, studies in university undergraduate physics courses have shown that, even though students apparently master the (decontextualised) physics principles (as evidenced by good performance in traditional tests and examination), they often in fact have poor conceptual understanding of the principles, and are unable to apply these to real world, everyday contexts (see, for example, Arons, 1983; Hewitt, 1983; Mc Dermott, 1991). Furthermore, despite the hierarchical nature of physics knowledge in terms of its

conceptual coherence, the research shows that students' knowledge about topics in undergraduate physics courses tends to be fragmented and disjointed (see, for example, Hammer, 1994; McDermott, 1993; White et al, 1995). Fuller and Unwin's (1998) reference to a study on apprenticeship, in which an apprentice engineer explained that she had never really understood mathematics until she became an apprentice where mathematics was taught in such a way as to be 'car-related', supports the above finding. Moreover, this apprentice wanted to know why schools could not teach maths in such a stimulating way.

5.13 Building confidence and demystifying science

The participants' presentations and interviews exhibited growing confidence and excitement, and keenness to seek out scientific principles underpinning daily life. For example, when Prins grasped Boyle's Law, he excitedly ran after me, exclaiming that though he had done the theory in school it was only now that 'it's in my head!'. This spontaneous reaction was re-experienced when Alfred excitedly brought his daughter's doodle-writing pad to confirm his feelings that the principles of both electrostatics and magnetism were operating in that technology. Again, developing student interest and spontaneous reactions were observed when Anand brought to the workshop a concise pocket encyclopaedia on science and technology, which he had painstakingly located from his attic. We were also very moved when he told us how proud he felt because for the first time he could discuss and help his daughter who was in high school with homework related to light and colour. Events like these made me appreciate and understand Lincoln and Guba's (2000: 179), words:

Classical social scientists would like to see "human phenomena" limited to those social experiences from which (scientific) generalisations may be drawn. New paradigm inquiries, however, are increasingly concerned with the single experience, the individual crisis, the epiphany or moment of discovery, with that most powerful of all threats to conventional objectivity, feeling and emotion. Social scientists concerned with the expansion of what count as

social data rely increasingly on the experiential, the embodied, and the emotive qualities of human experience that contribute the narrative quality to a life... (Lincoln & Guba, 2000:179).

5.14 Accessing the disciplinary discourse of science

The students in our study through their individual presentations and distinctly displayed shifts in discourse depicted by their increasing use of the specific science syntax used in its context, seems to support the notion of working out the meaning of an idea or science concept within the context of its use. This emanates from developing theories of learning. It also seems to support the neo-Vygotskian approach to the sociality of learning. The process, by means of its conscious introduction of concepts represented in its correct lexicon and applicable context, materialises the abstract syntax of science knowledge. Through a dialectical process from practice to theory and back to practice again, we believe we were able to make incremental shifts in terms of the zone of proximal development of our students. This leads us to re-assert the role of the educator as a crucial participant in the process of transformative learning. It is especially important within the context of the new outcomes-based education with its stress on a learner-centred approach briefly alluded to below.

5.15 The role of the educator in the learning process

In privileging an epistemological assumption about the constructed nature of knowledge, education department officials advocated a 'paradigm shift' from the previous teacher-centred approach associated with *apartheid* education to a new learner-centred approach in which children or adults were expected to engage knowledge, not as passive recipients of it, but as active participants in its shaping (Moll, 2002). Many of its critics were not against the old ideologically laden curriculum of the past, accompanied by the unequal power relations between

teacher and learner. Rather, they took issue with the loss of crucial content material through the negation of a syllabus advocated by the new 'paradigm shift', which they argued tended to work against thorough subject matter coverage, the conceptual advancement of specialised skills and concepts, as well as coherence in domain-specific or disciplinary knowledge (Reeves, 2002:5). Indeed, the belief that those students are capable of engineering the development of curricular knowledge on their own works from the assumption that they have some prior mastery of that domain specific knowledge. This may not necessarily be true, and, as Muller and Taylor (2002) argue, may act against, rather than for, students emerging from the legacy of *apartheid* education. However I believe that here again we seem to be moving towards polarising the two modes of learning.

The study demonstrates how during the initial phases, when the facilitator was in the process of gradually introducing and progressively building up the theoretical concepts, there was very little student-teacher interaction. However as he started integrating the theoretical concepts in application to their technologies, the lessons increasingly became more interactive, with students questioning the principles applied to the product/process nexus of their work. For example, during the phase of actually opening up the photocopier machine, as the discussion above has already noted, we were amazed at the interest of the students, who traced on paper the entire path of light depicting the correct angles of incidence and reflection. This they did of their own volition, working collectively and corroborating information with each other. I remember vividly the facilitator's comment that they were doing this "unasked for". There are strong elements of learner-centeredness at display here that seem to suggest that rather than conceptualising it as being oppositional to a teacher-centred approach it would be more informative to see it as lying on a continuum between the two modes of learning. The emerging trends suggest that conscious intervention, informed by the developing social-activity theories on learning, can challenge the rigid demarcation between work and the more formal knowledge domains.

5.16 Developing participants' technological literacy

In relation to the issue of technological literacy, I would briefly like to reiterate Gleeson's (1990) insights in relation to the nature of skills required of the new millennium economy quoted in sub-section 1.2 in this thesis, where he draws on Wellington (1987) to point out that, 'what industries needed were people with the abilities to develop new skills, to learn new knowledge, to acquire new concepts and theories and to adapt to technological change with enthusiasm and lack of fear . This was the essential meaning of technological literacy as opposed to technological skill. The work of both education and training was surely to provide people with the ability and enthusiasm to learn, to adapt to change and to be aware of, and at home with, new technology' (Gleeson, 1990:197).

In relation to the above comments, the discussion in this chapter has shown how through this social-cognitive oriented pedagogical process of integrating education to training, students were able to understand the deeper conceptual underpinnings of their practice. It needs to be noted that these deeper conceptual underpinnings were indeed general principles emanating from the formal disciplinary knowledge forms. The students were also able increasingly to articulate these principles within the relevant science and basic engineering syntax. This discussion has also shown how participants exhibited growing confidence, excitement and enthusiasm displayed in both the interactive nature of the learning process and in the seeking out of the science principles underpinning daily life.

Whilst this thesis was not about promoting economic rationality, I think it is informative to point out a development related to production, but also which shares certain characteristics with the issue of technological literacy. The development was related to the blurring of an image imprinted on paper. This was not only costly for the company, but a significant problem of industrial quality in a company which generally prides itself on the sharpness of its printed image. After numerous attempts that, for management, included tracing back from the 'machine minding' through to

the 'stripping', 'image setting' and 'graphic design' sections of the productive process, the problem was still not identified. The problem was found, however, after Anand, a student, suggested that the intensity of light generated in the plate-making machine was faulty. This aspect of the productive process was eventually looked into; his suggestion was subsequently found to be correct. The problem indeed lay with the duration and thus intensity of light generated within the 'plate burning' machine due to a fault in its exposure timing device. When asked how he knew this, Anand replied that his 'ideas and feelings' about the problem had been influenced by the science facilitator's comments much earlier in the course when they had briefly opened the machine. He explained how the ultra-violet light, with its shorter wavelength, emitted by the machine, directly affects the light sensitive coating on the aluminium plate. The importance of exposure time must be seen within the context of the intensity of the UV light emitted and its direct effect on the light sensitive coating, which in the final instance creates the image.¹⁶ This insight saved management both, production time and the expense of summoning an engineer from the urban area of Gauteng almost 300km away. The minders, with the help of a retired and very experienced lithographer hired by the printing company to assist during peak periods, installed a new timing device that regulated the intensity of light required for a clear image to be imprinted on the plate.

5.17 A Culturalist/Mentalist comparison of the learning process

I believe the nature of learning displayed above contains certain characteristics of the 'reflexive-learning' needed in late modern industrial societies, alluded to by Young (1998). It also seems to support a 'culturalist', as compared with a predominantly 'mentalist' or 'individualist' conception, of the learning process. This is the idea that knowledge consists of representations within the mind, or the idea that skill is the property of individuals. This is in sharp contrast to a social cognitive theory of learning that views the acquisition of knowledge as internal to the learners' ontology as socially engaged individuals, learning meaningfully only within context. This 'mentalist' or 'individualist' conception of the learning process has also been

strongly critiqued by Rogoff & Lave (1984:24-176) who argue that it emerges from a psychology drawn from an “ideology of rationality” which conceives knowledge as:

“... a set of tools’ stored in memory, carried around by individuals who take the tools (e.g. ‘foolproof’ arithmetic algorithms) out and use them, the more often and appropriately the better, after which they are stowed away again without change at any time during the process” (Rogoff & Lave, 1984:24; see also Lave, 1996:149).

She argues that that there is another sort of reason for pursuing a theoretical perspective on the social nature of learning. It is held that theories that conceive of learning as a special universal mental process impoverish and misrecognise it.

“Theories that reduce learning to individual mental capacity/activity in the last instance blame marginalised people for being marginal....It reflects and contributes to a politics by which disinherited and disenfranchised individuals, whether taken one at a time or in masses, are identified as the disabled, and thereby made responsible for their plight. It seems imperative to explore ways of understanding learning that do not naturalise and underwrite divisions of social inequality in our society.” (Lave’1996: 149).

Whilst British academic Lorna Unwin (1998) has gently warned against strongly polarising knowledge in the manner categorised above, the thesis tends to lend support to the latter stance stressing the sociality of learning. This chapter has drawn on situated cognitive theories of learning infused with a neo-Vygotskian methodological approach which stresses that:

the process of learning can consciously be advanced through the active relationship between the learner and phenomenon to be learned;
between the learner and co-learners in that context (as shown in chapter five)

between the learner and instructive conceptual knowledge often represented by a mentor or teacher, or (as this specific case has shown) a facilitator who learnt to see value in both instruction and facilitation.

This study also seems to support the neo-Vygotskian influences from activity theory which maintain that language acquisition is extremely context bound, and can thus be consciously expanded upon through the mentor – as this chapter five has certainly attested to. This process, as Daly and Mjelde (2002) comment, occurs in the ‘zone of proximal development’ – the necessary interplay between inductive, experimental learning of the subject, or ‘common speech’ as referred to by them, and the deductive generalising instruction of the teacher and the curriculum which helps expand understanding of generalised and abstract word meaning. Again this is supported by the findings detailed in this chapter five.

The important stated objects and findings of the thesis are detailed in chapter six which follows. As a result, the following discussion briefly outlines them below, and thereafter expands on the particular objective stated in chapter one related to the probing of a theoretical generalisability emanating from the link between technology-related tacit knowledge and the more formal and disciplinary knowledge domains of science and engineering. In terms of addressing the stated objectives outlined in chapter one, the thesis has, in the first instance, shown how the aim of designing a pedagogical learning programme was achieved in the desired way of being informed by developing situated cognitive theories of learning. The findings reflected through participants’ presentations showed also that the aim of deepening the conceptual underpinnings of their praxis was also met. The third stated objective in chapter one addressed the demystifying of disciplinary science and engineering related power discourses that inhibit access and occupational mobility, especially within the commonly found context of historically disadvantaged South Africans. This was achieved (albeit at basic levels) through the neo-Vygotskian applied theoretical insights with their stress on the learning of language and concepts within context.

The significance of the tutors' input to learning was also re-affirmed through this theoretically informed methodological design. The discussion will now shift its focus to the stated objective of probing the possibility that a theoretical generalisability can be drawn in terms of teaching and learning between tacit technologically-related working knowledge and the more disciplinary science and engineering knowledge domains. This is clearly a different question from saying that science and technology are linked, which, as chapter one has shown, is generally accepted to be the case. The question is rather, whether those who have so often spoken about this link, have actually seen the possibilities to use it to teach a worker whose work is embedded within technology the science, engineering and indeed certain mathematical principles underpinning the product/process nexus of work, in the way that this particular case study has done. This is the type of theoretical generalisability this researcher is referring to. This study has clearly established an epistemological link between these two knowledge forms, and, as a result, has shown that it was possible to teach from one mode of learning to the other. This researcher believes that this holds out interesting possibilities of replicating this study more generally, consciously reinforced by principles of science (Gamble, 2004; Mjelde, 1997).

5.18 Curriculum process issues

The discussion will now briefly comment on some curriculum process related questions relating to the epistemological link between workers' tacit technologically-related knowledge and broader formal science disciplinary knowledge. The experience in this case study revealed the sometimes tricky situation of designing coherence and progression into a programme of teaching science from technology. Clearly much more research needs to go into this. David Layton's work provides some very interesting insights related specifically to this issue. He has shown how, in some experimental situations, science education has moved in the direction of technological applications, both as contexts for the understanding of scientific principles and as illustrations of how science relates to action in industry and everyday life (Layton, 1993: 65). Referring to similar complex curriculum design processes related to developing the relationship between science and technology,

he comments that “this might be achieved by the sequencing of science curriculum topics to match the needs of technology, by cross-curricular activities or by the presence of a science teacher on the technology teaching team” (Layton, 1993: 76).

In some important ways our approach resembled that of Layton’s, briefly detailed above. After deciding upon the principles to be taught, the facilitator identified key concepts around each principle, which it was believed the students should be taught to enable them understand the principle as it works as a whole. For example, in the first principle related to angular acceleration and forces, the candidates were shown angular acceleration working through the acceleration and deceleration of the gears and cogs in their machines. The concept of torque was demonstrated through the work of loosening and tightening bolts with different length of wrenches. Force was explained in relation to the exertion of human, mechanical and electrical energy expended to shift or rotate a gear within their machines. Concepts about speed were illustrated as the actual distance travelled through the number of rotations of circular objects divided by the time taken. Also, a concept such as velocity was not too difficult to teach because it denoted distance travelled in a particular direction divided by the time taken. Acceleration was thus the rate of change in velocity. The other concepts related to gas laws, light and colour, optics and electrostatics such as pressure, volume, properties of lenses, and reflection of light, were also developed through their understanding of it in operation within their product/process of work (as reflected above). Most of these key concepts were extrapolated from their work processes, and taught to the students before the principle as a whole was put together in its working through their product/process nexus of work.

5.19 Policy conceptual incoherence

The discussion now focuses on some conceptual issues related to this central theme of meaningfully integrating education and training. Through critical discussion it will attempt to illuminate problems related to the conceptual coherence of the South African ET policy emanating from the literature reviewed in the historical chapter two,

with the hope of contributing towards a more conceptually coherent point of view. This requires a review of the important issue related to the organisational principle underpinning the integration of education and training, discussed in chapter two. It was shown that this integration was to be effected through the linking of 'core' and 'specialised' modules.

Core modules such as languages, maths, science, technology and social studies, were to be made compulsory because it was believed that they would contribute to the all-important generic and polyvalent skills required of the post-Fordist economy. These were skills such as those found within the industrial training systems of the consensual economies of Europe, and in particular those of Germany.

However, the discussion intends to show that the skills within the German industrial training system were rooted in cognitive theory. This was in sharp contrast to the South African version, which has tried to achieve the teaching of 'core' modules in a totally de-contextualised manner. In a similar reflection on the nature of 'core' skills in Britain, Wolf (1991:193) maintains that experiments with core skills have been poorly grounded in cognitive theory because they have been attempting to describe generic skills in a 'free-standing way', transferable anywhere and separated from the specific knowledge contexts in which generic skills arise (Wolf 1991: 192-193). In a similar critique of these 'core' or 'critical-cross-field' outcomes, as these skills have come to be called, Breier (1998:93) writes that there is concern internationally about the emptiness of the generic skill concept of current theories about the situated nature of all knowledge and learning.

This is not to say that transfer is impossible. She argues that there is a search for an alternative concept, which will explain what happens where it does occur and facilitate that process where it does not. However, she expresses doubt about 'whether any skills of any note can be independent of context', and, moreover, whether transfer occurs as often as is generally thought (Breier, 1998:94).

In other words, she takes strong issue with the principle of generic skilling required for transfer across contexts. As chapter two shows, this has been the explicit aim of the South African education and training policy makers since 'generic skills' has been presented as the best possible way to prepare workers for the demands of flexibility required of the new post-Fordist production paradigm.

The notion of 'generic' and 'polyvalence' emanates from the German Industrial Training system (as chapter two has shown), and the reason that its emulation is so sought after is the fact that the German enskilling process has given its economy the edge over most other economies under the new competitive international economic conditions. The nature of the country's high-quality ET system has played an important role in this, as pointed out in chapter two.

However, South African education and training policy makers did not realise that the German Industrial Training System is well embedded within situated cognitive theories of learning, while theirs is certainly not. This needs further elaboration. For example, the notion of 'polyvalence' has been interpreted within the British and South African contexts as the development of broad generic, transferable skills, which are thought to develop through the rotation of workers across different jobs. It has been adopted from Maurice *et al's* (1986) study of the rotational aspects of the German Industrial Training System, which is linked to high-quality theoretical training. A qualifications structure develops from this process (as outlined in chapter two). Maurice *et al's* (1986) study is quite explicit in stating that this takes place within Germany's Industrial Training complex where:

“...the fact that the industrial labour market in Germany features a limited number of basic occupational types, employed by all industries and based on early apprenticeship training is favourable to the development of polyvalence

since the skill base on which firms may draw tends to be relatively homogenous" (Maurice *et al*, 1986:68).

It becomes clearer from this information that polyvalence emanates from within Germany's Technical Industrial Complex where, understandably, the skill base tends to be relatively homogenous, therefore fostering a limited number of basic occupational types. They explicitly mention that it is within this given productive organisation that workers are rotated from position to position (Maurice *et al*. 1986:68). As the following quotation shows, the theoretical component of the above practical work also emanates from this very context.

"... the span of skill on German industry is relatively homogenous. This promotes broad co-operation between '*farachbeiter*'; '*meister*' and engineer based on their common background of theoretical and practical knowledge. Such co-operation is found not only within production departments but also between production and engineering or other support departments that employ personnel sharing in this common fund of technical knowledge" (Maurice *et al*, 1986:101).

It becomes clear that theory is intricately related to practical knowledge, which emanates from "this common fund of technical knowledge". Workers are rotated or 'shifted' from job to job within this same context, and the German notion of 'polyvalence' and 'generic' or 'flexible' skills emanate from the above context, and its meaning is surely rooted within this social context. This is in stark contrast to the South African ET policy which has totally neglected the specificity of context in their conception of the notion of 'generic skills'. This is what this researcher means when he says that the German enskilling process is rooted in developing social cognitive theories of learning. Moreover, as can be seen from the above quotation, theory and practice are progressively linked to a qualifications ladder. There is a clear articulation between '*facharbeiter*' (skilled worker), '*meister*' and engineer precisely because their share in 'a common fund of technical knowledge', which is then

progressively related to theory upon which a qualifications system has been historically developed and that can dialectically interact with the work-organisational process. This is what is meant by Maurice *et al*'s (1986: 68) statement that "the notion of qualification implicit in a given work system is revealed by the sort of polyvalence it fosters" (Maurice *et al* 1986:68). It is in this sense that the ELM integrates so successfully with the ILM and empowers workers with a skilled qualification. This is highly respected within German society as a whole, and gives their export products, underpinned by innovative technology, the economic edge within the international community. It is from this that, in essence, the debate derives. This researcher believes that their successful technical know-how is rooted in the context of an apprenticeship system in which tacit technical knowledge is meaningfully linked to its theoretical scientific base. The enskilling system is clearly rooted in socio-cognitive theory.

So Breier is quite right when (as recorded in chapter one) she draws from the perspectives of socio-linguistic theory to pose the question to South African ET policy makers:

"If knowledge and skills are linked as closely to context and mode of learning as these theories suggest, how can competence acquired in one context be equated with (or recognised or accredited) competence acquired in another?" (Breier, 1998:122).

In other words, it is difficult to equate competencies between the two – as the NQF structure tries to do – precisely because their practical and discursive traditions are so different from one another.

This is exactly the argument made here. The South Africans claim they have drawn from the broader macro-institutionalist perspective, strongly influenced by Maurice *et al*'s (1986) comparative study between the German and French industrial training

systems. Whatever the case may be, it certainly looks as if there has been some incoherence of conceptual applicability, in the sense that whilst the German system is rooted in social-cognitive theory, the South African Qualifications Framework, which has interpreted the notion of generic skills in a totally free-standing way devoid of context, is certainly not. A possible reason could be found in the statement cited by Kraak (1994) and drawn from Finegold et al (1990):

The qualifications system associated with the unified model has a central characteristic – to facilitate the maximum mobility of learners throughout the entire ET system, and in particular, mobility across the traditional vocational and academic divide (as cited in Kraak 1994: 368-369).

It seems as if in this noble quest for equity the principle of conceptual coherence has been marginalised. However, whilst academic critique has been strongly opposed to this incoherence (see chapter one), no one has yet offered more plausible alternatives. This researcher feels that the possibilities of a more conceptually coherent alternative, which certainly will require deepened research, do exist. Looking at some aspects of neo-Bernsteinian theorists could offer some insights into this. Here again I briefly draw on Breier's (1998:96) work. She brings our attention to the fact that, even within the vertical discourse, Bernstein has distinguished further between the hierarchical knowledge structure (detailed earlier in this thesis) which takes the form of an explicit, coherent, systematically principled and hierarchical organisation of knowledge – as in the natural sciences – and the horizontal knowledge structure amounting to a 'series of specialised languages each with its own specialised modes of interrogation and specialised criteria as in the humanities and social sciences'. Subjects such as economics and sociology also fall under this categorisation. Importantly, she draws on Bernstein to inform us that horizontal knowledge structures (which as noted above, actually fall within vertical discourse) share certain common features with horizontal discourse, such as segmental structuring and a closer relation between discourse and knowledge structure than in hierarchical knowledge structure (Breier, 1998:96).

A very good example of the possibilities of such closer relationships between horizontal knowledge structure and discourse (as discussed above) can be seen historically in both the economics and politics of trade union education! It is certainly the case where many working class people, as is prevalent in South Africa, are able to speak and understand sociological and political-economic syntax. This, I would argue, is an example of learning rooted in the discourses and practices of the sociology of work. This specific example, as well as that of this case study, shows the possibility that learning rooted in social-cognitive theory can overcome the divide between the work of the hand and the work of the mind, between practice and theory. Not unlike Germany, South Africa could root its qualifications structure within the context of developing situated cognitive theories of learning. This researcher believes that this is a more conceptually coherent option that is worth considering and that offers the possibility of affecting significantly more working class people, who have no easy access to post-compulsory education (as chapter two has shown),. The discussion in the above sub-section resonates well with both Kaplinsky (1991) and Kaplan's (1991) observations and recommendations about South Africa's lack of that important indigenous technological capacity (ITC) compared with newly industrialised countries such as South Korea, where this capacity has allowed them to compete favourably within the competitive international economic conditions of the new century. For these countries, acquiring this capacity involved moving along what these writers call a 'technological learning curve', a process which involved the transfer of technological expertise embodied within imported capital goods to human labour (disembodied technology) through extensive education and training (ET), innovative work organisation and learning – by doing technological adaptation. This, they argue, contrasts starkly with the South African reality, which has entailed the more passive buying of foreign technological know-how requiring little local adaptation. This researcher believes that the discussion related to the nature of training, which involved moving from the tacit to the scientific and back again, to effect technological literacy as it relates to workers – especially within the technical industrial training complex (not unlike Germany's) – can complement the nature of the 'extensive ET', referred to by the academics mentioned above.

CHAPTER SIX

Conclusion

6.1 Summary and Challenges

The initial chapter of this thesis traced the changes in post-*apartheid* South Africa's educational policy to the process of globalisation as well as to the emergence of post-Fordism in advanced capitalist economies. This economic paradigm, characterised by technological and industrial innovations combined with organisational changes to ensure that economies can compete successfully in world markets, does so on the basis of trade in value-added manufactured goods. It was shown how in its relation to education, post-Fordism required a highly skilled labour force that was able to employ the new technologies and add value to goods and services. At the heart of the new production paradigm was the notion of 'continuous innovation' with its implication of skilled workers constantly adapting existing technology through incremental innovative steps. It had also drawn on South African academic Kraak (1994), whose writings strongly influenced both ANC and Cosatu's educational policy process to argue that this notion of 'continuous innovation' was highly dependent on the presence of two knowledge forms in society and work – an abundance of formal (scientific and technological) knowledge and skilled worker 'know-how' or tacit knowledge.

Drawing on insights related to the above, such as that of Gambles (2002), as well as Gibbons (2000), the chapter argues that the challenge is to effect a deeper and more meaningful relation between tacit or working knowledge and the more formal scientific and technological knowledge domains. This was necessary for the purpose of innovation as well as the ability to adapt and respond quickly to the rapidly changing nature of technology under post-Fordism. The implication was that, in sharp contrast to job-specific or narrow Taylorist oriented enskilling process reminiscent of South Africa's past industrial training system, the new skill needs

under post-Fordism now require the worker to understand the deeper conceptual underpinnings of his practice. This was to be instituted through South Africa's new learnership programme. In this case it entailed understanding the scientific principles underpinning the product/process nexus of work.

The chapter shows how these conditions have had strong policy implications for the integration of education and training in South Africa and internationally. These developments, as has been noted, came under strong attack from a left critical discourse that had taken issue with the policies' neo-liberal underpinnings of subjugating education to the dictates of capital. It was, however, noted that such an integrated system had a particular significance for South African trade unionists. This system offered an alternative to the divisions that were such a dominant feature of racial capitalism by providing for the possibility of occupational mobility through training opportunities that had been systematically denied to black workers under *apartheid*. The new possibilities of linking tacit to scientific knowledge, and theory to practice through integration of education and training would thus provide the capacity to bridge the social stratification related to race, class and gender prevalent in the racial economy and maintained and mediated through high and low status knowledge forms. Moreover, as the historical chapter two also shows, integration of education and training as well as the labour-market proposals initiated by the Cosatu/ANC alliance during the early 90's could not simply be collapsed into neo-liberalism. This chapter has shown that *apartheid* capitalism was founded on a range of institutional mechanisms that acted to solidify the primary class, and that inequalities emerged historically. The chapter which has strongly drawn on Kraak's (1994) segmented labour market thesis has shown that two such institutional mechanisms were racially segmented labour markets and racially fragmented education and training institutions. These social institutions played a key role in class formation by effectively excluding the large majority of South Africans from further opportunities in the educational system and occupational structure. It has shown how Cosatu's proposals for active labour market policies and a unified education and training system were critical components of a reconstruction programme which aimed to dilute these structural features of racial capitalism. However, as this chapter also shows, the important condition for enskilling for international competitiveness as well as for worker emancipatory potential in terms of occupational mobility and in

terms of easing the class divide between those who work with the hand and those who work with the mind depended on the meaningful or deeper relationship between theory and practice, education and training. This was in sharp contrast to the narrow and Taylorist work-specific enskilling of the past. As this chapter and the thesis as a whole demonstrates, this was important for balancing the tension between equity and development. It was noted that it was within this conceptual context that this researcher ventured to study the relationship between theory and practice as constituted in the learnership. The case entailed a group of workers studying lithography within the designated trade of machine minding. In keeping with the theoretical underpinnings of the study a site was chosen where the product/process nexus of production was strongly underpinned by principles of science.

Preliminary research gradually convinced this researcher of the increasing vocationalisation of this learnership programme. The outcomes-based pedagogy specified mainly work oriented learning outcomes in unit standard format without reference to any of its underpinning concepts. There was thus no effective and meaningful relationship between the tacit and the scientific within the context that science and technology, together with mathematics and languages, were identified as part of the critical components considered important for 'generic' learning within all learnerships as outlined in an outcomes based instruction and assessment booklet printed by the Printing, Newspaper and Packaging Industries Education and Training Board (Undated: P.11). *The Umalusi Report* (2007) on the quality of the 'fundamental' component of qualifications in general and further education and training also raised the problem related to the confusion about the way these generic subjects should be integrated because of the fact that many Setas were teaching them either in a de-contextualised manner or indeed not at all. This was disturbing in view of developing research that argued that learning was extremely contextual. Indeed, those administering the learning process showed no awareness of new developing theories of learning that stressed the situated nature of cognition. This particular learnership lacked any conception in terms of linking the tacit to the scientific. As the chapter also shows, occupational mobility through the NQF towards machine minders' mechanical and electrical engineering-related occupations depended upon prior induction into these science-related knowledge fields. Workers were thus disempowered in terms of occupational mobility. The narrow enskilling

process of the theory/practice relationship under the learnership was restrictive both in terms of its redressive aims of occupational mobility and worker empowerment, as well as in terms of the economic aims of enskilling for global competitiveness and technological change. These are both well articulated aims of the NQF. It followed that the new enskilling process did not quite address its advocated epistemological and political aims of redressing equity and worker empowerment. The significance of this needed to be seen within the context of the political economy of knowledge debate, where the divide between the work of the hand and the work of the mind deriving from the development of capitalism has historically differentiated workers in terms of race, class and gender.

Concerns were also raised in terms of both pedagogy and epistemology emanating from the more general terrain. It had shown how some critical educationalists had taken issue with both the marginalisation of the teacher's role, as well as the loss of crucial content material, through the negation of a syllabus advocated by the new 'paradigm shift' from the previous teacher-centred approach to a new learner-centred approach advocated through outcomes-based education and training (OBET). Their argument that the negation of a syllabus tended to work against thorough subject matter coverage, the conceptual advancement of specialised skills and concepts, as well as coherence in domain-specific disciplinary knowledge seemed to support some of the concerns of this research at case study level. This is because only a narrow conception of work-based skills was articulated as the outcomes to be achieved. The chapter also draws on Fuller and Unwin (1998), who argued that a programme structured in terms of outcomes rather than processes was liable to produce inconsistent learning experiences, which could lack both 'content' and the sort of pedagogy leading to 'expansive' learning defined as deep reflective learning obtained via a transmission pedagogy which need not be autocratic in nature. Both these concerns of deep reflective learning and transmissions pedagogy were also manifested at case study level where an outcomes based approach to learning lacked deeper theoretical content. Its philosophically-underpinned acquisitions-oriented pedagogical process also marginalised the role of the teacher. An equally crucial point, debated at national level, was brought to our attention and certainly informed the micro level as well. This was related to concerns raised about the epistemological differences between the nature of the internal structures of working

knowledge and academic knowledge. In an appraisal of a *Report of the Study Team on the Implementation of the NQF*, commissioned by the Department of Labour to look particularly at problems bedevilling the NQF, it was found that the 'principal of equivalence' between disciplinary learning and workplace learning was a major contributing factor inhibiting the meaningful integration of theory to practice within the context of the NQF structure. These writers drew on the Bernsteinian theoretical distinction between two discursive forms, characterised as horizontal and vertical discourse, to argue that these knowledge forms were epistemologically and sociologically distinct. These neo-Bernsteinians emphasise that formal and informal, tacit and scientific forms, of knowledge are structured differently and therefore are associated with different learning processes or modes of learning. Describing the two knowledge domains as 'epistemologically' and 'sociologically' distinct tended to present them as mutually exclusive, which further polarised the mental/manual divide. At issue was its implication for the division between high and low-status knowledge forms.

The thesis argues that this was open to challenge within the context of literature that suggested that in university undergraduate physics courses, quantitative research studies had shown that even though students apparently master the (de-contextualised) physics principles (as evidenced by good performance in traditional tests and examinations) they often, in fact, had poor conceptual understandings of the principles, and were unable to apply these to real world, everyday contexts. Moreover, as is also argued, despite the hierarchical nature of physics knowledge in terms of its conceptual coherence, the research showed that students' knowledge of topics in undergraduate physics courses tended to be fragmented and disjointed. The following sub-sections outline the nature of responses formulated to meet the challenges at both the level of the individual case as well as at the more general level. It starts with the more general terrain which shares strong similarities with problems encountered at individual case study level.

6.2 Formulated responses to challenges

This dichotomy between de-contextualised and contextualised knowledge was particularly problematic because of the need to link tacit working knowledge to the

knowledge domain of science and technology to create the requisite skill needs in late industrial society. This debate needs to be seen within the context of the prominence given to maths and science in a new age of science and technology's relationship to global economic competitiveness. These concerns also relate to the situation in South Africa where previously disadvantaged students struggled to master the curricular version of its rigorous language of formal education where proficiency is an entrance requirement for occupational mobility. It was argued that, in this way, it constituted symbolic capital and conferred symbolic power. It had thus been identified by concerned educationalists as an exclusionary mechanism needing radical reform.

This researcher noted in the earlier chapters that while he may have agreed with Young (2003) that certain work-place occupations may not need deep conceptual learning, he argued that Young in that very 'appraisal report' does not limit his argument to this. 'Technicians' who may be aspiring to become engineers were also included (Young, 2003: 12). This researcher took issue with the broad generalisation that included technology-related work occupations. The significance to this objection needs to be seen within the context of thousands of workers in this country being engaged in technology-related work roles, and the possibilities that a study of this nature - generating a link between the tacit and the scientific through the process of applying socio-cognitive theories of learning to the educational process – may hold out in terms of learning possibilities for them.

My questioning of this Bernsteinian-derived divide between tacit technically related working knowledge and the more formal scientific and engineering related knowledge forms emanated from anecdotal experience of technology related work experience (as outlined in the theoretical chapter) that showed the possibilities of bridging the epistemological-based divide between the two modes of learning. As has been outlined, it was as a result of the quest to deepen my understanding of this experience, that I realised that it identified very strongly with developing theories of learning related to situated cognition. It was indeed this exciting possibility that initiated this study. A deepened theoretical understanding of my experience (detailed in chapter three) convinced me that one could deepen one's conceptual understanding through a conscious dialectical move from practice to theory and back

to practice, the one informing and being re-informed by the other. It was argued that the process of learning takes place through consciously bringing to the worker's consciousness the conceptual underpinnings of his/her work. This is especially true of technology related work occupations because they are underpinned by principles of disciplinary science. Thus what is usually abstract becomes concrete. This identified very strongly with developing theories of learning that argue for working out the meaning of an idea within the context of its use, and against the abstract de-contextualisation of knowledge as taught in schools.

I considered the prospect of testing these possibilities important because a very significant proportion of working class people are engaged in technology related work. I also saw in this the chance to de-mystify power discourses that limit occupational mobility through applying neo-Vygotskian insights that stressed learning formal concepts and language within relevant context. These insights were developed through the iterative process between anecdotal experience and developing socio-cognitive theories on learning, as detailed in the theoretical chapter three. As a result of this the Bernsteinian-derived epistemological divide related to modes of learning continued to puzzle me. This was especially because technology related praxis was underpinned by principles of science. A reading of Bernstein's elaboration on the theoretical distinction between horizontal and vertical discourse taken up in his later work did not directly address or characterise praxis related to technology within the context of his distinction between these different knowledge forms. As the chapter shows, a clue was found to the puzzle after reading Gamble's (2002) work on craft knowledge where she innovatively applied Bernsteinian theoretical principals to reposition craft knowledge within the horizontal/vertical divide. I drew on these insights to position technology as a modality of vertical discourse characterised by a horizontal knowledge structure and tacitly transmitted. This then identified an epistemological link between the specific vocation under study and the more formal vertical discourse of disciplinary science. As a result one could now transmit or teach, and thus bring to the level of workers' consciousness, the principles underpinning their practice. It was argued that re-positioned in this manner, the different modes of learning could be brought to collaborate with one another. The empirical chapter detailed how the specific technologies are operationalised procedurally through disciplinary science principles themselves and

in this way showed an epistemological link between the tacit and scientific knowledge domains in this study. It thus ruled out any notion of a 'contrived realism'. It was on the basis of this calculated assumption, informed by the logic outlined above, that this study examined the possibility of establishing the epistemological link between the tacit and the scientific through the process of explicit transmission in the form of conscious intervention methodologically influenced by an action research oriented learning programme. The pedagogical process was underpinned by newly developing theories on learning. In this way the study addresses the polarisation between the mental and the manual, created by the argument that because of the epistemological differences between the tacit and the scientific, their respective modes of learning also differed.

A second problem that needed serious consideration was the difficulty that students encountered in terms of understanding formal scientific syntax. These resembled wider general trends, as is mentioned in earlier chapters, where, in relation to these formal discourses, historically disadvantaged students struggle to master the 'curricular version of its rigorous language'. As previously mentioned, verbal proficiency is an entrance requirement for occupational mobility. In this way it constitutes symbolic capital, and confers symbolic power. Thus, the problem in understanding the difficult syntax of these formal scientific discourses has been identified by concerned educationalists as an exclusionary mechanism needing radical reform. There was also the important concern of a phobia by the candidates in this study about learning science, maths and engineering related subjects. These are also concerns related to the more general terrain. Castles (1991:13) article on the theme of adult education as it relates to a subject such as maths shows that these are indeed real concerns related to the more general terrain. In a similar reflection, Norwegian academic Mjelde (1997) has also identified the nature of this phenomenon of the fear of these formal discourses as a crisis of confidence, in their ability to learn. In relation to the concerns expressed above, the difficulty I had to consider was related to the concern of teaching general formal syntax from the particularities of practice. Our approach to addressing this challenge was strongly informed by neo-Vygotskian insights, detailed in the theoretical chapter three, that stressed that language acquisition – and especially formal conceptually underpinned

language acquisition – was extremely context bound, and could consciously be pushed to more complex levels through the aid of a tutor. This takes place within the ‘zone of proximal development’ – the necessary interplay between inductive, experiential learning of the subject which gives rise to word sense, and the deductive generalising instruction of the teacher and the curriculum which helps expand understanding of generalised and abstract word meaning. As noted in the theoretical chapter, Daly and Mjelde (2002) refer to this as the relation between the learning subject and the speech registers or genres, which is always a dialogue where socially established meanings interact with the learner’s immediate meaning of the moment, and with a different, more formal and/or inclusive speech genre of the instructor, mentor and educational system. The implication is that cognition or understanding can be advanced further by expanding on the learner’s ‘zone of proximal development’ through structured teaching and learning. In relation to expanding on the ‘zone of proximal development’ the chapter also draws on Engestrom’s idea of ‘transformative’ learning, which retains a role for a theory of instruction entailing an explicit role for concepts and ideas which may be external to the community, but which may deepen the process of cognition. The question – and I think, challenge – that Mjelde and Daly posed, was whether one could bridge the gap between horizontal knowledge (working class ‘speech register’) and vertical discourse (the more ‘formal educational genres’ such as those found in the sciences). The chapter drew on Mjelde’s (1997) position that technology as praxis could provide an avenue through which one moves from the particularities of practice to the generalisation of theory. It is a process that entails extrapolating the deeper scientific principles underpinning the machine that the worker is personally engaged with, and, through a process of ‘semiotic mediation’, bringing it to the level of the worker’s consciousness.

The methodological slant of the thesis draws on ‘action research’ because of its abiding concern with social issues of justice, and in this way resonates well with the concerns raised in the political economy of knowledge debate within which the aims and objectives of this thesis are also grounded. The developing literature related to participatory action research, as shown in chapter four, also complements the theoretical underpinnings of the thesis which is related to the *situated* in contrast to

the *abstract* nature of cognition within the context of communities of practice – especially its stress that:

‘action research concerns actual, not abstract, practices’. Moreover that it involves learning about the ‘real material, concrete, particular practices of particular people in particular places’ (Kemmis & McTaggart, 2000:596).

These writers have also stressed its emancipatory potential in regard to this more obstinate nature about changing particular practitioners’ particular practices, if in any way deemed unjust, rather than focusing on practices in general or in the abstract. Their stress on the dialectical relationship between theory and practice, referred to in the methodological chapter, complements further the study’s theoretical underpinnings, which advocate the generalisation of theory from the particularities of practice. It draws on, among others, Kemmis & McTaggart (2000:598) to argue that participatory action research involves ‘reaching out’ from the specifics of particular situations, as understood by the people within them, to explore the potential of different perspectives, theories and discourses that might help to illuminate particular practices and practical settings as a basis for developing critical insights and ideas about how things might be transformed. Equally, they argued, it involves ‘reaching in’ from the standpoints provided by different perspectives, theories and discourses to explore the extent to which these provide practitioners themselves with a critical grasp of the problems and issues they actually confront in specific local situations. In this sense, as noted in the methodological chapter four, participatory action research aims to transform practitioners’ theories and their practices as well as the theories and practices of others whose perspectives and practices may help to shape the conditions of life and work in particular local settings.

The application of these insights to the action research methodology can be seen in chapter five where planning the new learning programme was slowly developed through an intense initial observation of the particular practices and understandings

of the participants concerned. In contrast to the narrow work-specific enskilling process that the participants were exposed to under the previous learnership, the action research learning process carefully identified the underpinning science principles, and extrapolated them from these immediate and specific practices. The teaching of these principles drew on social cognitive theories of learning infused with a neo – Vygotskian pedagogical approach. In this sense, the learning process was taken forward, not only through relevant conceptualised learning, but also through the participating role of the teacher, and the conscious gradual and progressive introduction of new concepts. The process, by means of its conscious introduction of concepts represented in its correct lexicon and applicable context, materialised the abstract syntax of science knowledge. As chapter five demonstrates, this was evidently depicted by participants' increasing use of the specific science syntax articulated in their presentations. It also seems to support the notion that relates to working out the meaning of an idea or science concept within the context of its use which emanates from developing theories of learning with its emphasis on contextually bound learning. It also seems to support the neo-Vygotskian approach to the sociality of learning. Through a dialectical process from practice to theory and back to practice again, I believe I was able to make incremental shifts in terms of the zone of proximal development of our students. This led me to re-assert the role of the educator as a crucial participant in the process of transformative learning. It was especially important within the context of the new outcomes-based education with its stress on a learner-centred approach. This particular chapter also stresses the importance of re-conceptualising the learning process within a socio-cognitive approach, as opposed to a fundamentally 'mentalist, or 'biological', view of the learning process. Finally, this thesis draws on both its historical chapter as well as its empirical findings to raise some important problems related to the conceptual coherence of South Africa's new integration of education and training policy. It shows through argument that the integration of education and training stressed through this policy was not rooted in socio-cognitive theory, and argues that a more conceptually coherent alternative should root itself in new emerging socio-cognitive theories on learning.

NOTES TO EMPIRICAL CHAPTER

1. My observation during preliminary fieldwork prior to intervention programme at Dynasty Printers. March 2003.
2. Anand's comment noted during the explanation of angular rotation and speed in relation to their machines. Noted in July 15, 2003.
3. During my mathematical explanation of 'angular displacement' to Prins, at Dynasty workshop – Mokopane, 18th of July 2003
4. Observed during course of workshop presentation, 11 June 2004 -19 June 2004.
5. Comments noted by a member of the management team during the lesson on the engineering-related principle of torque, Dynasty Printers – Mokopane, 16th July 2003.
6. Noted a comment made by Prins, Dynasty Printers workshop – Mokopane, 8th July 2003.
7. Facilitator's comments noted during the course of opening the photocopy machine with students, E. Essop & Co. – Mokopane, 21st September 2003.
8. Noted Alfred and Anand's comments during the course of workshop lessons that dealt with colour, Dynasty Printers – Mokopane, July 2003.
9. Noted during lessons on the historical overview of the atom, Dynasty Printers, September 2003.
10. Collective Interview, Prins's house – Hamanskraal, August 2004.
11. Noted during the course of Anand's video presentation of the principle related to light, lenses, colour and electrostatics as operationalised in the photocopy machine. Videotaped by Gert and Sandra de Graaf of No Limits Video CC, Dynasty Printers – Mokopane, 19th June 2004.
12. Collective Interview, Prins's house – Hamanskraal, August 2004.
13. Collective Interview, Prins's house – Hamanskraal, August 2004.

14. Collective Interview, Oasis Hotel – Mokopane, July 2004.
15. Collective Interview, Prins's house – Hamanskraal, August 2004.
16. Informal Interview with Anand, Anand's House – Mokopane, August 2004.

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