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WHAT COUNTS AS MATHEMATICS?

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WHAT COUNTS AS MATHEMATICS?

Technologies of Power in Adult and Vocational Education

by

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Monash University,
Victoria, Australia

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I would like to acknowledge the inspiration and guidance from my friend and mentor, Alan Bishop; the continuing intellectual engagement with members of Adults Learning Mathematics; the assistance and encouragement from Michel Lokhorst and Irene van den Reydt at Kluwer Academic Publishers; and especially the unfailing support of my husband, Paul, in everything I do.

This book is dedicated to the loving memory of John Fauvel, 1947-2001.

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INTRODUCTION

JÜRGEN MAASS & WOLFGANG SCHLÖGLMANN

THEORY AND PRACTICE OF MATHEMATICS EDUCATION FOR ADULTS

Our world is dominated by technological developments: The philosopher Heinz Hülsmann wrote that "Atom, Gen and Bit" are the three basic principles now (see Hülsmann, 1985). Each of the so-called new technologies is based upon mathematics: The first computer was built as a part of the Manhattan Project to calculate models of the atomic bomb. The human genome project uses computers very often to find out the structure of the genome. And computers are mathematical machines, materialised mathematics.

Social organisations, companies, and not least governments use computers to process information. A precondition for this is to formalise the social or economical structure which "produces" the information. This formalisation is a type of mathematisation, too. The social and economical models of organisations or companies are a part of the process of mathematising the world.

Last, but not least, mathematics is a part of everyday life and work. People handle money, buy things, do handywork at home (measure areas to paint, and so on). All together, mathematics is not only the basis for technology, economy, work and everyday life, but a part of our culture.

It seems clear that everyone in our society should know more about this. Learning mathematics in the traditional way is not enough. But the tendency in school (enforced by many governments) is not to learn more and different aspects of mathematics (for example, modelling or statistics) but to learn less. Research in many countries shows that people forget most of the algorithms they learned at school. They are left with the feeling that mathematics is useless. And they do not like mathematics because they remember a lot of bad situations at school.

Mathematics education for adults is very important in this situation. Mature people have to learn what they did not learn at school or what they need to get a (better) job. Younger people would like to reach higher formal qualification levels in order to have better chances in life. And all people (as citizens) should know much more about mathematics in our society. This is not only helpful to get more money or a better job but also to have more chance of taking part in political discussions. Democracy depends upon understanding the world we live in.

Mathematics education for adults should not repeat the past mistakes of school teaching. Adult learners have different knowledges and different abilities. In most mathematics courses or open learning situations adults should primarily get the feeling that this is not a repeat of the typical school situation that served them badly in many cases. New and better ways of teaching are necessary.

It is a very important task for all teachers to find such new ways. Good mathematic educators find such ways. But only a very few of these good teachers start to communicate about their ways of teaching. There is very little literature about good ways of teaching mathematics for adults.

We think that there are several reasons for this:

- In many countries teaching mathematics for adults is not a primary occupation but an additional job for people with other formal positions such as engineer, teacher at school, university students or even literacy teachers.
- Only a very few teachers reflect on their work as researchers and then document it for the sake of others. This would be additional and unpaid work for them.
- Only a very few university mathematics educators are working in the area of mathematics education for adults. Most of them are only concerned with teaching at school.

Dr. Gail FitzSimons is a very positive example of a teacher who has started to reflect on this situation. She has published many papers on its different aspects, and this book gives a very good overview. It shows the actual status of international discussion, giving a detailed analysis of the situation in Australia as an example of the (potential) situation in other countries with similar political orientations. In short: Everyone who starts working in and thinking about the field of adults learning mathematics should read this book.

REFERENCE

Hülsmann, H. (1985). *Die technologische Formation-oder: Lasset uns Menschen machen.* Berlin Verlag Europaeische Perspektiven.

PRELUDE

0.1. A PERSONAL VIEW FROM THE MARGINS OF MATHEMATICS AND VOCATIONAL EDUCATION

Positioning is often discussed as something which is natural, authentic, timeless, and essential; to fully explain and categorise (Arber, 2000). Yet as I categorise myself professionally as a Technical and Further Education (TAFE) teacher and (neophyte) university researcher I realise that firstly, I am much more than these and that, secondly, each is necessarily changing the character of the other. As a TAFE teacher I specialise in mathematics, statistics, and numeracy subjects, and as an academic author my interest is primarily in research as it relates, directly or indirectly, to mathematics education in the Australian vocational education and training sector. My research interests, however, extend far beyond this. As a researcher, I have come to the realisation that, although my efforts are applauded by some fellow mathematics and vocational educators, this has placed me on the borderland (Gee, 1994) in terms of my status as a TAFE teacher and, to a diminishing degree, as a mathematics education researcher.

Drawing upon Henry Giroux's (1994) comment on borderland crossings (made originally with reference to ethnicity), identities are (re)fashioned in relation to the shifting terrains of history, experience, and power. It has become generally apparent that TAFE mathematics teachers in Australia do not feel valued *qua* teachers. What has brought about the change in TAFE mathematics (and other) teachers' morale, from a zenith, from the mid 1970s through early 1980s, to the widespread levels of despondency? What might be the effects on teacher-researchers such as myself of the comparatively lowly valuations placed upon their research within the sector although not necessarily outside of it? Might these developments be harbingers or reflections of changes in other sectors of education, in other countries?

If part of positioning is having one's identity defined, as Ruth Arber (2000) suggests, through articulations and silences, then there are many silences in the TAFE workplace. For example, these silences include the pedagogical (as opposed to administrative) issues of day-to-day teaching and learning, career structures for subject specialists, and a lack of transparency that inevitably accompanies the transition of education from a public good to a competitive industry.

One aim of this monograph is to tease out some of the many seemingly paradoxical issues that currently confront TAFE mathematics teachers in Australia — and, potentially, mathematics teachers elsewhere —, continually reforming their identities, in order to understand the conditions which contribute to their generation and which sustain them. Although the particular situation of TAFE mathematics teachers in Australia is necessarily unique according to the social, cultural, historical, and political contexts, readers from other sectors and other countries, and even other disciplines, may find resonances in the generalities.

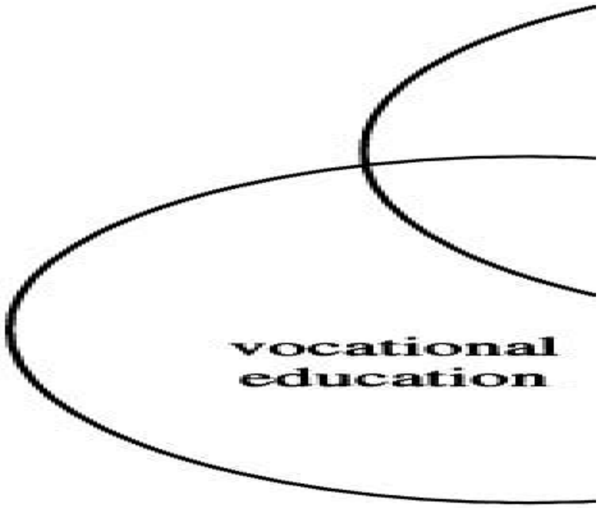

Figure 0.1. ***On the borderlands in educational research.***

As illustrated in figure 0.1, my work is also on the borderlands of three subfields of educational research: *mathematics* education, *adult* education, and *vocational* education — connecting all three. Perhaps it is due to these borderland crossings that my research is often located at the margins of each of these research communities.

A positioning such as my own can, however, be turned to advantage in that it compels the researcher to draw on a broad range of literatures which inform the various subfields of education; each of these discourses (mathematics, adult, and vocational) has broadened my own horizons; and of course they are not mutually exclusive. This growing trend towards interdisciplinarity in educational research enables the cross-fertilisation of ideas, the apprehension of new shades of meaning and insights. However, mathematics remains my primary discipline and mathematics education the central focus.

Consonant with recommendations from the Organisation for Economic Co-operation and Development [OECD] (e.g., Kogan & Tuijnman, 1995), Australian educational researchers (e.g., Porter, 1997; Sachs, 1998; Yeatman, 1996) exhort collaboration and co-operation between various members of the educational community (e.g., teachers, academics, union officials, administrators, and policy makers) on shared agendas. These actions are taken by Judyth Sachs as a means both to confront the uncertain times in which we live and to take advantage of the availability of possible new research spaces. By its very nature, vocational education research must extend this notion of co-operation and collaboration to industry, although it can sometimes be problematic in who actually speaks for industry at large; the research agenda should also be extended to include students in adult and vocational education. Damon Anderson (1997a, 1999a) has argued forcefully that the claims of Australian vocational education students as citizen-learners or as consumers be included in policy considerations, instead of having their interests conflated with the needs of business enterprises. As will be elaborated in chapters 5 and 6, Australian TAFE teachers have also been largely excluded from matters of policy affecting the formulation of research priorities and projects.

As a TAFE teacher of mathematics subjects working with vocational and further education students and as a researcher, I am both insider and outsider — working within and across discourses. The central theme of this monograph is an exploration of the technologies of power in Australian vocational education policy and practice — fragmented and conflicting as these are — as they relate to what counts as mathematics education in adult and vocational education. These technologies — manifested as skilled practices in particular ways of acting and visualising, aimed at achieving a particular social order — are viewed from the perspective of a practising *teacher* who is also engaged in the distancing activities of education research. On the other hand their implications, immediately and directly felt by practitioners and students, are viewed from the perspective of a *researcher* who has continuous classroom experience of approximately 20 years. Lived experience of the day-to-day issues, successes, tensions, and frustrations has informed the writing of this monograph. During these years my teaching, practice has shifted from a traditional transmission paradigm of teaching and diagnostic remediation, through constructivism to a position multiply informed by literatures on situated cognition, mediating artefacts, and post-structuralist pedagogies; constrained in the last decade by the discourse of competency-based education and training (CBT). Following Donna Haraway (1995) I am claiming a positioning that is situated as partial, locatable, and critical in its politics and epistemology — as opposed to that which is unmarked, disembodied, and transcendent. I will attempt to sketch tensions and resonances rather than charged dichotomies.

The work of Anna Yeatman (1994) has also been influential in that I have begun to consider the epistemological positioning of myself as a subaltern intellectual within different and conflicting lines of intellectual and political accountability. On the one hand, as a teacher I wish to address the chronic undermining of the values of professionalised knowledge with respect to mathematics education in the Australian vocational education and training sector. In my multiple positionings there are likely to be conflicting lines of accountability to the academy and the TAFE workplace. On the other, it is necessary to develop a theorised knowledge of how mathematics is and might actually be used in the workplace in order to serve the interests of the individual workers, their employers, and society at large. Accordingly, in chapter 2, I will review a selection of the literature (mainly Australian and British/European) on the mathematical knowledges associated with workplace competence, including the extradisciplinary ethnomathematical constructions which evolve continually in response to workplace exigencies. Herein lies a tension in that few if any mathematics (and other) education researchers can have expert knowledge of the particular industry being examined; once again there may be conflicting lines of accountability, in this case to the academy and to the industrial workplace.

It is anticipated that this monograph may be read by members of the various, multiply-overlapping educational research communities: mathematics education, adult education, and vocational education. I will therefore take into account the need to be specific in detailing current understandings of each. This will necessitate a broad-based review of the literatures in these fields, and theorisations of technologies of power concerning these, that I consider to be of relevance. Chapter 1, in particular, will focus on the institutions of mathematics and of mathematics education. In this monograph I wish to offer critical and reflective perspectives on the perplexing and somewhat paradoxical issues arising from the manifestation of technologies of power which appear to be detrimental to the survival of the discipline of mathematics in the technologically-oriented sector of adult and vocational education.

0.2. MULTIPLE PERSPECTIVES

The concept of mathematics in adult and vocational education is complex and may be viewed and construed from many valid perspectives, according to the interests of the person or group concerned. The interacting activity systems work of Yrjö Engeström (1999) provides one organising structure within which to address the issue of mathematics in adult and vocational education. In this context the concept of learner is taken broadly, to include *all* participants in the dynamic process, not just the students.

Firstly, within Activity theory, the prime *unit of analysis* is taken to be "a collective, artifact-mediated and object-oriented system" (Engeström, 1999, p. 4), subsuming individual and group goals, and generating actions and operations. Here, the systems of interest include primarily: (a) vocational and further educational institutions, (b) workplaces, (c) local communities, and (d) individuals. Their interests are assumed to be self-serving as well as mutually related, and their respective objectives to accumulate some or all of economic, symbolic, cultural, and/or social capital (Bourdieu, 1991).

Secondly, account needs to be taken of the principle of *multi-voicedness* — that is, the different positions for participants created by the division of labour within the activity system. In this case these include the multiple views, traditions and interests of students, teachers, managers, employers, and government bodies. On the part of individual students, reasons for learning mathematics could include: (a) self-realisation, (b) democratic empowerment, and (c) workplace promotion. In acquiring knowledge of the discipline of mathematics, together with incidental knowledge of mathematics education and knowledge of education-institutional structures, the bigger picture for students could include the possibility gaining workplace or lifeskills know-how and certification. Teachers are assumed to learn about the needs of their students and relevant industries, as well as their own institutional structures; employers to learn of the qualifications, and even perhaps of the underpinning theory; while governments need to be able to guarantee some form of public accountability for funding spent on adult and vocational education. From a pedagogic perspective, there is — or ought to be — dialogue and debate between positions and voices, focused (in this case) on mathematics education. From a social and economic perspective, interests of employers and government authorities may lie in the values of control over (potential) workers as individuals or groups. It is assumed finally that interests are focused on progress in the local or global economic and/or social spheres.

The third of Engeström's (1999) principles is *historicity,* "studied as local history of the activity and as history of the theoretical ideas and tools that have shaped the activity" (pp. 4-5), in order to understand the problems and potentials. Particularly in relation to adult and vocational mathematics education, it is important to be aware of the history of the students, their teachers, educational managers, employers, and government groups. In my opinion, this is pivotal to understanding what counts as mathematics (or numeracy, as it is often referred to) in this sector of education. At the macro-level, government policies — for example, economic rationalism, lifelong education, 'learning for work' and 'work for dole' schemes — impact directly on the work of educators and the conditions of students' learning. At the same time, to the extent that they implicate mathematics, these policies are underpinned by certain, historically-constituted, understandings of what mathematics is, to whom mathematical knowledge should be distributed, and how much (Bernstein, 1996). The same can be said, at the meso-level, for curricula and courses designed in accordance with these policies, as with the texts (both written and verbal) offered to students, face-to-face or via distance education means. At the micro-level, teachers and students enter the learning arena with unique histories of experience with mathematics and with mathematics education. Each of these needs to be taken into consideration. What is at issue are historicised, necessarily partial, accounts of mathematics as a discipline, of the role of mathematics in vocations and society generally, and of the crucial role played by formal mathematics education. Many of the changes to mathematics curriculum have been hotly contested, within the education sector as well as outside of it — for example, by traditionalists reluctant to see change occur (the 'back-to-basics' movement is a prime example), and by academics who feel that there is insufficient research upon which to base the changes (e.g., Clements & Ellerton, 1996) or by mathematicians who are wary of possible threats to their discipline (e.g., Wu, 1997). Here, of course, the impact of new teaching technologies cannot be overlooked — as vectors for learning, as object of learning (in the sense of tool manipulation), and possibly even as the subject of learning. Clearly, historicity exposes many problems in what is taken by various stakeholders to count as mathematics, but it also offers great potential to enhanced understanding.

Engeström's fourth principle claims a central role for *contradictions.* These are a source of change and development; historically accumulating structural tensions within and between activity systems — for example, the contradiction within capitalism between the use-value and the exchange-value of commodities. Contradictions arising from, for example, the adoption of new technologies may generate disturbances and conflicts, but may also lead to innovation, according to Engeström (1999). Within mathematics education, as King Beach (1999) points out, similar contradictions exist between the use-value and exchange-value of mathematical knowledge, creating tensions within students as to their reasons for learning it. In terms of pedagogical practice, in many places adult and vocational education in mathematics is rife with contradictions between intended curricula and actual workplace and community practice, between teaching resources available (including adequately trained staff and new technologies) and intended outcomes, and so forth.

Engeström's fifth principle proclaims the possibility of *expansive cycles* — "transformations in activity systems" (p. 5). In these relatively long cycles of qualitative transformations, questioning and deviation from established norms sometimes escalates into a deliberate collective change effort. According to Engeström (1999, p. 5) "a full cycle of expansive transformation may be understood as a collaborative journey through *zone of proximal development* of the activity." Might it be possible to involve some or all of the stakeholder groups listed above in a cycle of expansive transformation, to serve at least some of their mutual needs?

0.3. SOME WORKING DEFINITIONS

The study of adult and vocational education is necessarily made complex, particularly in Australia, by its diverse, ever-changing structures accompanied by a large number of acronyms and the specialised meanings given to some nomenclature. Therefore a glossary of acronyms will be found in Appendix 1, and in the next few paragraphs I will attempt to outline some working definitions for the sake of the less initiated reader.

0.3.1. Vocational Education and Training in Australia

Following the release of the Kangan Report (Australian Committee on Technical and Further Education [ACOTAFE], 1974) the post-compulsory sector of technical and further education was given a new acronym, TAFE, along with a new sense of identity (Rushbrook, 1995). One of the manifestations of this was the large-scale construction of high-profile TAFE colleges (later to be known as institutes) which helped garner public recognition for this burgeoning sector of education.

At time of writing the sector is known nationally as the vocational education and training (VET) sector, which is organised under the auspices of the Australian National Training Authority (ANTA), answerable to the Federal Minister for Education, Training and Youth Affairs. In this monograph, the acronym VET will be used to refer generally to the sector, including private and community providers; the acronym TAFE (forerunner of VET) will be used to refer specifically to institutionalised teaching and learning within this sector. Adult, community, and further education is subsumed within the VET sector, but with separate organisational structures and modes of operation unique to each state and territory.

Students enrolled in the Australian VET sector are generally aged 15 years or over. They may be undertaking initial education and training in preparation for, or concurrent with, paid work; or they may be enrolled in some form of continuing professional development. They may study on- or off-campus (either in industry settings or via distance education modes) or in some combination of these, as full-time or part-time students.

Because of the necessarily vocational focus of this monograph, it is necessary to distinguish between the terms *industry, enterprise,* and *workplace.* I am adopting working definitions as follows: workplace refers to the immediate site of employment for a given worker or group of workers; enterprise refers to a single plant or business; industry refers to the broad-based collective interests of a group of enterprises, for example the Hospitality or Electronics industries. Large employers, such as multinational companies or consortia may operate within several industry groupings; employees of enterprises may also collectively span several industries. These working definitions are given for clarification purposes only; is unlikely that they are used uniformly around the world. Chapter 2 will elaborate on the complexity of the world of work as it relates to mathematics.

0.3.2. Mathematics and Statistics

How is the term *mathematics* to be understood? In chapter 1, I will discuss from epistemological, historical, psychological, philosophical, and sociocultural perspectives the institutions of mathematics and mathematics education in what is known as a mathematico-technological culture (Bishop, 1988). The concept of *ethnomathematics,* taken as “the mathematics which is practised among identifiable cultural groups, such as ... labour groups, . . . professional classes and so on” (D’Ambrosio, 1985/1991, p. 18) — whose identity depends upon interests, patterns of reasoning, and codes outside of the realm of academic mathematics — will be adopted with particular reference to the culture of the workplace.

For the purposes of this monograph I will adopt a working definition of mathematics as it is generally understood in (Australian) vocational education. In terms of content it includes a large number of topics familiar from school and some undergraduate mathematics programmes. As a process it involves the solution of routine algorithms or simplification and evaluation of algebraic, geometric, trigonometric, and so forth, expressions in written or graphical forms. The generalised goal is the solution of ‘vocational problems’ as reflected in the range of so-called applications which accompany any designated topic; more often than not these applications take the form of ‘word problems’ typical of any school text book, not necessarily bearing any relation to the lived experience of the students. As a corollary it is not expected that students will become apprenticed to the discipline of pure mathematics (Buckingham, 1999) — instrumental ends are expected at all times to be visible or at least implied. As will be elaborated in later chapters, in Australia there seems to be an underpinning essentialist paradigm of curricular content — although, somewhat surprisingly, curriculum is no longer a central concept in vocational education — and an unproblematised notion of transfer between mathematics classes (wherever located in time and space) and the workplace or other vocational classes.

The term *mathematics education* will be used in the broadest sense, encompassing teaching and learning in all courses which include mathematics, numerical and spatial calculations, as well as statistical components, whether officially designated by recognisable titles or incorporated into other vocational modules. In the Australian VET sector, less academic-type instruction such as trade calculations or practical quality assurance is often taught by trade teachers or workplace personnel. More formal mathematics and statistics subjects are usually but not always taught by formally recognised groups of mathematics teachers or by teachers with more academic/professional backgrounds than trade teachers. That is, mathematics and statistics are not differentiated as is the case in some universities; rather theoretical statistics is generally treated as a sub-discipline of mathematics for teaching purposes, sometimes incorporated into mathematics modules and sometimes treated as a stand-alone subject. In both vocational and adult further education, numeracy is an emerging as a popular alternative to mathematics, but these subjects are often taught by literacy teachers with little or no post-school background in mathematics.

Technology is a central theme of this monograph (figure 0.2); it provides a nexus between mathematical and industrial practice, as well as their related educational subfields.

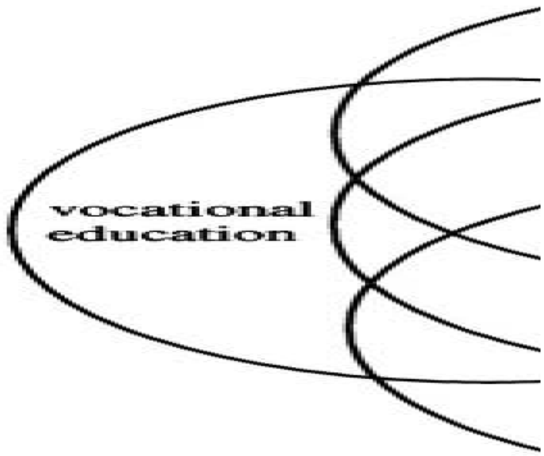

Figure 0.2. *Technology as a central organising theme.*

0.4. AIMS AND GOALS FOR THIS MONOGRAPH

In a report to the OECD, Maurice Kogan and Albert Tuijnman (1995) describe educational research as involving “the disciplined study of learning relations at several levels, including those of the individual learner, institutions and organisations, and the wider sociocultural, economic and political environments of societies” (p. 32). They identify three major levels of analysis: (a) at the macro- or societal level, where “the focus is on the overall social, cultural, economic and political premises that tend to define the competence requirements in a society”; (b) at the meso- or structural level, where “educational researchers study how learning relations are structured or arranged in addition to how knowledge is produced and selected;” and (c) at the micro- or operational level, where “researchers concentrate on the activities, interactions and behaviours of the individuals themselves” (p. 32). This monograph will focus on all three, particularly the first two.

The aim of this monograph is to investigate and analyse the power relations of adult and vocational mathematics education, focusing on the VET sector in Australia as a case study. This is in a contextual setting of trends towards globalisation and the adoption of the tenets of lifelong learning by an increasing number of governments — often in concert with new educational technologies for delivery (e.g., Herremans, 1995).

Crucial to any discussion of education is the concept of the profession of teaching, and fundamental questions need to be raised about the status of those who take part in the teaching of mathematics, whether officially designated as mathematics teachers or not. Whatever the mode of interaction with students, the professional teaching of vocational mathematics needs to be underpinned by a solid research foundation in domains such as teaching, learning, curriculum development, assessment, professional development, and flexible delivery — all of which are in some way connected to, if not underpinned by, technology.

Certain questions arise. Why, when mathematics and technology are dialogically related, does vocational mathematics education appear under-researched and under-theorised — particularly in Australia? What are the factors that have contributed to its seeming lack of status? How did this situation come about? What are some possible explanations for the failure to problematise the teaching and learning of mathematics, as well as the degradation of curricular content as well as mathematics teachers as professionals? How likely is the current provision of mathematics to meet the needs of various stakeholders, particularly students and industry? What kind of vocational mathematics education might be appropriate for the vocational sector in the future? What could account for the seeming inertia of decision-makers to address these issues? This monograph attempts to provide a range of theoretical perspectives on these issues.

There are two major goals for this monograph: (a) to present from a critical perspective examples of workplace research into mathematics as well as exemplars of textual material designed for adult and vocational students; and (b) to present theorisations on why a ‘developed’ country such as Australia should be pursuing such an 'anti-educational' (or perhaps anti-intellectual) trajectory in relation to vocational mathematics. The second point has serious implications for other nations or interest groups who may try to emulate the model or who may be unduly influenced by virtue of being recipients of Australian government aid (e.g., through AUSAID).

Australia calls itself a democracy. However, following the late work of Jacques Derrida (1994, 1997) — and acknowledging the contribution of Evan Kritikakos, from Monash University, in discussion on this issue — I consider that democracy is not the present, lived reality of Western 'liberal' systems of government. Neither is it a regulative framework, a source of deduction or determinate judgement. Nor is it a Utopia — an idealised concept that we should aim for and might achieve some time in the future. Rather, it is an ethical demand or injunction, concerning concepts of friendship, community, and so forth. It must be understood in terms of democracy to come; not in the future, but in the sense of maintaining now "l'ici maintenant," without presence. As I understand it, democracy is not a thing to be grasped, nor an absolute standard of moral judgement.

In its pragmatic realisation through representative democracy, power is likely to be distributed unequally. Barry Barnes (1988) comments that although the commonsense view of power is as an entity or attribute of things, processes, or agents, he sees power as a theoretical concept referring to capacity, potential, or capability. More strictly, it should be taken as referring to distributions of these.

> Any specific distribution of knowledge confers a generalized capacity for action upon those individuals who carry and constitute it, and that capacity for action is their social power, the power of the society they constitute by bearing and sharing the knowledge in question. (p. 57)

In other words, "social power *is* the capacity for action [embedded] in a society, and … is *possessed* by those with discretion in the direction of social action" (p. 58). Taking knowledge to be accepted, generally held belief, routinely implicated in social action and, consonant with Pierre Bourdieu's (1991) notion of cultural capital, Barnes asserts that the distribution of knowledge in society defines the distribution of power.

Thus, democratic power depends upon access to knowledge — information selectively derived from a range of possibilities and which is capable of being interpreted and understood — access to which is also unequally distributed. Mathematical knowledge is said to be empowering, but questions arise, such as: What mathematics? How much mathematics? For whom? Who decides? Who should decide? These are in addition to the pedagogically- and administratively-oriented questions concerning how, where, when, and why. My interpretation of the question "What counts as mathematics in adult and vocational education?" will be a consciously political one. The commitment that adult and vocational education students make to continuing their education is very precious — especially when the opportunity costs of time and money, not to mention emotional risks, are considered. It is therefore incumbent on those with responsibility for adult and vocational education to attend seriously to students' historicity, their multi-voicedness, and the contradictions that they face. In terms of democracy, is it possible that Critical

Mathematics (Skovsmose, 1994) might play a serious part in the intended and implemented curricula for adult and vocational education? What role might aesthetics play? Is it possible to value both cognitive and affective development in vocational education? How might alternative, more positive, public perceptions of mathematics education — to the benefit of all — be generated and enhanced? This monograph explores some of these possibilities but also the practices of subversion which wittingly, or otherwise, serve to undermine them.

0.5. OUTLINE OF MONOGRAPH

This monograph presents an institutional study, attempting to draw inferences from the current situation of mathematics within the Australian VET sector which might be applicable to other institutions of education internationally. The construct of institution is employed to set a theoretical foundation with regard to, respectively, the discipline of mathematics, the field of mathematics education, and the field of vocational education and training. Technology emerges as a unifying construct for the complex relationships between mathematics and industry, in both production and management discourses, and between mathematics and vocational education. From the meta-analytic stance of this monograph, vocational education itself has become an industry and its political and social structures are explored to elucidate the apparently ambiguous position of the discipline of mathematics within the sector. A recurring theme is public image — firstly of the discipline and study of mathematics, secondly of vocational education and training in an increasingly deregulated sector which relies on segments of public opinion for its continuing survival, and thirdly in relation to the discourses of lifelong learning.

Chapters 1 and 2 set the scene from a mathematical perspective, presenting reviews of literature which focus on the institutions and images of mathematics and mathematics education, on the one hand, and the relationship between technology and mathematics in and for the workplace, on the other. Chapter 3, *Interlude,* provides theoretical perspectives on technologies of power and new forms of knowledge production, drawing upon a range of intellectual work. However, Basil Bernstein's concepts of symbolic control, pedagogy, and identity appear to provide the most coherent framing for the terrain to be covered.

After a brief introduction to the historical and contextual setting of the Australian VET sector, chapters 4, 5, and 6 consider technologies of power — moving from the micro-level issues associated with teaching and learning, through the meso-level of curriculum and the conditions of teachers' work, to the macro-level of knowledge production and distribution, where the de-institutionalisation of education is looming as a serious challenge.

The monograph concludes by returning to the construction of image; firstly in relation to technologies of management, and secondly in relation to vocational mathematics as located within the public image of mathematics education. However, it is argued that even public image has become technologised.

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CHAPTER 1

WHAT COUNTS AS MATHEMATICS? INSTITUTIONS AND IMAGES

1.1. INTRODUCTION

In considering what counts as mathematics, in this chapter I consider understandings from a variety of perspectives, necessarily partial, with respect to mathematics and to mathematics education. I frame these within the concept of institution, attending to patterns of social conduct and value, norms and rules, embodied within everyday activities. In so doing I am attempting to elucidate what it means to think and work mathematically — with particular reference to the workplaces of the technologically-developed world. In this context, I also explore the somewhat contentious issue of mathematics and its relation to numeracy.

Morris Kline (1979a, p. v) asserts that there are many facets to the discipline of mathematics, which he claims is "limitless in extent and depth, vital for science and technology, and rich in cultural import." He recognises that in compulsory education at least that it may be presented in a dull manner, limited in the range of mathematical values presented. Instrumentally, the subject of mathematics is likely to be perceived by many students and teachers as a series of techniques illustrating *what* can be done and *how* this might be done rather than as a subject calling for reflection (Bishop, 1988).

The formal activity of learning mathematics at any stage of life is intimately bound up with the identity of the learner. Yet, public opinion is generated on a wide variety of issues not necessarily experienced, or even thoughtfully considered, by individuals (Vanderburg, 1988). As a consequence the public image of mathematics itself has many facets. Decisions concerning mathematics in adult and vocational education are made by a variety of stakeholders, coloured by personal and public opinions which may be quite distant from those of academic mathematicians or professional mathematics educators — and even these may not be in accord one another (Sierpinska & Kilpatrick, 1998). So, how is mathematics to be understood?

1.2. THE INSTITUTION OF MATHEMATICS

Every person of school age or over, in communities with so-called universal education, has come into formal contact with mathematics and formed opinions, consciously or unconsciously, about the nature of mathematics. Opinions are not only formed in the cognitive domain but also, often very powerfully, in the affective domain (FitzSimons, 1994; McLeod, 1992), interacting at the meta-level (Hannula, 2000; Schlöglmann, 2001). I will utilise the concept of institution in order to explore understandings of the discipline of mathematics from a variety of perspectives.

According to John Abraham and Neil Bibby (1988, p. 4) the discipline of mathematics "cannot be completely understood without some understanding of the social institution of mathematics." The concept of *institution* attends to patterns of social conduct and value; rules and procedures provide coherence and meaning to everyday activities and are embodied in regularised patterns of behaviour, specific vocabularies and particular roles (Popkewitz, 1988). Also recognised is the importance of human actions and commitments which have given rise to major developments in mathematics, as well as the role mathematics plays in the social structuring of thoughts and actions. In what follows I will be considering: (a) the social structuring roles, (b) the practices of mathematics, and (c) the relationships between knowledge and power and the discourse of mathematics.

Mogens Niss (1994) outlines four perspectives on the concept of mathematics as a discipline. As a *science,* in an epistemological sense, it may be oriented towards the domains of mathematical entities (pure mathematics) or towards extra-mathematical areas (applied mathematics). The difference between the two is in the focus rather than the content matter. As a system of *instruments*, in products as well as processes, it can assist in decision-making and actions, thus providing *tools* for a wide range of social practices and techniques. As a field of *aesthetics* it is capable of giving experiences of beauty, joy and excitement to many. Finally it is also a *teaching subject* in the educational systems of societies. Teaching in the vocational education sector demands an interrogation of instrumental uses of applications, yet cannot overlook its aesthetic side. (Simone Weil, sister of mathematician André Weil, argues that work itself should have an aesthetic dimension, according to Gary Lewis, 1988; see also Richard Bagnall, 1997.) Within the academic purview at least, the instrumental uses are founded upon the epistemological science of mathematics. By contrast, as will be discussed in chapter 2, in the workplace and the community a more pragmatic approach to 'what works here under these circumstances' may be adopted.

Jean-Pierre Kahane (1998, p. 83) observes that, unlike other sciences, mathematics is not defined by its subjects in nature or society. "… mathematics acts on notions coming from different fields, generalizes, simplifies, purifies, makes a theory out of them, with mathematical definitions and deductions. Then and only then are these notions available to the unexpected." This is particularly pertinent to the workplace in dealing with the non-routine problems which arise continually over time and space.

Kline (1979a) asserts that, historically, the prime value of mathematics has been that it has enabled the answering of questions about the physical world, the comprehension of the operations of nature and the dissipation of much of the mystery of life. In his opinion the supreme value is the revelation of order and law from apparent chaos; although he later acknowledges (1987) the fallibility of human construction of rational designs based upon increasing factual knowledge of the physical world. Kline (1979a) also makes reference to the concept of aesthetics, including the mathematical branches of number theory and projective geometry —

the former may be linked to information technology; the latter is illustrated in subsequent readings to be of direct relevance to the vocational area of art and design.

Other mathematicians are even less modest about their discipline, as evidenced by an Australian discipline review (National Board of Employment, Education and Training [NBEET], 1995b) which proclaims:

> Mathematics is the study of measurement, forms, patterns, variability and change. It evolved from our efforts to understand the natural world. . . . Modern mathematical science is a supreme creation of the human intellect; it is also critical for economic competitiveness, and a basis for investigations in many fields, (p. ix)

This 'supreme creation' nevertheless had humble and pragmatic beginnings.

1.2.1. Historical Aspects of Mathematics

From archaeological studies of Egypt and Mesopotamia, James Ritter (1989) asserts a close, symbiotic relationship between mathematics and writing, based on the need to measure, divide and distribute the material wealth of societies. Without writing, the limitations of human memory limited the degree of numerical sophistication. Conversely, material needs, particularly the need for record keeping, were central to the development of writing. Ritter observes that no word for "mathematician" existed in these ancient languages. Rather, there were scribes who could become mathematics teachers or work as accountants — to calculate work, rations, land and grain.

George Joseph (1990) traced the spread of mathematical ideas through the ages across the Asian and African continents in an attempt to overcome the legacy of Eurocentrism — the dominance of Europe and its cultural dependencies — over the last 400 years as manifested in the historiographically biased accounts of mathematical activity. In a similar manner, Mary Harris (2000), Valerie Walkerdine (1994), and Margaret Wertheim (1997), among others, have highlighted some of the barriers erected to suppress, even prohibit, women's participation in mathematics in European cultures, together with the ongoing resistance to recognition of their achievements — only somewhat ameliorated in recent decades. This will be discussed further below under the section on the institution of mathematics education.

There is not one single mathematic, absolute and infallible (Davis & Hersh, 1980/1983; Ernest, 1991; Kline, 1980, 1987) but rather a plurality of mathematics which operate on a pragmatic basis, linked to time and place. The discipline of (abstract) mathematics emerged from a codification of sets of arithmetic and geometric problems. A more important step was the ability to state general rules for solving problems of a particular type, and a further step was to arrange these problems so that they could be treated in more general and abstract terms (Restivo, 1992). Thus Sal Restivo claims that academic mathematics as we know it evolved through the confluence of certain socio-cultural conditions, such as the rise of commerce, the need for time-saving devices such as algorithms, as well as the spread of printed material — all underpinned by ceaseless competition among mathematicians, but with a generational continuity. As Restivo observes: "The nature and availability of organizational and material resources can change the organizational structure of mathematics" (p. 87). The work of Otto Spengler (1926) provides further support for Restivo's (Durkheimian) argument concerning the relationship between ideas and contemporary social conditions, and thus against the notion of context-free formulations and applications. Spengler argued that, rather than progressing through a staged sequence of development, a certain type of mathematical thought is associated with each culture. The two major cultures in Spengler's scheme are Classical and Western. The Classical mathematics of Ancient Greece dealt with number as magnitude, as the essence of visible, tangible units; the Western paradigm of modern Europe, from the 17th century onwards, dealt with number as an object of pure thought, focusing on the concept of function, and thereby liberating mathematics from the boundedness of sensory perceptions.

The history of mathematics used in the work environment indicates that 'Applied' Mathematics has generally been regarded as inferior to its more detached academic counterpart nowadays known as 'Pure' Mathematics (e.g., Jahnke, 1994; Kline, 1980). In many cases its worth was and still is disparaged or ignored, even to the point of being invisible to its users, especially when it comes under the categorisation of numeracy (see, for example, Coben, 2000a). However, as Gibbons et al. (1994) argue, the adequacy of traditional knowledge-producing institutions is being called into question with the emergence of a new mode of knowledge production (see chapter 6).

These brief historical accounts illustrate the dependence of the social construction of mathematics on the social and cultural milieu of the times (see also Davis & Hersh, 1986/1988; Harding, 1998). This complex inter-relationship is particularly relevant to the workplace context where mathematical problems and solutions are continually being generated at all levels of operation, from manufacturing production operator or service worker to management, across all sectors of industry. This is not to say that they are necessarily recognised as mathematical by those involved.

I now focus more particularly on the discipline of mathematics as expressed in the viewpoints of sociologists and others concerned with the interrelationship between mathematics and particular societies and cultures in which it is embedded. This is in order to contribute towards accounting for the immanent, somewhat paradoxical, duality of beliefs and attitudes towards mathematics among members of the public, including vocational students and other relevant political and industrial decision-makers — elaborated later in this chapter.

1.2.2. Sociological Aspects of Mathematics

Sal Restivo (1993) argues that the foundations of mathematics are located in social life, not in logic or systems of axioms; Spengler's theory of mathematics yields a weak and a strong sociology of mathematics. In the weak form attention is drawn to the variety of mathematical traditions across and within cultures, for example ethnomathematics (see D'Ambrosio, 1985/1991). The strong form, in Restivo's words, "implies the sociological imperative—the idea that mathematical objects are constitutively social" (p. 251): "mathematics are reflections of and themselves worldviews" (p. 253). Restivo makes the further point that it is not mathematicians who manufacture mathematics but it is that mathematical forms or objects, containing the social history of their construction, are produced "*in* and *by* math worlds" (p. 250).

With increasing specialisation and levels of abstraction, the origins of mathematical work and its products become increasingly obscure. In fact, Philip Davis and Reuben Hersh (1986/1988) argue that:

> Each attempt to view mathematics as existing outside of time and human society strips away a layer of meaning and exposes a desiccated kernel. The way in which detemporalization is carried out is precisely by such a stripping process. Detemporalization leads to a naive faith that formal manipulation may be productively and authoritatively invoked in any situation. (p. 200)

They argue further that "abstraction is extraction, reduction, simplification, elimination. Such operations must entail some degree of falsification" (p. 281). They note that in the compression of meaning "one of the reasons why probability and statistics did not flourish until the 17th century was precisely the refusal of people to suffer the loss of the individual" (p. 282). And yet, in the dehumanising effects of the mathematising and computerising of policies and actions which affect individuals: "*What is often not pointed out is that this dehumanisation is intrinsic to the fundamental intellectual processes that are inherent in mathematics*" (p. 283).

As will be discussed in chapter 3, Max Weber observed that the emergence of formal rationality or 'calculability' in social action fostered the development of the rational state; in fact it was one major condition for the rise of modern capitalism (Giddens, 1972). In a striking parallel, Restivo (1993) notes that specialisation, professionalisation, and bureaucratisation are aspects of the organisational and institutional history of mathematics as a discipline. Their effect on the system is to generate closure in the system, which Restivo asserts may be helpful to some degree in facilitating innovation but is ultimately inhibiting of progressive change. The effect on the larger population tends to provoke feelings of exclusion and alienation.

Roland Fischer (1993) provides an explanation for the apparent alienation of people from mathematics on a personal level when he outlines the duality of mathematics as a means and a system:

> mathematics provides a *means* for individuals to explain and control complex situations of the natural and of the artificial environment and to communicate about those situations. On the other hand, mathematics is a *system* of concepts, algorithms and rules, *embodied in us*, in our thinking and doing; we are subject to this system, it determines parts of our identity. This system runs from everyday quantifications to elaborated patterns of natural phenomena to complex mechanisms of the modern economy. (pp. 113-114)

In this duality humans are both subjects and objects of mathematics; the means so created build into a system which then in turn reacts on the person — the relationship between mathematics and computerisation is an example. However, according to Fischer, most people are unaware of the subjective, systemic side of mathematics inherent in humans, thereby allowing the domination of the objective, controlling and explanatory side. In order to emphasise the systemic side and the reciprocal actions between means and system, he recommends the study of relationships between people and mathematics.

Brian Martin (1988/1997) developed the theme of social interests and mathematics, asserting that as a product of society mathematics can both reflect and serve the interests of particular groups. In his sociological study of the work of mathematicians he notes that the choice of areas of mathematics was not simply a reflection of the economic system of production in Marxist terms, but mediated through the institutions of science which predated the growth of computational mathematics. The development of mathematical frameworks is often shaped by factors such as views about the nature of reality. It is often the case in practice that the values held by mathematical modellers are incorporated, consciously or unconsciously, into their theoretic formulations whose results ultimately legitimate those same values, according to Martin. (This issue will be discussed further under the section on mathematics and technology.)

Although mathematical models are not intended as facsimiles of reality, they can in fact be used to construct new social realities such as in economic and social planning (Fischer, 1993). Martin (1988/1997) also observes that sources of funding, corporate and government, inevitably influence the areas of study and applications developed, and that ambitious mathematicians are influenced by the social organisation of the discipline. Mathematics is seen as a masculine domain, suitable for those who are "rational, emotionally detached, instrumental, and competitive" (p. 165). This male domination is linked with dominance of other social institutions to which professional mathematics is tied, and may in fact contribute to its high status. The characteristics associated with masculinity — as opposed to models of reality that are seen as subjective and value-laden — enable mathematical models to gain added credibility. The specialisation, in establishing enclaves of experts, serves to ensure that there is limited scrutiny by outsiders. Mathematical models are socially significant both in their practical applications as well as their use in the legitimation of policies or practices, according to Martin. In other words, mathematical ideas which have often been portrayed as value- and culture-free (Ellerton & Clements, 1989) are crucially influenced by social interests and pressures.

On the question of high status knowledge, Michael Apple (1992) observes that business and industry, as well as government, place a high value on knowledge that is convertible ultimately into profits and control. Apple utilises Bourdieu's (1991) notion of *cultural capital,* which sees legitimate knowledge as convertible into an economic commodity, to substantiate the gatekeeping role played by mathematics and science in the distribution of social and economic power. He explains that, as a scarce resource, the need to optimise knowledge production is of more concern than its widespread distribution; powerful demands are placed especially on universities "to produce technically oriented knowledge that can be controlled and utilized by the economy" (p. 421).

In spite of the NBEET (1995b) report stressing the importance of the mathematical sciences to "Australia's economic competitiveness and quality of life" (p. x), in the higher education (university) sector many Australian mathematics departments are being reduced in staff or closed as enrolments decline (Albert, 1998; Thomas, 2000). This apparent paradox may be explained to some extent by the concomitant rise in demand for technically-oriented rather than disciplinary-oriented tertiary courses, such as business studies and information technology. However, disciplinary attenuation comes at a price in the failure to regenerate its community of specialists. This is a critical moment for school mathematics education in many countries as mathematics teachers become scarce due to short-sighted policies of governments. What, then, for vocational mathematics education?

Particularly as a category of schooling, mathematics plays a role in social structuring, according to Thomas Popkewitz (1988). He outlines three assumptions which underpin this role:

1. "Mathematics instruction gives symbolic reference to the scientific and technological base of society.... Its cognitive character signifies enlightenment, a path by which a rational, scientific and pragmatically organized society will bring progress to its material and social world." A modernist project it is symbolic in that most school mathematics "rarely, if ever, goes beyond 19th century mathematics."

2. "As a preferred category of understanding, mathematics is to be recognized as of value even for those who cannot master its codes. . . . [it] carries status differentials, social divisions and hierarchies found in the work in society."

3. Mathematics has a dual quality in the construction of reality. It can "enable us to understand relationships and guide interpretations in ways not available in other discourses. In this sense, it provides a form of knowledge that transcends our immediate situation and experiences. But the language of mathematics can also obscure and mystify our social conditions." (p. 234)

Drawing on a Foucauldian analysis of discourse, Popkewitz continues that "subjects become objects, power is hidden in the maze of numbers, and purpose is made to seem irrelevant to the constructions of social life" (p. 235). Evidence in support of Popkewitz's assumptions may be found below under section 1.4, on images of mathematics.

These considerations of the role of the discipline of mathematics in social structuring are summarised in Alan Bishop's (1988) theorisation of mathematics as a bearer and product of three complementary pairs of values. Each have been valorised by those within the mathematical community and yet have tended to further the alienation of those external to it. The ideological values of rationalism and objectism, which separate objects from ideas and allow abstractions to be treated as objects, have vested mathematics with power and authority. Associated in particular with the Enlightenment, Valerie Walkerdine (1994) problematises these values as normative, based on a limited selection of attributes reflecting the dominance of white European middle-class males, marginalising all other groups. The second set, sociological values of control and progress underpinned by technology, have resulted in improvements in many aspects of society but, as Bishop (drawing on the work of Jacques Ellul) and others have observed, this has not been unproblematic. Although mathematics has provided a tool for gaining control over physical and social environments through modelling and computer simulation, humans are now entrapped in a technological society. The third seemingly paradoxical pair of sentimental values of openness and mystery in mathematics have in first case been linked, albeit tenuously, to democracy and in the second to widespread feelings of ignorance and confusion in the minds of many non-mathematicians. However, mystery is also associated with a sense of wonderment — even aporia (discussed below & in chapter 7).

Collapsing discussion of the discipline of mathematics to a set of technical statements — as a body of knowledge or a methodology — without the social perspectives presents an incomplete picture (Restivo, 1993). In the following section I will address some of the rules and norms which also make up the institution of mathematics embodied in the practices of mathematicians (and other users). I will then examine the thesis of the formatting power of mathematics propounded by Skovsmose (1994), leading to a deeper consideration of the dialogical relationship between mathematics and technology which structures our society not only in economic terms but increasingly in educational and managerial terms.

1.2.3. Practices of Mathematics

Alan Bishop (1988) describes mathematics as a pan-cultural phenomenon, founded on what he claims to be six key universal activities: counting, locating, measuring, designing, playing, and explaining. He continues that the internationalised discipline we recognise as Mathematics is a very powerful version, based on an increasingly technologically-centred environment. In chapter 4 I argue that each of these activities is generally present to varying degrees in workplaces — especially manufacturing industries, but also symbolic-analytic and service industries where interpersonal communication is recognised as of vital importance (Shah & Maglen, 1998). Mathematical knowledge is such an integral part of our society, albeit often unrecognised, that it is difficult to imagine effective communication taking place in its absence or near-absence.

What is known about how mathematicians actually work? Thomas Popkewitz (1988, pp. 236-237) makes five observations about reason, thought and practice in mathematics:

1. There is no single method of enquiry. There is a community of practice which provides a cognitive structure of expectations, demands, attitudes, and emotions. "It is in the social structures of experiences that a psychology of mathematical thought and reason must be constructed rather than as cognitive structures abstracted and separated from the complex social, political and intellectual conditions in which knowledge is produced."
2. "... the concepts of science and mathematics are both answers and questions. Concepts are answers in that the categories create boundaries," but they also provoke questions: mathematicians imagine new possibilities rather than merely following existing lines of reasoning.
3. "... many concepts are the subject of constant debate and exploration.... At the cutting edge of science and mathematics is a conceptual playfulness and a competition among colleagues to generate knowledge. Such playfulness, skepticism and competition are central dynamics of enquiry."
4. "... concepts are at once affective and cognitive expressions about the world.... concepts in mathematics do pre-suppose relations and causal networks; mathematical models tend to emphasise linear rather than dialectical relations."

5. ". . . science and mathematics both have internal and external influences on knowledge growth."

These observations of mathematical activity indicate its complex social structuring, its imaginative and playful aspects, and the integration of cognitive and affective domains. (For further discussion of the last point see Allchin, 1998, who elaborates on the values which the discipline of science both imports from and exports to society.) The first three of Popkewitz's observations on the work of mathematicians resonate with other descriptions of occupational competence — to be elaborated in chapter 2 — but are not often recognisable in the mathematical studies of those enrolled in vocational education and training courses.

Part of the difficulty in identifying mathematical work, especially in industry, is the tacit nature of much mathematical knowledge. (Discussion of the implicit and explicit *uses* of mathematical knowledge will be included below, under the next subsection on technology.) Paul Ernest (1998b, 1999) describes the recognition of the explicit-tacit knowledge distinction as a recent shift in the conception of knowledge. Following the work of earlier philosophers (Ryle, Polanyi, Kuhn, and Kitcher) he notes that not all knowledge can be made explicit; 'know how' and tacit knowledge are important in all areas of human thought. Mathematical knowledge, in addition to publicly stateable propositional knowledge, includes 'know how,' but most personal knowledge in mathematics is tacit, according to Ernest (1998b). He describes tacit mathematical knowledge as including:

> methods, approaches, symbolic operations, strategies and procedures which are often applicable to new problems, but used differently in different situations. . . . while the applications of these procedures and strategies are explicit, the more general knowledge underpinning them normally is not. (p. 13)

Based on the work of Kitcher, Ernest proposes a model of mathematical knowledge where he categorises as 'mainly explicit' the components of: (a) accepted propositions and statements, (b) accepted reasonings and proofs, and (c) problems and questions. Kitcher's components of: (d) meta-mathematical views and (e) language and symbolism are classed as 'tacit' — with the meta-mathematical views being built up by mathematicians through experience and not able to be taught explicitly. The language and symbolism Ernest claims are mainly tacit, although aspects are explicitly known to some extent. Finally Ernest adds two more, mainly tacit, components of: (f) methods, procedures and strategies, and (g) aesthetics and values — he feels that these are more able to describe the practices of mathematicians, as well as the processes of learning mathematics. (See also Davis & Hersh, 1980/1983; Kline, 1979a, 1987.) Chapter 2 will attempt to tease out some of this tacit mathematical knowledge in the workplace, but there is still much work to be done in this burgeoning research area.

As a summary of the issues raised so far, one could account for mathematics as: (a) having a diverse history across cultures and time, selections from which have become a generally accepted body of knowledge, but which is fallible; (b) being a living social construction, with its own values, institutions, and relationships with society at large; and (c) framing a psychology of mathematics — as Ernest's (1991) theory of social constructivism claims. Ernest (1994) also claims that social views of mathematics resonate with the aims of critical mathematics education in their critical evaluation of its social uses. However, according to Skovsmose (2000), Ernest's work fails to raise questions concerning a critique of mathematics in its failure to acknowledge the problematic nature of scientific rationality — an issue highlighted by Sandra Harding (1998).

Ole Skovsmose (1998a) describes the term *aporism* — as being derived from the Greek word *aporeo,* which he takes as 'being in a loss' or 'being without resources' (p. 90) — in terms of two theses, which he claims might be true. These concern the formatting power of mathematics as a source for action and decision-making which impacts deeply on social affairs, and the difficulties in identifying and criticising the social role of mathematics. I will discuss both, particularly the formatting power of mathematics, in the next subsection. Skovsmose continues that aporism acknowledges the possibility of failure to carry out an adequate critique of reason. The question arises as to whether, for example, the rationality of mathematics is ever under challenge in adult and vocational mathematics education, or even in other sectors. This issue will be discussed further below under the section *The Institution of Mathematics Education.* However, the issue of scientific rationality is closely intertwined with technologies of management.

1.2.4. Mathematics and Technology

The histories of development of mathematics and technology indicate that they operate in a relationship which is dialogical (i.e., interactive, without reaching closure) — often invisibly to members of the community, even those with substantial background in mathematics. As Skovsmose (1994, p. 55) observes: "We live *in* technology, *for* technology and *by means of* technology." It is part of our very existence and yet its nature causes us oftentimes to take it for granted. The concept of technology is ubiquitous and multifaceted.

There are complex interrelationships between industry, technology, mathematics, and education. In this section I will attempt to tease out some of these from the perspective of mathematics education, in terms of both the structure of technology and the structuring role it plays in our society.

Skovsmose (1994) interprets technology as a basic, although not necessarily deterministic, condition for social development; it reflects the social and economic features of a society. He provides illustrations through distinguishing four types: (a) generic technology in the form of tools, exemplified by the hammer, where mathematics is implicit in the construction as a tacit competency; (b) energy technology, more often in the form of fixed capital, exemplified by the steam engine, based on the innovations of natural sciences; (c) social technology, adopting often uncritically and with limited success the paradigms of natural science to manipulate subjects, as in the algorithmic approach to scientific management, exemplified by the watch; and (d) information technology, closely related to mathematics and logic, applying simple or complex mathematical models, exemplified by the computer. He observes that the applications of formal mathematical methods come to colonise all other areas of life, and that other types of technologies become dependent on if not absorbed by information technology.

The metaphors of the *black box* and *technology transfer* (Maass, 1998) may be utilised to interrogate the role of mathematics in the technological formation. According to Jürgen Maaß and Wolfgang Schlöglmann (1988), black boxes have evolved historically — from the chance making and use of tools to their planned production and application through the codification of their necessary rules and methods of use. They compare this transmission of knowledge to the social division of labour — packaged knowledge must be freed from its historical methods of discovery and reduced to an essential core necessary for application. However, there must still be a certain commonality of background and structural similarity in order for the transfer to succeed. Commonality of needs in a society allows the abstracted knowledge to be applied to more than one situation. The solutions provided by black boxes are necessarily contingent upon social and historical contexts which set the conditions for possible solutions and their acceptance (e.g., the development of navigation instruments).

Building on the sociological systems-theory of Niklas Luhmann, Maaß and Schlöglmann (1988) identify the problem of transfer of meaning as the system-specific reduction of complexity in the conversion from the scientific code of 'truth' into the economic system of 'money.' They give as an example the scientific method of complexity reduction through differentiation between true and not-true statements which is in itself not necessarily usable outside of the system of science. It is only when mathematical theories such as linear optimisation or graph theory are converted into computer programs, for example, that they can be applied to industrial or other sites in the economic system to maximise productivity. Originally, they assert, mathematics lagged behind the development of technology, but the advent of computers has enabled the planning, simulation, and testing of new production models; industry is experiencing a switch from mechanical controls to computer controls in the workplace.

Maaß and Schlöglmann (1988) observe, however, that there are limitations not only due not only to limited computer capacity but also to the relatively high costs of technology compared to the low costs and inconsistent qualities of some raw or semi-processed materials, or even the selling price of the product. Comprehensive automation also introduces the possibility of new sources of error and increased sensitivity. Other limitations of technology they note are the inability of most users to determine or even modify the processes (see, for example, Pozzi, Noss & Hoyles, 1998), and the possible consequences of work intensification or job loss. Inappropriate applications to social sciences which need an orientation to action as well as technical knowledge have often been blamed on the inexactness of natural language as a medium for formulating rules, ignoring the issues of social and historical contextualisation. Maaß and Schlöglmann draw attention to those educational arenas associated with the institutionalised transfer of knowledge which reduce the concept of technology transfer to that of a tool, supported by uncritical, mechanistic applications of a certain selection of teachable mathematics (see also

Keitel, Kotzmann, & Skovsmose, 1993). This theme will be pursued in later chapters.

Maass (1998) further analyses the connections between mathematics and technology from a philosophical perspective:

> According to a definition by Beckmann (1777), technology is the theory of the processing of raw materials, or the science of the transformation of raw materials into finished products and the method of their processing. (p. 59)

However, he observes that in this definition the aspect of social context is missing. At a 1988 Austrian conference the question of the relationship between mathematics and technology came up against the issue that mathematics is not an empirical science. A broader definition was required:

> [The] posing of the problem of 'mathematics as technology' is a pre-condition, and we mean by 'technology' not only the theory of techniques, but also the totality of theories of real and possible production processes and the cooperation between mathematics and each specific technology. (Ruben 1989, quoted in Maass, p. 60)

At the same conference, Hülsmann believed that this division in the preconditions of the technological formation overemphasised the formal aspects at the expense of the formative aspects. Taking Leibniz's 'mathesis universalis' as a possible approach to reality, there is a structural connection, a unity. In technological form individual sciences cannot operate separately, but "the operation of knowledge must be understood as [a] technological totality, as it realises its technological form in all the disciplines" (Hülsmann, 1989, quoted in Maass, p. 60). The formative aspects of technology in structuring society will be discussed further below.

Christine Keitel, Ernst Kotzmann, and Ole Skovsmose (1993) see technology as determined by a complex of causality, rationality, and sociality. In accordance with Maaß and Schlöglmann (1988), they note that mathematics provides both the means of acting and a delineation of a scheme for action, with computers as materialised mathematics serving as thinking tools. They observe that mathematical models are serving descriptive, predictive and, increasingly, prescriptive purposes, with the effect that decision-making processes are increasingly influenced by them — often in a manner which is taken for granted (cf., Fischer, 1993). George Grant (1969, quoted in Andrew, 1988, p. 311) notes the homogenising implications of abstraction of information:

> Abstracting facts so that they can be stored as information is achieved by classification, and it is the very nature of classifying to homogenise. *Where classification rules, identities and differences can appear only in its terms. Indeed the word "information" is itself perfectly attuned to the account of knowledge which is homogenising.*

The black boxes created out of thinking abstractions (which may be transformed back into realised abstractions, even if only in symbolic form) contain what Keitel, Kotzmann, and Skovsmose (1993) called *implicit* mathematics. They observe that the most important concepts already turned into realised abstractions are *time*, *space*, and *money*. Because these abstractions are not made explicit, they are largely invisible to and unrecognised by the general public, including those working in extra-mathematical fields of applications — even mathematicians and mathematics educators (Niss, 1994). Niss (1979, cited in Niss, 1994) had earlier coined the phrase *relevance paradox* to describe the simultaneous objective relevance and subjective irrelevance of mathematics: mathematics is both socially significant and personally invisible.

A further paradox exists in the parallel processes of 'demathematisation' of society in terms of explicit mathematics needed in everyday or professional life and the increasing 'mathematisation' in terms of the specialisations of mathematicians and computer scientists (Chevallard, 1989; Keitel, Kotzmann, & Skovsmose, 1993). It appears that as technology becomes more sophisticated there is an apparent reduction in the amount of explicit mathematical knowledge required for its operation while the amount of implicit mathematics embodied in social objects (material and non-material) increases. Although it is the explicit uses in business and industry that are valorised, they are mostly concealed from view and, with the exception of arithmetic, not visible to the general public except through their experiences of school mathematics. On the other hand, according to Yves Chevallard, implicit mathematics are crystallised into objects, almost always in considerable amounts compared with the negligible amount of explicit mathematics used in producing a given object. The growth of science and technology has resulted in a continuing rise in the amount of implicit mathematics in objects and techniques, making them more mathematically powerful. At the same time their mathematical value — "the average, socially determined mathematical labour-time needed to produce them" (Chevallard, 1989, p. 52) — steadily decreases, thus making them more socially available. Correspondingly, "the average mathematical expertise required to consume those goods and services steadily decreases" (p. 53). Social debates tend to centre on explicit mathematics, obscuring the true role and major mode of presence of mathematics in society (Chevallard); implicit mathematics, by its very nature, cannot be questioned as to its values or meanings (Keitel, Kotzmann, & Skovsmose).

1.2.5. The Structuring Roles of Technology

Keitel, Kotzmann, and Skovsmose (1993) address both the formalisation and formative, or structuring, processes of technology. They argue that there is transmission and mediation between the formalisation of language and the formalisation of action. The application of formalised languages, such as mathematics, helps to construct new images of reality, both in perception and in formulations of (mathematical) models such as new algorithms for working processes.

> Normally, a mathematical model is not a model of a piece of reality as such, but a model of a conceptual system, created by a specific interpretation based on a more-or-less elaborated and more-or-less explicit theoretical framework; the selection of the theoretical framework as well as of the model is guided by interests and purposes. To understand and evaluate the model we have to analyse the premises and assumptions of these intentions and purposes. (p. 253)

They continue that mathematical modelling is constituted by instrumental (tool) and systematic (theoretical) aspects, with mathematical concepts as means and ends. However, for applications outside of the discipline mathematics they claim that the theoretical mathematics background is generally neither wanted nor understood. Models are generally taken to be of something concrete. However, if a model does not fit reality, it is possible to adapt reality in such a way that the language does describe something. Objects may be invented, based on a formalization of routines, thus giving mathematics a prescriptive role in social reality. This is the kernel of the retransformation of thinking abstractions into realized abstractions — which could be useful, or dangerous, or formidable, according to Keitel, Kotzmann, and Skovsmose.

Keitel, Kotzmann, and Skovsmose (1993) summarise the new paradigm of empiricism and heterogeneity towards which mathematics is moving as having: (a) a clearly problem-oriented focus; (b) much greater complexity in modelling; (c) an emphasis on experimental aspects; and (d) greater consideration for interdisciplinary representations, problems of visualisation, and mediation to non-mathematicians. However, there are ambiguous consequences in that there are "difficulties not only in comparing the original problems with *calculable problems* and intended solutions with *calculable solutions*;" as well as the consequences of potential mistakes, "because of the scale and complexity of technological objects being transformed into calculable problems" (pp. 262-263). As predictions become prescriptions, the reliability of computer models is often confused with reliability of classical models, that is, empirical as opposed to closed solutions in polished theories. Public opinion tends to place unwarranted faith in computer printouts, which may be based on vague formulations without adequate theoretical background, or on rough quantification. Also, technological feasibility and mathematical computability are confused with controllability (e.g., nuclear disasters). In other words, mathematical models only work reliably within certain parameters, and there are still risks involved for society to the extent of our dependency on these models.

Keitel, Kotzmann, and Skovsmose (1993) argue further that when mathematics and formal sciences enter the process of problem solving it becomes undemocratic by nature; outside the competent 'discourse' in society (see also Martin, 1988/1997). The processes of realized abstractions tend to become irreversible, and tend to gather momentum and influence social decisions by their very existence (e.g., double entry bookkeeping has enabled economic arguments which are blind to the content of the production and the ecological costs). As Skovsmose (1994, p. 55) notes, "it is possible to see an ontological transformation of formal structures into empirical and social realities."

Skovsmose (1994, 1998a, 1998b) proposes the thesis that the formatting power of mathematics structures and eventually constitutes many social phenomena. However, it is not mathematics per se nor mathematicians as a group to which Skovsmose refers. Rather the thesis is about mathematics in context, the interplay between mathematical techniques and resources for development and other sources of social development (cf., Restivo's, 1993, 'math worlds'). As mentioned above, the powerful language of mathematics allows for social, political, and economic interests to be pursued. Drawing on the work of Pierre Bourdieu and Michel Foucault, Skovsmose explains the symbolic power of mathematics as resulting from the legitimacy accorded it by those who are dominated by it, yet who believe in the metaphysics of its reliability. Further, he asserts that neither neo-empirical nor constructionist philosophies spell out the possible codification of the power of mathematics. What Skovsmose calls *the technology of mathematics,* providing answers and only rarely articulating the questions from which they originated, helps to create an invisibility. In addition, there is a distancing function which separates those who have more mathematical knowledge from those who have less.

As indicated above, Skovsmose (1998a) invoked the concept of aporism in an attempt to clarify the paradox of the double role played by mathematics in society: as an extension of human rationality and as a powerful force acting, for better and for worse, on society. Aporism, as translated in (modern) Greek as 'wonder,' or 'perplexity' [my trans.], expresses an uncertainty and perplexity associated with critique above and beyond that directed at instrumental reason as it relates to Weber's concept of goal rationality and the development of bureaucracy. To support this Skovsmose drew on the work of Ulrich Beck (Beck, Giddens & Lash, 1994, cited in Skovsmose 1998b) which distinguishes between reflection which tries to address the issue of mathematics and power, and reflexion as a process whereby successful industrial society produces an input to itself thereby creating a risk society. As mentioned previously, aporism acknowledges the possibility of failure to carry out an adequate critique of reason. Ultimately, the production of reason in social reflexivity gets beyond the reach of reflection. Skovsmose (1994, 1998b) uses the term *mathemacy* to be tentatively understood as a kind of competence bringing together mathematics-oriented, model-oriented and context-oriented reflections as an epistemic unit; also lifeworld-oriented reflection, where learning mathematics is seen as a social responsibility. This concept will be discussed further under the subsection on numeracy; the concept of aporism will be revisited in chapter 7.

This subsection has briefly explored the structuring roles of technology. However, structuring operates dialectically. As Andrew Feenberg (1995) observes, there are socio-political implications in technological development: "differences in the way social groups interpret and use technical objects are not merely extrinsic but make a difference in the nature of the objects themselves" (p. 10). This is supported by Michael Hammer and James Champy (1994)'s view of the computer evolution: As business managers switch from deductive thinking to inductive thinking, from enhancing or improving current practices which focus on technologies and applications that are trivial and unimportant, they are able to visualise entirely new classes of applications.

In the first section of this chapter I have discussed epistemological, historical, sociological, and psychological aspects of the discipline of mathematics; as well as technology and its structuring roles in our society. One of the multifarious manifestations of this structuring is through the institution of mathematics education. The context here is primarily the teaching of mathematics *about, through,* and *for* technology; education *by means of* technology as a strategy for delivery will be discussed in chapters 5 and 6.

1.3. THE INSTITUTION OF MATHEMATICS EDUCATION

Having addressed the institution of mathematics, including its complex relationship with technology as a formatting power, I now wish to separate analytically the institution of mathematics education — although for many members of the public they appear as a monolithic unity. For example, personal experience indicates that the profession of mathematics teaching is frequently conflated with that of the academic mathematician. As a teacher I often hear sentences which begin: "You're a mathematician, so you would know/understand …"

Heinrich Bauersfeld (1980, p. 35) views the process of teaching and learning "as a highly complex human interaction in an institutionalized setting" — an interaction which forms a distinctive part of the participants' lives. He observes that these institutions have been established by society

> explicitly to produce shared meanings among their members. Institutions are represented and reproduced through their members and that is why they have characteristic impacts on human interactions [within them]… . They constitute norms and roles; they develop rituals in actions and in meanings; they tend to seclusion and self-sufficiency; and they even produce their own content — in this case, school mathematics. (p. 35)

In fact Bauersfeld reminds us that understanding mathematics is more than using logic, exhibiting divergent thinking, or knowing proper definitions: it is realised in social interaction, "inescapably dependent upon the interpretative, indexical [indicating, *inter alia,* expectations and emotional concerns], and reflexive constitution of meaning" (p. 35). However, the structural institutionalised setting can no longer be taken for granted. Two decades later, as will be elaborated in chapter 6, education in the Australian VET sector is in the process of becoming de-institutionalised. Here, I will stay with the concept of institution as introduced at the beginning of this chapter, as patterns of social conduct and value.

I will begin by tracing briefly selections from the history of the institution of mathematics education, largely in Europe. I will then explore the work of various commentators on the political and social aspects of the relationship between mathematics education and society. I will focus primarily on the reflexive structuring roles played out between mathematics education and the (industrial/technological) society in which it is located in time and space. Finally, through the lens of values, I will address the articulated goals for school mathematics education.

1.3.1. Perspectives on the History of Mathematics Education

As noted above, Harris (2000), Restivo (1993), and Wertheim (1997) assert that mathematics education has been controlled by sectional interests — from the Church to the élite and powerful in civil society — and harnessed to their own perceptions of personal and social good. This hegemonic interest worked to the detriment of women and the lower classes, by excluding or restricting their participation in the full range of mathematics offered to those more privileged. This exclusion was achieved through restricted access to education and through curricula designed to reflect and reproduce social differences.

After the late 18th century the pattern of domination of institutionalised education in most European countries by religious aims (i.e., Christian and Muslim) slowly began to change (Howson & Mellin-Olsen, 1986). As national governments became stronger the concept of state control of education emerged. In the 19th century, mathematics education became

> ... a tripartite system of education . . . created in several countries with entry to the varying divisions depending initially almost entirely upon social class. At one extreme were the esteemed schools with a classically based curriculum, in the middle came schools with vocationally-oriented curricula designed to meet the demands of commerce and industry, and finally there were the elementary schools which mathematically sought to do little more than to provide that basic arithmetic required by the masses. (p. 4)

However, in the 20th century Howson and Mellin-Olsen observe that increased access to secondary education for working class children was accompanied by an increasing focus on compensatory education. The traditional pattern has been to identify shortcomings in the *pupil* rather than the curriculum and is still, I assert, a feature of vocational mathematics education in many countries today.

At the turn of the 20th century in Australia, in a colony developing largely through primary and fledgling secondary industries, reforms to school mathematics curricula designed to meet the needs of the majority rather than a tiny minority were only achieved *after* similar agreements concerning entrance requirements had been reached by the Universities of Oxford and Cambridge (Clements, 1989). Ken Clements (2000) suggests this ‘colonial’ mentality also lingers on elsewhere.

In the UK, an example of the dialectical relationship between curriculum and social forces, utilising mathematics as a technology of management, is provided by Fred Inglis (1985). Arguing that social disintegration arising from the industrial revolution impacted on the curriculum for lower classes, he traced the genesis of home economics, included under the 1904 *Regulations for Secondary Schools* which codified time to be spent on instruction. He asserts that housewifery for girls, together with manual work and physical exercises for boys, was a consequence of the nation’s realisation of the destruction of social fabric where, within a period of eighty years, “the urban poorest no longer knew how to bake bread or make butter or brew beer, even if they could have found the ingredients” (p. 36). It appears that the situation of the poor has changed little in terms of social and political disempowerment, justified in the name of economic progress based upon mathematical models, after nearly a century. Questions could be raised as to how well, if at all, current offerings, including mathematics, address the personal, social, and civic needs of school or adult and vocational students.

Mary Harris (2000) argues that throughout history people with responsibility for running households and rearing children, animals, and plants, must have had to be numerate to survive, even if they were classed as illiterate. She also argues that, although much of women’s work throughout the ages has been invisible, the most consistent subject of a girl’s education was work with cloth: its production and the manufacture of clothing. However, the advent of capitalism, with the gendering of work, transformed tasks that had been developed into art-forms into means of social control while imposing idealisations of femininity. Whenever it was recognised that work in clothing and textiles implied a knowledge of mathematics, it was trivialised or ignored. Thus, until the challenges of feminists and others in the 1970s, compulsory schooling engendered low intellectual expectations for girls, accompanied by feelings of low self-esteem and self-confidence, according to Harris — thus reflecting a gender (and class, race, etc.) segmented system of education.

In a study of the history of mathematics teaching in Germany, Gert Schubring (1998) notes the fragile social status associated with mathematics instruction, caused by general public disparagement linked to the limited success enjoyed by the few and the impression of failure experienced by the great majority. He claims that research on teachers generally focuses on the content of instruction as the main dimension and, for mathematics teachers in particular, research on socialisation indicates that their professional identity is closely linked to their love of the subject. Schubring traced the emergence of the profession of mathematics teaching from the early nineteenth century in Prussia when mathematics became a major teaching subject as part of systematic educational reforms and mathematics teacher education was institutionalised. Biographies of first generation mathematics teachers indicate their isolation from colleagues in classical languages and resistance of all kinds from the director, colleagues, students and their parents. This state of affairs appears to bear comparison with the situation of present-day mathematics teachers in the Australian VET sector (FitzSimons, 2000b).

Schubring's research provides some structural insights into social and cultural factors of school mathematics and its teachers — arguably relevant to vocational mathematics.

- School mathematics does not reflect or project the scholarly discipline of mathematics, either in historical or modern forms.
- The relative status of mathematics as a school subject is contested.
- School mathematics is moulded by culturally determined epistemologies, varying historically on a continuum from purely mental training to applicability and vocational utility.
- There is enormous variability in the relation between school mathematics and scientific knowledge, varying from a hermetic body of knowledge with its own standards of rigour and content hierarchy to the extreme of openness where methodological views converge with academic mathematics.
- There is a dominant, often unreflected, epistemological belief in the cumulative development of mathematics — following the lead of Whitehead, Kuhn, and others. (See, Harding, 1998, for example, for a critique of these beliefs concerning scientific rationality.)

Yves Chevallard (1989) addresses the cultural fragility of the discipline of mathematics, asserting that mathematics teaching is used as a means of overcoming the relative invisibility caused by its social effectiveness. He questions why mathematics is taught at secondary level when engineering and medicine, for example, do not begin until tertiary level. His theorisation suggests that although the teaching of mathematics is publicly justified in terms of the individual's interests, it is actually performing a role in the communal interest. He claims that the essence of the problem is the socio-ontological question: the question of mathematics' "very existence as a social practice" (p. 55). In convincing society that mathematics teaching is both necessary and desirable the 'noosphere' propagate an apologetic discourse about individuals' personal needs — which is neither the ultimate reason nor the efficient cause of its being taught. According to Chevallard, modern societies are infused with individualism, and communal needs are ignored unless they appear to coalesce with individual needs. However, this confounds the duality of mathematics as a social means of production and the individual's personal relationship to mathematics as a body of knowledge. Chevallard's solution is for mathematics to be taught as a cultural initiation; this is pursued by Ernest (1998c) among others.

The issues raised by Schubring and Chevallard in relation to the socially constructed nature of mathematics curricula are certainly pertinent to the Australian VET sector in terms of status, epistemology, ontology, content, rigour, and purpose — not to mention the professional status of mathematics teachers. What might be learned from the history of mathematics education? Could these issues apply elsewhere? Might a narrowness of curriculum focus be of benefit or hindrance to vocational students or the industries they aspire to, or currently, work in? Would a focus on cultural initiation, or 'the big picture' serve the interests of some or all stakeholders any better? Given that curriculum will always be contested, what are some of the major influences which impact on the determination of vocational mathematics curricula? Mathematical work and mathematical knowledge operate in complex interrelationships with political, educational, and other social and cultural factors. Restivo (1993), among others, claims that mathematics is embedded in and embodies a web of roles, institutions, interests, and values. What could this understanding mean for vocational mathematics curriculum and teaching? In the following section I will look at the views of some researchers as they pertain to school mathematics curriculum and teaching with, I assert, sufficient justification to apply to adult and vocational mathematics education. The focus here is on ideological, cultural, and social dimensions.

1.3.2. Perspectives on Ideological, Cultural, and Social Dimensions of Mathematics Education

Two decades ago, Michael Apple (1979, p. 14) remarked that a neglected area of educational scholarship was the "critical study of the relationship between ideologies and educational thought and practice, the study of the range of seemingly commonsense assumptions that guide our overly technically minded field." *Ideology* is taken as a system of ideas, beliefs, or values; as a way of seeing, thinking about, and with which we construct our social reality. Apple argued that it has a dual role as a set of rules that give meaning and as a rhetorically potent force in arguments over power and resources. Drawing on the work of Antonio Gramsci, he claimed that the concept of *hegemony* — taken as the deeply saturating commonsense consciousness and practices underlying our lives, explicitly and implicitly emphasising the facts of domination — helps in thinking through the complex characteristics of ideology. Apple also employed the metaphor of distribution, such as the uneven distribution of *knowledge,* related to political and economic *power* of certain groups to help understand the role of culture in our society; however, he warned against situating the institution of schooling, knowledge forms, and educators in an overly deterministic manner.

Apple's claim of neglect in critical scholarship may no longer hold for sections of the international mathematics education and the vocational education research communities. If, as asserted by Apple (1979), the control of the knowledge preserving and producing institutions of a particular society is a critical element in enhancing the ideological dominance of particular classes, certain questions arise. Which interest groups contest control of these institutions in relation to vocational education and training, and which have been successful in recent times? In the Australian VET sector the ahistorical nature of most educational activity, and dominance of an ethic of amelioration through technical models is a feature of most curriculum discourse. Is this the case elsewhere? Twenty years ago Apple observed that many people looked at schooling as a black box, measuring inputs and outputs; even as global macro-economic returns to investment. Why does this sound so familiar now? (See Gjone, 1998.) Importantly it must be remembered that education as means of contributing to social and economic change does not and cannot exist in isolation from political decision-making. Yet it appears to be the case that the discourses concerning Australian school mathematics education (Ellerton & Clements, 1994), as in the VET sector, often hide the underlying complex nexus of political and economic power and resources. The construction of curricula, as with any eventual evaluation or assessment, appears to be managed through technical procedures which not only avoid ethical or qualitative issues, but also serve to render them the province of 'experts.' Apple argues that this reduction in the complexity of the issues becomes an aspect of cultural reproduction — not as a conspiracy but as "a 'logical necessity' for the continued maintenance of an unequal social order" (p. 40). Discussion of these issues of technologies of management will be further developed in later chapters.

Apple (1979) argues that the reification of knowledge as a commodity in our society together with its partial distribution is related to hegemony. Whenever there has been substantial funding for mathematics curriculum development it has seemed relatively non-controversial. "It has a (supposedly) identifiable content and . . . stable structure that both are teachable and, what is critically important, testable" (p. 38). In the Australian VET sector, where large amounts of money have been spent in recent years on mathematics curriculum audit, rationalisation, and module development, questions remain concerning the identification of content: Under what parameters was the research conducted, and for whose purposes? In any vocational mathematics programme, further questions arise: Beyond the surface features of 'exemplary' textual material, tests and assignments, what really is being taught and tested or assessed? What are the ideological, cultural, and social forces operating? As will be illustrated in chapter 4, mathematics can never be a value-free component in any sector of any education, including adult and vocational education.

As noted previously, Western conceptions of rationality have been deeply influenced by the Enlightenment (Harding, 1998; Popkewitz, 1997; Walkerdine, 1994) with negative effects for certain social and cultural groups. Walkerdine argues that the apparent ‘lack’ of rationality in such groups stems from the organisation of the education system, originally introduced in England to abolish child labour as well as to produce a ‘docile workforce’ with habits suited to a capitalistic economy. Thus, education was not organised for liberation but the production of appropriate kinds of subjects. This was achieved by producing a theory of what was ‘natural’ and pathologising deviations. Walkerdine also claims that there was nothing natural or inevitable about the approaches to development which saw a progression towards the goal of advanced abstract reasoning; accompanied by a ‘stage’ model of development which was self-fulfilling. She argues strongly for the need to move beyond such meta-narratives, “towards a model of thinking produced within practices that are themselves historically and culturally located.... We need to view thinking as a socially and historically produced practice, not as an abstract and disembodied entity” (p. 70). Of all curriculum areas, mathematics education probably has the strongest association with abstract reasoning and suppression of all contextual reference, according to Walkerdine (see also Kline, 1987).

Herein lies a major tension for vocational education and training. Most workplace activities, especially at trade and technician levels, are essentially contextually loaded. Thus, further questions arise: To what extent is vocational mathematics education — to the extent that there is an implicit focus on abstract reasoning, in spite of the rhetoric about its being practical (e.g., Maass & Schloeglmann, 1997; Straesser, 1999) — implicated in the production of a docile workforce? What are the possibilities of vocational mathematics education playing a liberatory role in the lives of citizens in and out of workplace contexts?

A possible explanation for the conflicting public images surrounding mathematics arises in terms of the connections between the *structural* aspects of mathematics and the *ideological* roles it might be expected to play. Richard Noss (1994a, 1994c) claims that the structural aspects of the discipline of mathematics (e.g., the rules and relationships), apart from trivial examples, play little role in our mass culture. For most people its structures are inaccessible and not available for debate, discussion, and appreciation in the way that those of music are, for example. This brings us back to the work of Chevallard (1989) and Niss (1994) in that, although mathematics is an integral part of our technological society, it is mostly implicit. As Noss (1994c, p. 5) reminds us, “mathematics itself is often invoked as a source of certainty and power and equally, as a mechanism for replacing judgement by calculation” (i.e., as a technology of management, providing a technical solution). Yet, even the structural meanings attached to proofs — seen as the essence of mathematics — have varied over the centuries (Restivo, 1992). On the other hand, Noss continues, mathematics is supported by an ideological meaning, that “mathematical proof is generally superior to everyday justification.” This accords with publicly held views on the superiority of abstract, mathematical thinking over everyday, practical thinking embedded in Western culture (Walkerdine, 1994). Nicholas Balacheff (1988, cited in Noss 1994c) identifies these two kinds of meaning as different discourses, with the central issue being that of *rigour* which has been used to import ideological meanings of *general* intellectual superiority into mathematical thought. Thus mathematics education has been utilised to perform roles of socialisation comparable to the study of the classics in previous centuries or of Euclid in former times when certainties were seen as necessary and desirable. As outlined by Chevallard, mathematics education cannot be justified solely on the basis of its usefulness to individuals.

This discussion highlights one of the major tensions surrounding vocational mathematics education. Although the structural meanings of mathematics are available to few members of the public (including Australian VET sector decision-makers such as bureaucrats, members of Industry Training Advisory Bodies (ITABs), TAFE institute managers), mathematics is taken as a source of certainty, with calculation frequently used as a surrogate for judgement — especially in present-day business and public sector management. At the same time mathematical thinking purveys aspects of intellectual superiority, which may be generalised, and which may well present a perceived threat to employers and politicians if allowed to flourish unchecked among otherwise docile workers. Noss (1994c, p. 8) concludes that "mathematical thinking is a (non-unique) form of *theoretical thinking*" which may be used as a means of accessing formal thinking rather than being seen as the epitome of formal thought. Thus, the role for theoretical mathematical thinking in vocational education is confounded when workers are required simultaneously to be creative problem solvers and to 'know their place.' These aspects of the public image of mathematics are rarely problematised. The Australian mathematics discipline review for universities (NBEET, 1995b) provides testament to the fact that higher order thinking is reserved for the more élite university students, even though their peers undertaking courses at upper, paraprofessional levels in TAFE institutes may be covering comparable work. For the latter there is no public discussion of the importance of their mathematical studies.

Keitel, Kotzmann, and Skovsmose (1993) note that, although mathematics education seems to avoid the issue of explicitly developing a metaknowledge about mathematics, students will develop certain views in any case, not only based on content. They are concerned that most school mathematics curricula implicitly support a philosophy of absolutism, with no distinction being made between the reliability attributed to mathematical propositions interpreted as a consequence of other mathematical statements and the reliability of a mathematical formula used for a 'real world' problem. They continue that although mathematics education does not define the discipline of mathematics it does define the role of students. Textbooks frequently present an image of mathematics being everywhere, without explaining how and why this is the case. Mathematics education appears to justify the use of any mathematics and students become adjusted to the world of realised abstractions without necessarily being able to recognise them. Behind the assertions that mathematics education serves a purpose in students' general epistemological development (see also Robitaille & Dirks, 1982, concerning psychological development) they see that there is a hidden curriculum in the socialisation of students to prepare for routine work in the technological society. That is, mathematics education is developing in students "an ideological base for a servility towards technology" (Keitel, Kotzmann, & Skovsmose, p. 269).

Students in schools *may* be persuaded explicitly "that everything can be the object of reasoning and mathematical manipulation" (Keitel, Kotzmann, & Skovsmose, 1993, p. 269), that mathematics provides certainty and rationality, and its language rigour and precision. However, these qualities are not necessarily manifest in vocational mathematics classrooms. For example, the appreciation of the 'rationality' of mathematics may be absent or misguided in the pursuit of the 'certainty' it offers, as many teachers will testify, when students express the desire to be given the 'right formula,' then proceed to follow it (to the best of their ability), and accept unquestioningly their calculator's output. The servility to technology is unquestionable. But the rigour and precision of students' mathematical language and reasoning may leave much to be desired. Certainly, the social aspects of mathematics are rarely, if ever, under consideration.

Although embodying the values of rationalism and objectism (Bishop, 1988), mathematics is paradoxically presented by many teachers as apparently value-free. According to Keitel, Kotzmann, and Skovsmose (1993), this image of mathematics is achieved through the 'forgetting' of contexts (cf., Walkerdine, 1994) and alternative models and applications, possibly creating the belief that mathematics is universal, teleological and eternally true. Mathematics also acts as a colonising force through engendering the belief that it will always be possible to find an optimal technological solution at any time and for any case. The obvious question is: What metaknowledge about mathematics might vocational education students be developing through their experiences of curriculum and teaching? How might appropriate forms of metaknowledge be developed that will advantage the students, industry, and society generally?

As will be discussed in chapter 6, education in Australia has become commodified and educational policy, especially as it relates to the VET sector, has been strongly influenced by the neoliberal philosophies of the British New Right (Marginson, 1997; Raggatt, 1998). Vocational mathematics education is imbricated in these philosophical and ideological constructs. In the UK Paul Ernest (1991) used the 1970 Perry Scheme — a psychological theory concerning the development of individuals' epistemological and ethical positions — as a basis for distinguishing ideologies, providing a framework for his comparison of different philosophies of mathematics education. Of interest here are two influential groups of people holding philosophies of mathematics that are described by Ernest, building on the 1961 work of Raymond Williams, as absolute, and with ideologies that are classed respectively as dualist and multiplist: namely *industrial trainers* and *technological pragmatists.* The former are identified politically by Ernest with the New Right in Britain, favouring basic skill training; the latter are 'descended' from the former but differ in their composition and aims for education and are concerned with a broader range of skills, knowledge and personal qualities seen to be of benefit to industry. Ernest (1991) describes the aims of the industrial trainers:

> The overt mathematical aims of this position concern the acquisition of functional numeracy, but the aims extend beyond this to social control and the reproduction of the

> social hierarchy. In support, the means of teaching are such as to discourage critical thinking and originality, and to foster obedience and docility. (p. 150)

He rejected these aims on the grounds that they do not serve the needs of modern industrial society, and may even be counter-productive in terms of training for industry.

The aims of the technological pragmatists were described by Ernest (1991) as lacking a proper epistemological, moral or social foundation. In their view, education is for the acquisition of the knowledge and skills necessary to serve the immediate and future technological needs of industry, commerce and employment; as well as the certification of potential employees to facilitate the processes of selection for employment.

Epistemologically, knowledge is viewed by technological pragmatists as unproblematic and given; it can be applied in practical situations. Resting on notions of utility and expediency, technological and industrial development are seen as positive forces for social progress, and not problematic for society or the environment. In their technocentric approach there is a tendency for centrality to be given to objects of technology, above people, cultures and goals. Ernest (1991) concludes:

> With regard to the aims of mathematics education, the concern with needs of industry alone may be narrow and counterproductive. For as some of the industrial lobby realize already, general knowledge and transferable skills suit industry better than narrow vocational skills. . . . Unless creative and aesthetic aims are included alongside the utilitarian aims of mathematics education, the teaching of the subject will be stilted, and fail to contribute fully to the education of the whole person (Isaacson, 1989). . . .The means it adopts may fail to be the most efficient for meeting its own ends. (pp. 165-166)

Clearly there are tensions between the industrial trainers and the technological pragmatists, even though they may share common interests. (Ernest's point about employers preferring general knowledge and transferable skills will be taken up again in chapter 2, on mathematics and the workplace.) These ideological and philosophical positions are clearly value-laden and it is argued that the deliberations of those who provide advice on government policies as well as those employed to implement them must reflect certain values. I turn now to a discussion of values as they relate to mathematics education.

1.3.3. Values and Goals of Mathematics Education

According to Jasmin McConatha and Frauke Schnell (1995, p. 80), "values are primary constructs which affect an individual's interpretive schema and his or her sense of self, thereby exerting a direct or indirect influence on attitudes, beliefs, feelings, and the perception of the social and political world." They continue that values are not innate, immutable given qualities as has often been perceived, but are endogenous properties, shaped by cultural factors. Although values are transmitted from individual to individual, group to group, and generation to generation, educators remain one of the primary agents of values transmission. They argue that the study of values is consequently central to understanding the current philosophical debate regarding educational policy. In education, as Peter Machamer and Heather Douglas (1999) argue for the case of scientific practice, the separation of social and cognitive values will not achieve the goal of distinguishing legitimate or acceptable reasons from those which are not. In the VET sector there appear to be few arguments given to support policy decisions which make explicit their educational or other political (economically and socially focused) goals or purposes — as distinct from largely unsubstantiated rhetoric about increasing competitiveness, raising productivity, and so forth. What might be the purposes and goals of mathematics education?

According to Mogens Niss (1996), internationally, fundamental reasons for teaching (school) mathematics include: contributing to the technological and socio-economic development of a society; contributing to its political, ideological and cultural maintenance and development; and providing individuals with prerequisites which may help them to cope with life in the various spheres of education or occupation, private life, social life, or life as a citizen. Affective and cognitive aims are clearly imbricated in Niss's account. Several aims point in the direction of critical analysis, implying that the development and utilisation of mathematical ideas and techniques cannot be value-free. However, the intra-disciplinary values of mathematics (e.g., Bishop's, 1988, three pairs of complementary values) appear to be largely implicit. As mentioned above, mathematics itself must be an object of critique (Skovsmose, 1994, 1998b).

It is clear that societies take an interest, albeit to varying degrees, "in providing mathematical prerequisites to the population at large to master their private and social lives as individuals and citizens" (Niss, 1994, p. 375). In recent years the phenomenon of *numeracy* has come to assume an increasingly important role in the political realm impacting upon educational practice. The nexus between numeracy and the discipline of mathematics is complex and contested.

1.3.4. Numeracy: A Contested Concept

From its nomenclature the term *numeracy* is suggestive of both literacy and numbers, perhaps literacy with numbers; and indeed it is widely accepted that it was coined as a counterpart to literacy. However, over the years its conceptualisation has broadened from being concerned with numbers alone — that is, the 'basics' of the four operations on whole, then rational numbers — to include, in some cases, aspects of algebraic, geometric, statistical thinking (or quantitative literacy), as well as problem solving (e.g., Jablonka, in press; Manly & Tout, 2001; Steen (Ed.), 2001).

FitzSimons, Jungwirth, Maass, and Sehlöglmann (1996) trace a brief history of the development of official interest in this topic, predominantly in Anglophile countries. For example, in the UK, the USA, and Australia there has been a burgeoning public interest, and this has more recently spread to some countries of the European Union (DEETYA, 1998; DETYA, 2000; DfEE, 1998a, 1998b; Gal & Schuh, 1994; Galbraith, 1988; Groenestijn, 1997; Kemp, 1998a; O'Donoghue, 2000). Developing countries are also experiencing a push for adult numeracy, along with adult literacy (Clements, 2001) — although the latter is usually regarded as of prime importance. Usually programmes are publicly targeted towards individuals or specific community groups.

Ubiratan D'Ambrosio (1985), borrowing the term *matheracy* from Tadasu Kawaguchi, associates it with the codification of popular mathematical practices in relation to daily needs, including the capability for quantification and qualification and some patterns of inference. His concern is that, in developing countries in particular, it is this spontaneous knowledge which is denied in the push for 'learned' mathematical knowledge, instilling — whether consciously, as in experience of colonisation, or not — a sense of helplessness and dependency among children. The same phenomenon can occur when experienced adult workers are subjected to ill-conceived mathematics or numeracy programmes (see chapter 4).

A fundamental consideration is which knowledge interests are being served. Using a Habermasian framework (Habermas, 1963/1974), it could be argued that many official reports and semi- or fully-funded programmes are serving primarily *technical* or instrumental, manipulative interests, and *practical* or hermeneutic, communicative interests. Adults are to develop the instrumental skills, confidence, and competence to function effectively in the workplace, the home, and society — as producers and consumers of commodities and/or information. The third of Habermas's interests, *emancipatory,* is understood by Jayne Johnston and Mairead Dunne (1996, p. 53) as "constituting a position from which to critique the absence of an explicit recognition of the politics of knowledge constitution in the technical and practical positions." They continue that, within the technical interest, claims to value-neutrality and objectivity deny the social construction of knowledge. Within the practical interest, although knowledge is regarded as socially constructed, its claims to consensus come via the knowledge of 'experts.' Thus, political considerations are hidden in the first and distanced in the second. By contrast, the third, emancipatory interest, focuses overtly on power relations, addressing questions about knowledge production and legitimation and exploring social structures which serve to maintain and reproduce the interests of those holding power.

An example of technical and practical interests in numeracy is given in the Cockcroft Report (1982):

> We would wish the word 'numerate' to imply the possession of two attributes. The first of these is an 'at-homeness' with numbers and an ability to make use of mathematical skills which enables an individual to cope with the practical mathematical demands of his [sic] everyday life. The second is an ability to have some appreciation and understanding of information which is presented in mathematical terms, for instance in graphs, charts or tables or by reference to percentage increase or decrease. (p. 11)

In the last two decades many reports have focused on adult numeracy, albeit with greater consideration of the contexts in which people act, and the processes of being able to choose and use appropriate mathematical ideas (Willis, 1990). Few, however, have adopted a critical stance towards the production and legitimation of power, including the impact of technological development on our society.

Numeracy, particularly in its technical and practical senses, often seems inherently to be linked to that mathematics which is useful (e.g., Willis, 1990) —

thereby inserting an arbitrary, judgement-based binary division within the discipline of mathematics (i.e., according to the viewer's perception of the usefulness or otherwise of the contextual situation). Whose judgements prevail and whose interests are being served? On the other hand, Steen (2001) makes a clear distinction between mathematics and numeracy, arguing that students need both. Whereas mathematics requires a distancing from context, numeracy (or quantitative literacy, in his words) "is anchored in real data that reflect engagement with life's diverse contexts and situations" (p. 58).

The recent interest in numeracy by governments around the world has been concomitant with the upsurge of interest in educational outcomes and accountability. According to Dave Baker (1998), the UK Adult Literacy and Basic Skills Unit [ALBSU] has formulated what he terms an *autonomous model* of numeracy as culture- and value-free; determining the basic skills (supposedly) needed by all adults. Content — activities, techniques — is the essence of this dominant, autonomous view. In standards models such as these, there is no debate about which skills are central, whose standards they are, or why they are needed (see also Coben, 2001). Baker continues that the existence of multiple numeracies leads to the questioning of the validity of these standards; power relations also need to be made more explicit and open to challenge and critique. It may, perhaps, be inevitable that international studies such as the *Adult Literacy and Lifeskills* project deliberately avoid any confrontation with ideological situations which may provoke political dissent. One practical justification could be that it might be unfair to the adult subject to cloud their performance on numeracy skills assessment tasks with consideration of issues which may be considered emotive.

Emancipatory interests have been championed by some teachers (e.g., Frankenstein, 1989, 1990, 1996; Knijnik, 1996, 1997, 1998; Webber, 1988) as well as academics. Niss (1994) argues against mathematics education being limited to everyday private and social uses.

> Those not in possession of mathematical competence beyond what is used in everyday life will be excluded from influencing important processes in society that have a considerable impact on their lives as individuals and citizens. If we want to stimulate a democratic development of society — as distinct from both an authoritarian one and a populist one — the fostering of intelligent and concerned citizenship is of crucial importance. (p. 376)

Accordingly, he recommends a mathematics education oriented towards the ultimate end of enabling people to take positions on and to act in relation to processes significant to society and themselves as individuals.

Henry Giroux (1989, cited in Skovsmose, 1994) describes literacy as a double-edged sword

> . . . necessary in today's society for informing people about their obligations, and for people to be employable in essential work processes. However, literacy can serve the purpose of empowerment because it can be a means of organising and reorganising interpretations of social institutions, traditions and proposals for political reforms. (pp. 24-25)

Not only is literacy a precondition for social and cultural emancipation but, more than merely reading and writing, it is "fundamentally related to forms of political and ideological ignorance that function as a refusal to know the limits and political consequences of one's view of the world" (Giroux, 1989, p. 151, quoted in Skovsmose, p. 25). Mathematics knowledge is implicated in this ignorance as well.

Skovsmose (1994) wonders whether *mathemacy* could be used for purposes of empowerment? Whether it could help people to reorganise their views about social institutions, traditions and possibilities in political actions? As a radical construct, "mathemacy has to be rooted in the spirit of critique and the project of possibility that enables people to participate in the understanding and transformation of their society" (p. 27). Therefore, mathemacy becomes a precondition for social and cultural emancipation. Skovsmose (1998b) refers to mathemacy as an integrated kind of competence including different forms of reflection: mathematics-oriented, model-oriented, context-oriented, and lifeworld-oriented reflections. While the first two refer to the results of mathematical tasks (i.e., correctness) and the relationship between mathematics and an extra-mathematical reality (i.e., validity), the third asks: "What is the purpose of carrying out the modelling? What, in fact, is the political and social function of applying mathematics to a certain situation?" (p. 16) —in order to unearth the latent functions of the model, and to attempt to address the issue of 'mathematics and power'. Finally, the lifeworld-oriented reflection sees the learning of mathematics as a social responsibility.

Some Australian educators include numeracy as part of mathematics taught to university students in (vocational) primary education and electrical engineering courses. Keiko Yasukawa, Betty Johnston, and Warren Yates (1995) assert that numeracy is a

> critical awareness [which] enables us build bridges between mathematics and the real world, with all its diversity. Being numerate involves not only having this critical awareness, but also involves the responsibility of reflecting that critical awareness in one's social practice. Thus, being numerate means being able to situate, interpret, critique, use, and perhaps even create mathematics in context, taking into account all the mathematical as well as social and human complexities which come with that process. (p. 816)

They continue that in order to engender numeracy it needs to be socially situated, incorporating personal reflection and social negotiation; it needs to "excavate, uncovering assumptions and value systems, and whose interests are being served by any given representation of reality" (p. 819). Numeracy is necessarily subjective. In addition, the wider institutional context will affect the extent to which teachers' and learners' ideologies can be enacted.

John Foyster (1990) argues for mathematics to be appreciated for its aesthetic qualities:

> When, in our concern for societal functioning, we focus our attention upon numeracy and its attainment we run the risk of perceiving mathematics as having only utility and ignoring the capacity of mathematics to add pleasure to our lives. Mathematics is, I think, quark-like for most people — difficult to grasp and certainly strange. But we are unlikely to understand how to make it useful until we acknowledge and use its truth, its beauty, and its charm. (p. 136)

How many adult and vocational education numeracy programmes even consider aesthetics? Contrary to Bagnall's (1997) exhortation for the inclusion of aesthetics into vocational education generally, it is often recommended that aesthetics and recreational aspects of the cultural heritage of mathematics should be ignored.

Baker (1998) proposes that numeracy practices include social, cultural and ideological perspectives. For example: the specific contexts and purposes which preclude universality; individuals' beliefs, values and epistemologies which affect practices; and the ideological relationships between people — their status and roles; people and knowledge concepts — all of which affect what is taken as acceptable and legitimate numeracy.

Assessment surveys and assessment criteria for predetermined learning outcomes cannot but have an influence on numeracy teaching, especially if funding is tagged to meeting official criteria. Rarely do these documents go beyond mathematics-oriented reflections — if they consider reflections at all. The control and atomisation of curricular content (see chapter 4) is a manifestation of what Skovsmose (1994) regards as a controlled concept of knowledge. According to him, this assumption of the homogeneity of knowledge was developed concomitantly with foundationalism in epistemology. He claims that critique as an a priori activity, separated from the accumulation of knowledge, leads to the consequence of the basic 'logic' of education becoming that of 'delivery of knowledge.' This has been a prevalent assumption in the history of education, he asserts, with the reproduction of some of the most simple and basic parts of the body of knowledge through teaching.

On the other hand, Skovsmose (1994) treats the act of *knowing* as an open concept. In his opinion "a belief conflict is not problematic from an epistemological point of view" (p. 200). It cannot be solved by any empirical test; rather it has to be solved in terms of negotiation. In the sphere of adult and vocational education, where students have extensive practical experience of 'what works' — albeit often within limited contextual scope — conflicts of belief in relation to mathematics are likely to abound, whether explicitly expressed or tacitly held. Skovsmose continues:

> The existence of knowledge conflicts means a breaking down of the assumption of the existence of an authorised body of knowledge. . . . A critical investigation of a knowledge claim becomes a permanent necessity. There is no knowledge without pre-conception and prejudice. (p. 200)

Yet, he acknowledges that "to take up a critical attitude presupposes a decision made by the learner" (p. 201) — it cannot be mandated. One important consequence is the need to develop learning theories which view the learner as an agent in the learning process. Thus, 'intention' and 'reflection' are established as educational concepts.

Notwithstanding Skovsmose's theorisations, many vocational students would be surprised to comprehend that they are to challenge an authorised body of knowledge such as mathematics; most have been conditioned over the period of compulsory schooling to accept absolutist philosophies and epistemologies of mathematics. It seems that the way of resolving the apparent paradox is for 'what works' to be called 'common sense' and what is learned in formal education to be called 'mathematics' — not necessarily intended to make sense. To establish the concepts of intention and reflection within agentic theories of learning would represent a major shift in much of what passes for adult and vocational mathematics education.

Skovsmose (1994) is critical of the Piagetian version of constructivism (see also Skovsmose, 2000) — popular with authors of numeracy handbooks who have moved on from the transmission paradigm — which he describes as a *mono-logical epistemic* theory. However, in this combination of rationalism and empiricism, Skovsmose asserts that "communication is reduced to a pedagogical and methodological implement" (p. 204). The result is that critique, as self-critique, is oriented towards the individual construction of mathematical knowledge; the 'politics of knowledge' is excluded.

By contrast, under *dia-logical epistemic theories* which accept knowledge conflict as a reality, 'knowing' presupposes an interpersonal relationship, according to Skovsmose (1994). Conflicting claims "cannot be solved by adding new information, collecting more observations or by performing more careful calculations" (p. 205). Rather, critique and reflection are needed. This shift makes impossible the notion of knowledge as authority and education as 'delivery'. However, Skovsmose claims this interpersonal relationship also relates knowing to power, whose agents can be traditions, paradigms, or persons. Yet, as will be evident throughout this monograph, "the notion of the power of mathematics makes sense only when understood as an interplay with other power structures of society" (p. 207). Thus he claims the concept of knowing in critical mathematics education explodes in different directions. Skovsmose concludes that mathemacy could be ascribed an importance similar to that of literacy, "as a competence by means of which we become able to interpret and to understand features of our social reality" (p. 208). Behind dia-logical epistemic theories of knowing lies a major difference in ideology and epistemology from that of the 'functional effectiveness' espoused by proponents of everyday numeracy for work, home, and civic life.

Having considered the institutions of mathematics and of mathematics education from the perspectives of professionals within the respective fields, I turn to address publicly-held perceptions of these. One important reason for so doing is that the Australian VET sector prides itself on being 'industry-driven' or 'client-focused' — although students as 'clients' generally take second place to industry. Through the interplay of ministerial edict and recursive funding mechanisms, these two stakeholder groups of industry and students (albeit unwittingly through their course completion rates) exert considerable influence in determining the quantity and quality of mathematics education in the Australian VET sector. Images, consciously held or otherwise, cannot but influence the outcomes.

1.4. IMAGES

In this section I will review a selection from the literature on personal and public images of mathematics and mathematics education. In this technological era image and mythology are very powerful determinants of public opinion, reflexively linked to political processes although not in a simplistic, unidirectional manner from rulers to ruled or vice versa (Vanderburg, 1988).

1.4.1. Images Public and Personal

The institutions of mathematics and of mathematics education, although often confounded by members of the public, have each in their own way contributed to the public images of mathematics. These images are created and reflected both in the cognitive and the affective domain and concern, *inter alia,* knowledge, values, beliefs, attitudes, and emotions. As is the case for values, (Seah & Bishop, 2000), images held by any one person may not be logically consistent, may come into play consciously or unconsciously, and do not form a static entity. As I will elaborate in chapters 5 and 6, processes of decision-making in the Australian VET sector are multifarious. At all levels, from ministerial policy determination, through industry-driven curriculum advice and development, to local TAFE administration and the classroom or workplace, decisions are being made purposefully or inadvertently which ultimately affect the teaching and learning processes and hence learning outcomes for all students — whether enrolled in an officially recognised mathematics subject or in others which may use mathematical ideas and techniques. By and large the range of people making these decisions are likely to have few if any tertiary qualifications in mathematics or even in education — that is, apart from long-serving TAFE mathematics teachers. Yet each person has formed, over a lifetime, opinions about the nature of mathematics, its importance to society generally and to themselves personally, and how it might be taught. What does research tell us about these images of mathematics and mathematics education that influence to a greater or lesser extent the decisions made by all stakeholders, including students, in the VET sector? The intention here is not to make generalisations about each group of stakeholders but to establish a foundation for a critique of current practice in later chapters.

1.4.2. Images of Mathematics

Lira Chap Sam and Paul Ernest (1999) claim from a review of the literature that there is, as yet, no consensus on the definition of 'image of mathematics.' They conceptualise it as "a mental picture or view of mathematics derived as a result of social experiences" (p. 1). Images of mathematics are formed directly through experience of mathematics (and other) education, as well as communicated through personal interactions with family and peers, for example, or by the mass media.

Ernest (1995, p. 449) describes the widespread public image of mathematics as "difficult, cold, abstract, theoretical, ultra-rational," that is, inhuman. Many people who would be regarded as having high levels of competency in numeracy, graphicacy and computer literacy claim that they cannot 'do maths.' By 'maths' they usually mean academic or school mathematics beyond a certain level; Diana Coben (1997) has suggested that 'maths' is the label given to that which is beyond the individual's capacity, while all else is 'common sense' — see also Cockcroft (1982). Ernest argues that this image is consistent with 'separated' values (see, for example, Belenky, Clinchy, Goldberger, & Tarule, 1986; Brew, 1999) which help to make mathematics a 'critical filter' (Sells, 1973) denying access to many areas of study and to fulfilling professional occupations. Ernest relates this phenomenon to absolutist philosophies of mathematics which are concerned with the epistemological project of warranting mathematical knowledge rather than describing mathematics or mathematical knowledge. These are contrasted by Ernest with an opposing humanized image of mathematics, consistent with 'connected' values, which he claims is finding academic support in recent fallibilist philosophies of mathematics. He argues that, although these two philosophical positions have a major impact on the ethos of mathematics classrooms, there is no direct *logical* connection. Instead, he concludes, "the values realized in the classroom are probably the dominant factor in determining the learner's image and appreciation of mathematics (and hence, indirectly, that of society)" (p. 449).

The explicit and implicit uses of mathematics, discussed above, have obvious bearings on the public images of mathematics. In social settings there is an ambivalence towards the usefulness of mathematics. Eva Jablonka and Uwe Gellert's (1996) survey of student teachers (primary and secondary) confirmed Niss's (1994) subjective irrelevance paradox that mathematics was considered publicly important but personally irrelevant — apart from survival mathematics ('basic numeracy') and professional interests including career entry. Since personal usage is judged only in terms of explicit mathematics, it is seen as virtually mathematics-free — consistent with the demathematisation process described by Keitel, Kotzmann, and Skovsmose (1993). Jablonka and Gellert's study also revealed an unwillingness by student teachers to question their algorithmic usage of elementary mathematics or the underlying assumptions involved in mathematical modelling.

One implication of this public image of diminished personal relevance and increasing invisibility of mathematics is that accounts of workplace mathematical usage tend to undervalue its quantity and quality (Buckingham, 1997; Noss, 1997). John Foyster (1988) identifies two problems associated with labelling mathematics as such:

> Firstly, it is not generally true that one needs to understand the mathematics of a situation to perform satisfactorily; indeed over-analysis may lead to a worsening of performance. . . . Secondly, and more forcefully, it is an unavoidable truth that many students leave school and/or training disliking mathematics: to encourage these young workers to 'see the mathematics' may be extremely counterproductive. (p. 3)

Foyster (1988, 1990) notes that many school leavers, even when they showed competence and confidence in workplace situations, lacked confidence in their own mathematical ability, especially when presented with a paper-and-pencil task. Employers, when asked which mathematical skills were important, frequently nominated arithmetic skills, even when they were no longer vocationally relevant (see also Harris, 1991). This overwhelming belief among the public, including teachers, in the importance of arithmetic over all other branches of mathematics for school leavers is supported by Peter Galbraith and David Chant (1993). They also found general agreement that "mathematics is important for the prospects of both females and males, and that mathematics performance is used as a proxy for general intelligence" (p. 272), and beyond the reach of many.

Thus, it appears that the public images of mathematics could be described as alienating to many, privately irrelevant yet publicly important, and all but invisible except for arithmetic, even in many workplaces. The implications for vocational mathematics curricula of images portrayed by workplace personnel and by mathematics education researchers will be discussed in chapter 7. How might this sense of private irrelevance — not to mention alienation — affect the decisions of the range of stakeholders in the Australian VET sector (i.e., students, teachers, TAFE and industry managers, bureaucrats, and politicians)?

1.4.3. Images of Mathematics Education

Mathematics education attracts a very high degree of public interest, as witnessed by the media attention around the world paid to the recent Third International Mathematics and Science Survey (TIMSS), and the numeracy strategies for school children and the unemployed (see, for example, DEETYA, 1998; DETYA, 2000; Kemp, 1998a, 1998b in Australia; also the UK report *Improving Literacy and Numeracy: A Fresh Start,* DfEE, 1999). A very strong influence on the public image of mathematics comes from the experience of formal mathematics education. This is not to deny other influences such as stereotypes reinforced by popular media, or personal expectations conveyed explicitly and implicitly by significant others such as peers and close relatives.

In a critique of the foundations of research into women and mathematics, Helga Jungwirth (1993) argues that rather than seeking to understand and ameliorate the deficiencies of women in relation to mathematics and technology there is an alternative viewpoint. That is, if technological progress itself is treated as problematic, then women's distancing themselves could be regarded as reasonable. In her analysis of models which could account for the acquisition of gender-specific behaviour in relation to mathematics, Jungwirth suggests that subjective meaning may be a central point.

> Maybe there are different approaches to mathematics, different ways to experience mathematics as meaningful, and different aspects of mathematics that make or do not make sense; and maybe mainly those ways are ignored and those aspects are emphasized in the mathematics classroom that make females rather than males feel uncomfortable because of a lack of meaning. To turn away from mathematics in this view would be a decision of females who make fruitless efforts to create meaning out of what is going on. They would not be victims of gender-role expectations; they would like to live in worlds that make sense. (pp. 141-142)

Mathematical competence, Jungwirth argues, should be considered as a product of the social interaction in the classroom, constituted by the practices of all participants. Accordingly, she called for a systemic-ecological approach to research in mathematics education.

This issue of subjectification is taken up by Mary Klein (1998, p. 296). Students have "lived and know an institutionalised discourse of teacher and text as authoritative keepers of mathematical truths and their mathematical dispositions have been constructed within the regulatory power of the mathematical discourse." As well as constructing mathematical knowledge, students themselves are constructed by the power-laden language and practices of the classroom, according to Klein. As learners of mathematics they become more or less successful reproducers of others' knowledge, and she attributes this structuring and positioning to the frameworks of developmental psychology and liberal humanism (see also Klein, 1999a, 1999b, 2000a, 2000b).

What images of mathematics and mathematics education are formed by women and by men as a result of their subjective experience of mathematics education? In what follows I will review research on university undergraduates in mathematics courses, non-mathematics majors studying psychology, and graduates from other disciplines auditing university teaching in mathematics and science subjects. I will then move to TAFE students in a post-year 11/12 science course, and finally to the general public and women returning to study.

Working with about 300 newly enrolled undergraduates in mathematics courses, Katherine Crawford, Sue Gordon, Jackie Nicholas, and Mike Prosser (1994) found that 77% of first year mathematics students held a fragmented conception of mathematics, and 82% adopted a surface rather than a deep approach toward learning mathematics. Those with a cohesive conception and/or able to adopt a deep approach tended to achieve at a higher level after one year of university study. (However, see Biggs, 1993, for problematisation of this dichotomy between deep and surface learning.) Earlier work by Gordon and Nicholas (1992) with 60 mature-age university students enrolled in a statistics course indicated perceptions of mathematics as being (very) difficult, logical, and boring.

Gilah Leder (1989) used case studies to analyse factors affecting participation in tertiary mathematics classes through the reflections of articulate, well-educated non-mathematics graduates acting as novices. The public image generated, in spite of the best intentions of participating lecturers, was that mathematics is difficult and anxiety-provoking. Leder observed two categories of learners: those who mastered the rules acquiring the necessary concepts and strategies and those who were still struggling to make meaning of earlier material at the end of the session and who were alienated by the process. In the USA Sheila Tobias (1990) carried out similar case studies in the field of the physical sciences, finding students were discouraged by: (a) the method of instruction, which focused on technique at the expense of historical development and connections with the real world, lacking any overview; and (b) the absence of community, which was exacerbated by large class sizes and lack of contagious enthusiasm for the subject matter, even among the students who were doing well. This lack of enthusiasm manifested itself in competitiveness as distinct from willingness to work co-operatively. Arguably these criticisms still apply to many tertiary mathematics classes. If this public image is generated among those more educationally advantaged, what does it mean for others?

Gail FitzSimons (1994a) found that beliefs about mathematics of science laboratory students in a TAFE institute contrasted with those of tertiary students in the survey by Crawford et al. (1994). A larger majority held fragmented conceptions of mathematics — predominantly as numbers, rules and formulae (held by twice as many TAFE students as tertiary students), whereas the study of mathematical application to problems was a conception held by relatively fewer TAFE than tertiary students. In terms of cohesive conceptions, very few saw mathematics as a way of thinking and, perhaps not surprisingly, none saw it as a complex logical system for solving problems or for providing new insights. While learning mathematics was generally regarded by TAFE students as a negative rather than a positive experience, their comments showed a thoughtfulness and concern for overcoming difficulties, and a realisation of the necessity to complete prescribed courses. Emotions were fundamentally centred on wanting to gain complete understanding and having the ability to complete successfully set problems. The overwhelming number of negative responses indicates that this cohort of students has not been given the opportunity to gain mastery over the mathematics to which they have been exposed, and that they felt some degree of anguish over this state of affairs. So, if these are reflections from a relatively advantaged segment of the population in educational terms, how does the 'ordinary person in the street' view mathematics at a personal level?

Lim and Ernest (1999) studied the responses of 548 adults (17 years and over) from a range of occupational subgroups regarding images of mathematics. Their study showed that over 50% of the sample liked mathematics, but 33% disliked it, with the highest proportion of the latter among 17 to 20 year-olds. Noting the conflation between images of mathematics and mathematics education, they were able to classify five views commonly held: (i) absolutist/dualist, (ii) utilitarian, (iii) symbolic, (iv) problem solving, and (v) enigmatic. Commonly used metaphors to express images of mathematics were as: (i) a journey, (ii) a skill, (iii) a daily-life experience, and (iv) a game or puzzle. Coben (1997) also suggests metaphors of a brick wall, a door to be passed through, and an 'invisible mathematics' — that which is taken as common sense. However, some indication is given of shifts in public image — in the UK, at least. Lim and Ernest found that the myths of mathematics — as difficult and as only for an élite — were commonly shared but that of mathematics as a male domain no longer prevails. Stephen Lerman (1999), in a preliminary analysis of responses from over 600 senior school students in London, found some cause for optimism in an apparent shift in the social acceptability of becoming mathematical in the classroom.

About two decades earlier the Cockcroft Report (1982) was commissioned to enquire into the teaching of mathematics as it related to further and higher education, employment and adult life generally. Although there were some people who could cope confidently and competently with any situation requiring the use of mathematics in everyday life, there were many others for whom the reverse was true. The report observed:

> The extent to which the need to undertake even an apparently simple and straightforward piece of mathematics could induce feelings of anxiety, helplessness, fear and even guilt in some of those interviewed was, perhaps, the most striking feature of the study. (p. 7)

There were no connections found between levels of qualifications and the extent of mathematics usage; between mathematical competence and occupational group; or of self-estimates of mathematical competence and level of usage. People with high academic qualifications experienced particular feelings of guilt about their lack of confident understanding of mathematics as there was a general imputation of superior mathematical ability.

Others felt guilty that they had not used the 'proper' standard classroom algorithms. For many, if their single method for solving a problem failed, they lacked the ability and confidence to use an alternative approach — even an awareness of the possibility. Some felt that there always had to be an exact answer, and were unable to approximate or round off results. Others expressed long buried anxieties about speed and accuracy, as well as the requirement to show a neatly written solution, often to demonstrate a method that they had not personally used. (For a graphic videotaped representation of these behaviours, see Victorian Ministry of Education, 1985.) Are these public images of mathematics education still prevalent today?

Ascription of failure and consequent dislike was often linked in the Cockcroft Report to specific causes associated with family and schooling when young; also the deprecating comments of current close family members. A decade later FitzSimons (1993, March; 1993a; 1994b) provided personal accounts by women returning to study of differential treatment within the family; humiliation, intimidation or being ignored by teachers; penalties for being slow; disruptions to learning; language barriers; and a pervasive lack of meaning. By contrast Tine Wedege (1999b), utilising Bourdieu's (1991) concept of *habitus* and building on the subjective irrelevance paradox mentioned in the previous section, attributes the phenomenon of blocks and resistances among adults returning to study to the generation of a habitus of personal competence. This habitus is constructed over a lifetime in the apparent absence of recognition and need for explicit mathematics apart from the utilisation of arithmetical skills.

These portrayed public images of mathematics are largely negative in relation to the affective domain, and limited in the cognitive domain. The seminal work of Laurie Buxton (1981) and Sheila Tobias (1978/1993) identified causes and possible solutions to the widespread phenomenon of mathematics anxiety largely attributable to formal mathematics education; the Lawrence Hall of Science in Berkeley, California has an ongoing *Equals Project* aimed at improving mathematics education for women and minority groups, with links in Australia through the *Family Maths Project (FAMPA).* However, these approaches have been criticised (e.g., Mura, 1995) for failing to problematise the disciplinary content of mathematics education. Why might it be that issues of cognitive and affective constructions of mathematics and mathematics education brought by adult and vocational education students seem seldom to be problematised — to say nothing of the disciplinary content?

Public outcries over the last two decades, at least, in English-speaking countries suggest that almost everyone has an opinion of the teaching of mathematics, often based on their somewhat deluded memories of 'the good old days.' Recent public criticisms of the numeracy skills of unemployed school leavers and even graduates (e.g., Kemp, 1998a; Kirby, 2000) suggest that school and VET mathematics curriculum (and teaching) of today could be considered to provide inappropriate preparation for the world beyond, in spite of the utilitarian underpinning rhetoric.

Could it be that the explanation lies in the socialising function of mathematics education (Noss, 1994b) in the production of citizens who ‘know their place’ as a result of the unequal distribution of mathematical knowledge?

Are there other powerful forces operating to destabilise any tendencies towards change from tradition in mathematics education? What can be learned from analyses of the impact on education of the pervasive neoliberal philosophies of individualism promoted by governments? What is the effect of public denigration of existing state-run systems? One effect has been that creativity and innovation in mathematics education have been stifled; conservatism has been rewarded (see, for example, Horwood, 1997). Yet, at the very time when curricula are becoming more conservative and post-compulsory institutions such as TAFE and universities are increasingly controlled by government funding requirements which encourage uniformity (Marginson, 1999), there is a cry from employers (Kirby, 2000) echoed by the Australian Minister for Education, Training and Youth Affairs that graduates “were perceived to be deficient in creativity and flair, oral business communications and problem-solving ability” (Koutsoukis, 2000, p. 11).

More importantly, it appears that every opinion on education — whether from the largely right-wing owned and managed public media, politicians, the general public, or academics in mathematics or mathematics education — carries equal weight. David Berliner and Bruce Biddle (1999) provide a graphic account of the bias in media accounts influencing public opinion in the USA. A critical question is: What does this presumed equality of opinion mean for vocational mathematics education, particularly in the Australian VET sector?

What are the implications of these public images of mathematics and mathematics education in a sector which is proclaimed to be industry-driven and framed by a policy of ‘User Choice’? (User Choice will be discussed in chapter 6). In relation to vocational mathematics education, on what basis are decisions made about worthwhile knowledge? On what basis are decisions made about the mediating factors in this sector of education such as teachers, texts, and flexible delivery modalities; or about establishing a research base to address issues such as curriculum and assessment, teaching and learning, or ongoing professional development specifically related to mathematics education? My heartfelt fundamental question is: Why are these not problematised in the Australian VET sector?

To conclude this chapter I turn to the field of mathematics education research which has existed for two centuries, burgeoning over the last 30 years (Kilpatrick, 1992) — mainly concerned with the education of school children and the preparation of their teachers, but increasingly encompassing the tertiary sector (e.g., Niss, 1997; Tall, 1991). What can this field contribute to the policies and practices of mathematics teaching in the vocational sector? How might the messages of the international mathematics education research community penetrate the seemingly impermeable barriers in the Australian VET sector to be comprehended by policy makers, TAFE managers, and practitioners alike?

1.5. RESEARCH IN MATHEMATICS EDUCATION.

Summarising the proceedings of the 1994 International Commission on Mathematical Instruction [ICMI] study conference on research in mathematics education, Anna Sierpinska and Jeremy Kilpatrick (1998) note the difficulty of classifying the field because of the theoretic/pragmatic duality of its character. As with educational research in general, it is seen to be interdisciplinary and wide-ranging; yet from the perspective of some mathematicians its major purpose is to design more effective teaching processes. Questions arose as to the object of research in mathematics education: is it the teaching and learning of mathematics, or mathematical knowledge? or the inner and outer worlds of people learning mathematics? There was also a reflection on the problematic nature of mathematics education research itself.

Paul Ernest (1998a) argues for a postmodern perspective on research which sees mathematics education as a field constituted by a multiplicity of practices. In order to make comparisons with the dearth of related research in the Australian VET sector I list in detail his categorisations. These include, firstly, the practices of: (a) the teaching and learning of mathematics at all levels in school and college; (b) out of school learning (and teaching) of mathematics; (c) the design, writing and construction of texts and mathematics learning materials; (d) the study of mathematics education in pre-service teacher education; (e) the graduate study of mathematics education texts and results; and (f) research in mathematics education at all levels. Ernest suggests that the recursion in this list indicates that mathematics education research is reflexive, in that it tries to account for itself, as in Bloor's (1976, cited in Ernest, 1998a) 'strong program' in the sociology of knowledge (see also Restivo, 1992).

As primary objects of research he includes: (a) the nature of mathematics and school mathematical knowledge; (b) the learning of mathematics; (c) the aims and goals of mathematics teaching and schooling; (d) the teaching of mathematics, including the methods and approaches involved; (e) the full range of texts, materials, aids and electronic resources employed; (f) the human and social contexts of mathematics learning/teaching in all their complexity; and (g) the interaction and relationships between all of the above factors.

Ernest then suggests that secondary objects might be taken to include: (a) the nature of mathematics education knowledge: its concepts, theories, results, literature, aims and function; (b) the nature of mathematics education research: its epistemology, theoretical bases, criteria, methodology, methods, outcomes and goals; (c) mathematics education teaching and learning in teacher education, including practice, technique, theory and research; and (d) the social institutions of mathematics education: the persons, locations, institutions (universities, colleges, research centers), conferences, organizations, networks, journals, etc. and their relationships with its overall social or societal contexts.

Although Ernest's list of practices is comprehensive and includes 'all levels' of education as well as 'out of school learning,' I believe that the reality — as borne out by the characteristics of chapters published from this conference held in 1994 — was that adult and vocational education was of marginal importance. Has the situation changed since then? Diana Coben, John O'Donoghue, and Gail FitzSimons (Eds.) (2000) provide evidence that there has indeed been a shift on the international scene, particularly in the case of research into mathematics (or numeracy) for adult education. However, in Australia, research in mathematics education for vocational education at the post-compulsory level seems to remain almost invisible. Apart from adult numeracy, few major VET research centres have shown interest in vocational mathematics education research — neither have policy-makers, or teaching and curriculum practitioners. This is despite the burgeoning research interest shown for example at recent ICME (International Congress on Mathematical Education) conferences, the Freudenthal Institute in the Netherlands, and Roskilde University in Denmark (see chapters 2 and 7). Why should this be so?

In addition to the theory-practice theme at the 1994 ICMI conference, the issue of what actually counts as mathematical activity was a recurring question. It was proposed that questions of the meaning and genesis of mathematical notions constitute the intersection of research in mathematics and in mathematics education, thus distinguishing the latter from general education research (Sierpinska & Kilpatrick, 1998). Several authors saw the need to address specific social and institutional contexts which influence the growth of mathematical knowledge in school as opposed to the academy. Chevallard's theory of *didactic transposition,* whereby mathematical knowledge from the discipline is transformed by educators into teachable material, was invoked by Anna Sfard (1998) to explain the disparity between the two sites of mathematical knowledge construction. She argues that mathematics education researchers are torn between two incompatible paradigms: one of Platonic certainty and absolute truth in the discipline of mathematics; the other of fallibility, intersubjectivity, and pragmatism in the social sciences (see also Davis & Hersh, 1980/1983, 1986/1988). However Sfard hypothesises that, unlike many mathematics education researchers, those research mathematicians with absolutist and objectivist epistemologies may well be positioned as vulnerable in an increasingly postmodern world. The solution may lie with Guy Brousseau's reported proposal that activities such as communication of mathematical results and organisation of mathematical knowledge be included in the academically understood meaning of mathematics, as they are for mathematics education. This is because, I assert, communication is an essential characteristic of workplace practice.

In discussion of research goals and directions Sierpinska and Kilpatrick (1998) distinguish between an outcomes focus where aims were seen as being the ultimate goals of research, and a process focus where they could be thought of as "directions or orientations of research activity, research problems, issues for research, or *problématiques*" (p. 531). The term *problématique* was defined by Nicholas Balacheff (1990) as:

> … a set of research questions related to a specific theoretical framework. It refers to the criteria we use to assert that these research questions are to be considered and to the way we formulate them. It is not sufficient that the subject matter being studied is mathematics for one to assert that such a study is research on mathematics teaching. A problem belongs to a *problématique* of research on mathematics teaching if it is

> specifically related to the mathematical meaning of pupils' behavior in the mathematics classroom. (p. 258)

However, it was noted that the prior identification of *problématiques* by funding authorities or journal editors could have an unwarranted limiting effect on the generation of new theories, and may even be used as means of political or economic discrimination — as a technology of power. Nerida Ellerton and Ken Clements (1998) question the tendency towards conservatism in aspects of current research agendas such as the influence on current practice of outdated assumptions, and the lack of interest shown in alternative forms of mathematics. (See also Clements, 2001.)

In discussion of the practice of mathematics education research, it was suggested that the problems posed are typically dynamic entities which evolve and become reformulated as the investigation proceeds. For example, questions posed to study the effects of certain innovations cannot assume a static role for the institution of mathematics education which is implicated in the innovation: epistemological status and knowledge content are both emergent. I would also include sociocultural dimensions in this analysis — for example the willingness of an educational entity to support innovation and its presumed interest in the outcomes. The relations between theory and practice (both of mathematics and of mathematics education) can be cyclic or reflexive. This issue is important not only for research methodologies but also for curriculum development. It also led to another debate at the conference: the criteria for evaluating research results. While some participants supported the publishing of explicit, agreed-upon criteria, others (e.g., Ellerton & Clements, 1998) argued that each product of research be seen in its historical, cultural and social contexts.

As noted above, Paul Ernest (1998a) includes among the multiplicity of research practices the study of mathematics education in pre-service teacher education and in post-graduate studies — areas which are considered of little importance for mathematics teaching in the Australian VET sector. He also includes 'college' levels, which I take to encompass university undergraduate education, especially for non-mathematics majors. Mogens Niss (1999) addresses the issues of research in mathematics education as it applies to university undergraduates. He observes the changing conditions of university education, such as the intensification and increasing accountability of the work of its teaching staff; and the increasing responsibility placed upon students who are enrolling in larger numbers (in service subjects), who are generally not as well prepared or motivated as students of the past. The goals for the didactics of mathematics at university level are specified normatively by Niss (1999) for educators to: (a) specify and characterise desirable or satisfactory learning of mathematics; (b) devise, design and implement effective mathematics teaching; and (c) "construct and implement valid and reliable ways to detect and assess, without destructive side effects, the results of learning and teaching mathematics" (p. 8).

As preconditions, Niss called for theoretical and empirical research to aid understanding of the role of mathematics in science and society, the explication and conditions of learning, the modes and conditions of teaching and assessment, and the influence of teachers' background, education, and beliefs on teaching. Another ICMI study conference took place in 1998 which, according to Niss (1997, p. 5), was expected to (a) identify, review, encourage and disseminate, research in educational matters at the university level; (b) identify obstacles which might prevent the learning of mathematics; (c) discuss equity and other issues relating to mathematics education at university level; (d) discuss the goals of teaching mathematics to a range of students with different backgrounds and needs, and who should be responsible for that teaching; (e) find ways to meet changing needs without compromising the integrity of the subject; (f) identify, publicise, and expose to scrutiny, new teaching methods and the positive use of technology; (g) discuss the transition and the relations between secondary school and university level; and (h) consider ways to improve the preparation of teachers of mathematics at university level.

The goals and preconditions specified by Niss (1999) and the ICMI research agenda may be contrasted with the silences in these areas within the Australian VET sector—all the more astonishing given the overlap in content for many courses.

As mentioned above, the teaching of university mathematics has been formally addressed in Australia through a discipline review (NBEET, 1995b). There are documented examples of research concerning the teaching and learning of mathematics at university in Australia and overseas (e.g., FitzSimons, 1996c; FitzSimons & Godden, 2000). But where in Australia can one find equivalent published research pertaining to teaching and learning in the VET sector? Why is this issue not being addressed by policy makers and their advisors in the Australian VET sector? Two reports on literacy and numeracy commissioned by National Centre for Vocational Education Research [NCVER] (Falk & Millar, 2001; Watson, Nicholson, & Sharplin, 2000) go a little way to touch on some of the issues, but the focus is primarily on literacy. Is it possible among the international mathematics education research community that there will ever be a call for proposals for a study conference related to vocational education and mathematics — as distinct from numeracy surveys such as the International Life Skills Survey (ILSS), now known as the Adult Literacy and Lifeskills (ALL) project?

1.6. CONCLUSION

This chapter has presented a necessarily partial view of the institutions of mathematics and mathematics education (including research), together with a discussion of image formation. The following summarises and extends the literature reviewed.

As a discipline, mathematics is distinguished from science in the possibilities it offers for acting upon ideas and concepts from other fields. Historical aspects include the Eurocentric bias in historiographical accounts, and its ongoing links with industry — especially since the rise of commerce. Spengler's (1926) differentiation between Classical and Western mathematics is noteworthy in that, as will be illustrated in chapter 4, mathematics curricula in the Australian VET sector remains predominantly located in the former, bounded by sensory perceptions, where certainties were once assumed — and still are desired by many. The dependence of mathematics as a construction of the social and cultural milieu of the times has been noted by many authors.

From a sociological perspective, mathematics is seen as an exclusive discipline, a masculine domain, usually portrayed as value- and culture-free, yet with certain interests impinging upon mathematical models that are created and used in society. The objective side tends to dominate over the subjective side of which most people are unaware. Qualities which underpin the social structuring role of mathematics, particularly as a category of schooling, are its symbolic reference to technology, its status differentials, and its dual construction of reality. The latter is especially related to the three complementary pairs of values in mathematics proposed by Bishop (1988): rationalism and objectism, control and progress, and openness and mystery; each of which across time and location have been valorised by sections of the community while they have contributed to the alienation of others. This complexity of the discipline of mathematics, while part of its rich tapestry, leaves it vulnerable to abuse and to criticism in times of rapid social and economic change where citizens yearn for certainty and stability. This is particularly in evidence in political climates where short-term technical solutions are sought to intransigent problems, utilising data that are easily quantifiable and capable of being reported simplistically. As a social and economic construction, mathematics may be used as a weapon in the technologies of management by the more powerful against the less powerful politically, economically, socially, and educationally.

Observations about the social and cultural practices of mathematicians at work, and the tacit nature of much mathematical knowledge have important implications for research into the teaching and learning vocational mathematics, where consideration of practical solutions to real and demanding workplace problems in all their cognitive and social complexities might be expected to be paramount.

In society generally, but particularly in the workplace, mathematics and technology operate in a dialogical relationship. It was asserted by Skovsmose (1994) that we live in a technological environment: in it, for it, and by means of it. Following Luhmann's social systems theory, Maaß and Schlöglmann (1988) considered technology as the transfer of meaning, but noting the limitations. Identification of the descriptive, predictive, and prescriptive roles that technology is coming to play in our society introduced discussion of the phenomenon of implicit mathematics, and paradoxes of relevance and de/mathematisation processes. Keitel, Kotzmann, and Skovsmose's (1993) discussion of the structuring roles of technology led to Skovsmose's subsequent interrogation of the concept of aporism to clarify the double role played by mathematics, where there is now reflexivity beyond reflection, and the possibility of an inadequate critique of reason.

The second section turned to the *Institution of Mathematics Education.* Bauersfeld (1980) observed that educational institutions have been established by society to produce and reproduce shared meanings, constituting their own norms and roles. As a formal entity mathematics education has been controlled systemically by sectional interests, resulting in segmentation, and the privileging of interests of the dominant classes over time. In the UK, the USA, and Australia, at least, the trend in the school and vocational education sectors has been to identify shortcomings in the pupil rather than the system. The distribution of vocational mathematics or numeracy knowledge is often of a segmented nature, according to perceived destinations of students — thereby contributing to limited perceptions and expectations of and by students. This will be elaborated in chapter 4.

The history in Germany of the professional identity of mathematics teachers, and the resistance and isolation they faced in the early 19th century (Schubring, 1998) reveals that the sense of isolation and lack of status currently faced by Australian vocational mathematics teachers is not unique. Schubring also highlighted several differences between social and cultural aspects of school mathematics, its teachers, and the discipline of mathematics. These differences may be paralleled in adult and vocational education, and are centred on the epistemological and social status of mathematical knowledge and its teaching.

Chevallard (1989) presented an argument that, although the teaching of mathematics is usually justified in terms of individual interests in support of its socio-ontological status, it is actually performing a role in the communal interest. He claimed that the focus on individual over communal interests in modern societies confounds the duality of mathematics as a means of social production with the individual's personal relationship to it as a body of knowledge. This work provides insight into problems confronting adult and vocational mathematics education with respect to its goals and purposes for mathematics. Until these are clarified it may not be possible for a firm foundation to ever be set, and mathematics education in the sector will continue to drift, perhaps even drown, in the sea of vocationalism. However, in Australia at least, it may already be a political decision not to ask such questions, not to problematise the status of mathematics in the VET sector.

Many authors have noted the construction of rationality as a social and cultural production. There are tensions in the suppression of context as the epitome of rationality, from both mathematical and workplace perspectives. Continuing the discussion of structure and ideology in mathematics, tensions may arise from the fact that most people are not conversant with the structural meanings of mathematics (including most VET sector stakeholders!), and succumb to its ideological meanings that offer mathematics as a source of certainty and empowerment. This may account for its partial distribution, with a possible explanation lying in the perceived fears by employers of the consequences of workers having too much knowledge for their own good, threatening existing power relationships. Ernest's (1991) analysis of philosophical and ideological constructs held by groups that he termed industrial trainers and technological pragmatists — both of whom may be identified, in part at least, with the kinds of stakeholders representing sections of industry and government in Australia today — suggests that their aims and the means adopted to achieve them may actually be counter-productive.

All policies and practices in education embody sets of values, whether explicit or implicit, shaped by cultural factors. Internationally, justifications for the teaching of (school) mathematics include its contribution to technological and socio-economic social development; political, ideological and cultural maintenance; and individual development in all spheres of life (Niss, 1996). Niss's list of aims for the learner includes those which are focused upon personal development, mathematical learning and appreciation, and critique of the uses to which mathematics is put; both affective and cognitive domains are imbricated in these. The question remains as to the kind of aims that might arise for vocational mathematics should representatives of all VET stakeholders (including teachers and students) be given the opportunity to contribute to these, based on honest and open discussion of their value positions.

Numeracy, as a contested concept, was explored from technical, practical, and emancipatory perspectives. The absence of a critical perspective in inter/national surveys and curriculum documents for adults is noteworthy, as is the omission of aesthetic and recreational aspects, particularly where vocationalism is emphasised. Perhaps Skovsmose's concept of mathemacy, incorporating critique and reflection, might ultimately prove to be more empowering to individuals, if not society as a whole, than traditional concepts of numeracy. However, there are many structural obstacles to the acceptance of these ideas — as exemplified in the current international fervour for quantifiable measures of numeracy skills.

The images of mathematics and mathematics education which prevail in contemporary societies are, I believe, crucial in the formation of decisions with respect to mathematics by all stakeholders — students, their immediate families, teachers in school and VET sectors, employers, industry advisory and peak bodies, politicians and their advisors, and so forth. These decisions are made individually and collectively in rapidly changing social, economic, and political contexts.

In image formation there is a degree of reflexivity. For example, a student's prior educational experience impinges upon their approach to vocational mathematics education which necessarily re-forms, for better or for worse, their image of mathematics and mathematics education and, by implication, their self-image in relation to work and their broader social and democratic competence. Students' decisions to enrol in, persevere with, and complete (or not) mathematics modules impact upon the VET sector at all levels. Ultimately, political decision-makers act upon bureaucratic advice to ameliorate what they perceive as politically threatening situations, or to exploit those considered expedient. Inevitably their decisions will be coloured by their own personal experience of mathematics education as well as by media portrayals of mathematics and mathematics education; almost always in the absence of theoretically well-founded knowledge of these issues. And so the cycle continues. The issue of public image will be revisited in chapter 7 from a more theorised perspective in relation to the underlying theme of this monograph: technologies of power.

The subsection on research highlighted the complementarities of the dearth of research into vocational mathematics, in the Australian VET sector at least, and the lack of interest by the mathematics education research community, internationally, in adult and vocational education until recent years.

In this chapter I have explored aspects of the discipline of mathematics and its complex interrelationship with technology, together with the field of mathematics education. Each of these contributes in some way to the two-sided public image of mathematics: the positive aspects for which it is valorised and valued and the negative aspects which tend to make it invisible or the object of fear and loathing. In fact, throughout this chapter there have been many notions of duality in relation to mathematics. I believe that these tensions contribute to the unique situation in which vocational mathematics often finds itself— it is simultaneously demanded publicly and yet ignored strategically; it may be problematic for many students yet its curriculum and teaching are seldom if ever problematised.

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CHAPTER 2

TECHNOLOGY, MATHEMATICS, AND INDUSTRY

Mathematics In and For the Workplace

2.1. INTRODUCTION

This chapter will focus on primarily on the role of mathematics in the workplace. Firstly from the perspective of industrial needs it will elaborate on conceptions of the workplace and workplace competence. It will then address technology as it applies to changing notions of the workplace in a knowledge economy. Following this there will be a review of a selection from the literature on the dialogical relationship between mathematics and the workplace. Finally it will address recommendations made by various authors concerning mathematics education which might be applicable to the workplace to meet the needs of adult learners as they participate in, or prepare for, employment — whether it be aiming for an initial qualification, continuing professional development towards advancement or promotion, or even a change of employment.

In a world which is increasingly dependent upon technology there is debate about the roles of explicit and implicit mathematics (as discussed in chapter 1) and the implications for what mathematics may be actually required in the workplace. Analyses reported in this section will suggest that the workplace is characterised by its own discourses which interact with dominant (including mathematical) discourses in different ways. An important aspect is the role of decision-making allied to a need for democratic competence (Skovsmose, 1994). A large majority of adult and vocational students are accorded full rights of citizenship in the broader society, and their democratic participation at work, study-site, community, and home is likely to be enhanced by appropriate mathematics education of the kind described in chapter 1 as *mathemacy.*

2.2. GLOBALISATION

At the start of the new millennium the most salient contextual issue appears to be that of globalisation. In asserting the need to review and analyse the wide-ranging changes resulting from globalisation Keith Forrester (1998, p. 426) quotes Korsgaard's (1997) characterisation of globalisation as "qualitative change towards a system in which distinct national economies are subsumed and re-articulated into the system by international processes and transactions." Yet, although the term *globalisation* is frequently used to describe a major influence on our personal, political, and 'professional' lives, it is not something imposed from on high in the Platonic sense. John Wiseman (1998, quoted in Butler, 1998b, p. 5) asserts that choices have been made, within certain restrictions of bounded freedoms, by governments, corporations, communities and individuals to participate in the processes of history-making, at each level up to the transnational.

Globalisation, according to Wiseman, "is the most slippery, dangerous and important buzzword of the late twentieth century." Australia's ready acceptance of globalisation has been supported and informed by ideological shifts towards neoliberalism. In its wake, as will be discussed in chapter 6, education has come to be regarded as a commodified, positional good, subject to an increasingly deregulated quasi training market (Marginson, 1997); it has come to be regarded as a tradeable, personal good rather than a public service. Yet education is imbricated in discourses of global competitiveness — as evidenced in the recent strategic push for lifelong learning in Australia (ANTA, 2000; n.d.-b), the UK and the European Union (DfEE, 1998a, 1998b; EU, 2000).

Forrester (1998, p. 426) claims that understandings of the role and implications of this issue "shape the very nature of the problems and possible solutions available." Accordingly there are calls for new educational designs, new systems of learning, and new ways of thinking about learning. While traditional social and economic problems remain, Forrester asserts that their character, implications, and hence solutions have changed drastically. At the same time the social transformation implied by Ulrich Beck's (1992) notion of the *risk society* — where risks are no longer limited by time or space, but distributed unequally with greater burden on those at the bottom — supports calls for changes in the agenda of adult educators (Jansen & Van der Veen, 1992, cited in Forrester).

In pragmatic terms lifelong learning, especially for young adults but also for other groups regarded as 'at risk,' is proposed by local and global policy makers as a means for them to accumulate social (valued relations), cultural (primarily legitimate knowledge), and economic capital (Bourdieu, 1991). These are deemed necessary for survival in times of rapid change, where high skills approaches to economic development are associated with income equity, and low-skill, low-income jobs tend to migrate to economies with lower labour costs (Kirby, 2000; McKenzie, 1998). But the problem remains to achieve an equitable distribution of scarce educational resources, especially when those more privileged inherently have greater access.

2.3. THEORISATIONS OF THE WORKPLACE

In any discussion of 'the workplace' it must be acknowledged that there is no generic workplace — the term is used for ease of communication and analysis. In the same way there is no generic 'worker' or 'workplace competence.' Each conception of worker, workplace, and workplace competence must be situated, located in time and space, within a specific community of practice with its multiple relationships across social and cultural settings. In this section I wish to problematise the notions of workplace and globalisation. In the following subsection I will attempt to tease out some of the complexities of workplace competence. Most of the literature appears to be premised on conceptions of full-time paid work but this is not to deny its possible relevance to other categories of labour.

2.3.1. Problematic Representations of Workplaces

Elaine Butler (1998a) observes that the literature on workplaces overwhelmingly represents work as primarily full-time, paid work in the 'official' labour market. Marilyn Frankenstein (1996) outlines several other categories of the labour force which may or may not be included in official statistics (e.g., people already employed but wishing to change their work status, or people discouraged from looking for work). Such omissions in official statistics in addition to the non-market labour in the private or domestic sphere, both productive and reproductive, have ongoing and contested equity implications, according to Butler. At the same time formal categorisations assume a compartmentalisation of (and by?) workers of their knowledges and identities — a notion Butler claims is challenged by poststructuralist and feminist theories as well as discourses of practical politics. Distinctions between public and private spheres are further complicated by considerations of voluntary work, outworkers and home-based employees. In short, she notes that the representation of work, workplaces and workers is multi-layered and deeply problematic; there is no single construct of 'work' or 'workers,' and yet these are treated unproblematically in the discourses of workplace-based learning, and lifelong learning as they are harnessed in support of the economy.

Butler (1998a) observes that workplace learning takes place both in association with, and despite, formal training.

> Workplace learning is not a neutral, a-political activity. Rather, it is about the production, ownership, valuing (or otherwise) and use (or abuse) of knowledges produced by workers and others in the materiality of workplaces, and in their day to day practices of living and working. (p. 90)

In recognising that issues of power and knowledge are central, she concludes with a plea for the voices of the workers/learners themselves be heard in order to temper the unproblematic representation of 'worker' and 'learner' in texts on workplace learning. Similarly, Lesley Farrell's (1996) study of textile workers, menders whose competence was rendered 'invisible' in their workplace, notes that the 'competency' approach which stresses outcomes is in conflict with 'quality' approach which stresses processes; in this case the process was to document and eliminate faults. Elizabeth Buckingham (1997) also draws attention to workers learning when *not* to speak. Much of mathematical competence is also rendered invisible, but in this case under the guise of 'common sense' (e.g., Coben, 2000; Cockcroft, 1982).

Thus, there can be no universal conception of workplace competence, particularly in times of rapid social and economic change. However the term is central to current discourses of vocational education and training. In what follows I will elaborate on general conceptions to be adopted in this monograph, with applicability to manufacturing, service, and symbolic-analytic sectors as they pertain to vocational education and training in Australia. Although I draw from both European and USA sources, the former predominate because I believe that Australia's population size and economic situation are closer in many respects to some European countries than to the USA.

2.3.2. Workplace Competence

The concept of workplace competence is often taken for granted, but is in fact understood in complex and sometimes contested ways. Per-Erik Ellström (1998) explicates three views encompassing five meanings of the notion of competence. Firstly, *as an attribute of the individual* it may be: (a) formal competence — measured, for example, by years of schooling completed or by credentials received; or (b) actual competence — as the potential capacity of an individual to successfully handle a certain situation or to complete a certain task. This approach approximates human capital theory, but ignores qualitative differences in education and the fact that actual competence also includes "outcomes of work [as well as] a wide range of different, informal, everyday activities" (p. 42). Secondly, as *a job requirement* it may be: (c) officially demanded competence, for example as a basis for recruitment or the setting of wages; or (d) the competence actually required by the job. Official demands may be influenced by demand and supply of qualified people, also professional interests; actual requirements may be unknown due to difficulties and costs associated with job analysis. Both views are actually socially constructed arising from a complex interplay of external (macro) factors (e.g., economic, technological, political) and internal (micro) factors at the level of the company or enterprise (see also Achtenhagen, 1994a). A third, *interactive view* is: (e) of competence in use, as "a dynamic factor mediating between the potential capacity of the individual and the requirements of the job" (p. 43). Whereas previous experience and self-confidence are likely to be important individual factors, the competence that an individual actually uses to perform his/her job is likely to be strongly impacted by "the formal and informal organisation of the workplace with respect to worker autonomy, participation, task characteristics, and feed-back" (p. 43). This last notion of workplace competence is complex and multi-layered. Discussion in this monograph will be premised on the third, interactive understanding of the term competence, and the development of an individual's capacity in relation to mathematics.

In terms of the work an individual performs, Paul Blackmore (1999) differentiates between the terms *role, function,* and *skill,* which he asserts collectively contain all formal approaches to occupational analysis. Role analysis is likely to contain a structural and an interactive aspect; to be illuminative rather than seeking an exhaustive description of all aspects. Role is "characterised by a tendency to select ways of working in accordance with circumstances, flexibly and with a willingness to change" (p. 63). It is contrasted with functional analysis which breaks job roles into distinct parts for investigation. Its products are standardised competences, "which would describe the knowledge, skills and understanding necessary for competence in an occupational area" (p. 64). However, Blackmore doubts whether these can be brought into a single framework; in fact he claims that it is this universality which provokes frequent criticism.

Blackmore (1999) makes several criticisms of the notion of elements of competence as incorporated into the British National Vocational Qualifications (NVQs) — arguably these also apply to competency-based education and training (CBT) in Australia. These are: (a) difficulties in representing excellence — in describing how these qualities will be manifested, and in describing the performance of interlinked activities; (b) the under-representation of underpinning knowledge and understanding — based on positivistic analyses, implying that knowledge is a generalisable and an objective truth; (c) the lack of a developed model of interrelationships between competencies, which also ignores context; (d) the neglect of reflectiveness; and (e) the superficial, if any, attention given to values and principles. "Functional analysis is an attractive tool to anyone who wishes to see social and political relationships, in the workplace and beyond, as unproblematic, ordered and without tensions" (p. 66). It has clearly been an attractive tool in the Australian vocational education and training context (e.g., Johnstone, 1993) both as a technology of management over worker/students and their teachers, also in its contribution to 'rational' curriculum construction.

"Whereas the term 'task' or 'function' refers to the job to be done, 'skills' refers to the human capacities that are required for successful performance" (Blackmore, 1999, p. 67). These are often termed 'generic competenc(i)es,' although Blackmore warns against simplistic approaches to the modelling of human expertise. Transferable skills (and skills of transferring) are a major issue, related to context. Blackmore continues that, in contrast to the functional analysis approach, the skills focus is on process, as individuals develop and access task-specific local knowledge bases; psychological aspects include reflectiveness and reflexiveness. He concludes that the existence of recognised generic skills admits that people do draw on a central repertoire of skills in dealing with a wide range of contexts including novel situations. However, the challenge is to codify the expertise of an occupational area. Importantly, the skill of using mathematical ideas and techniques is included in the Australian key competencies, although its realisation in the current codification practices of CBT mathematics (and other) curricula continues to be problematic. As noted by Gibbons et al. (1994), the requirements for tacit and codified knowledge vary according to the contextual situation, but this is not to deny the importance of a sufficiently strong body of codified knowledge for each worker. However, the content of that codified knowledge is (or should be) an issue for debate in relation to changing work practices, and will be developed further.

Many definitions of competence implicitly presuppose a functionalist, adaptation perspective, defined and evaluated in terms of successful performance of certain given or predetermined tasks. Ellström (1998) claims that this perspective

> fails to recognise the active modification and subjective redefinition of the work task that occurs continuously and with necessity during the performance of a job. . . . In fact, as argued by Norros (1991), operators in many complex production systems are in a certain sense involved in a continuous process of redesigning and improving the system. In contrast to an adaptation view, the developmental perspective strongly emphasises

> that people have a capacity for self-management, and that they also are allowed and expected to exercise this capacity. (p. 44)

He continues that much developmental work is complex in character, with a need to move between routine and non-routine work. Approaches towards research into workplace competence have followed two major, contrasting perspectives, according to Ellström — namely cognitive-rational and intuitive-contextual. The development of a change-oriented competence requires both kinds of perspectives, according to the experience level of employees, and the pressure, complexity, and structure of the workplace task or activity. "In many cases [a synthesis] may only be accomplished through the use of work teams composed of individuals with different competencies and experiences" (p. 46). The requirement for self-management by workers can be problematic in that there is also a shift in responsibility (even blame) for conditions not always under their control. As noted above, the permission to exercise self-management (or even to speak) is also problematic in some enterprises (e.g., Buckingham, 1997; Farrell, 1996), especially if they continue to operate under Taylorist management practices as discussed below.

The observations of Blackmore (1999) and Ellström (1998) provide an indication of the possible complexity of skills which may be required of any particular worker operating in a dynamic work situation. This also suggests that the CBT approaches typically adopted by Australia and other Anglophone countries, which offer functionalist, individualistic curriculum and assessment, are based on simplistic assumptions of competence and outmoded, modernist perspectives of industry. How appropriate are these for developing the workplace competences needed in the future?

Jeroen Onstenk (1998, 1999, 2001a) integrated the concepts of core skills prevalent in Anglophile countries with those of key competences and key qualifications to develop the concept of *broad occupational competence*. The focus of core skills is on educational activities, whereas Onstenk's concept is drawn from an holistic perspective of the workplace. Figure 2.1 shows Onstenk's conception of broad occupational competence, which he built on the activity theory approach of Yrjö Engeström. At first glance this model appears to have more application to manufacturing or symbolic-analytic (knowledge) sectors than to the service sector, but Onstenk (2001a) argues convincingly for the latter where production demands include human tasks (see also Stasz, 1996).

Although Onstenk was arguing for the adoption of core problems as a pedagogical strategy, this figure is useful as an indication of the complexity of workplace competence. According to Onstenk (1998):

> Broad professional skill … is defined as a multi-dimensional, structured and internally connected set of occupational technical, methodical, organisational, strategic, co-operative and socio-communicative competencies, geared to an adequate approach to the core problems of the occupation. (p. 126)

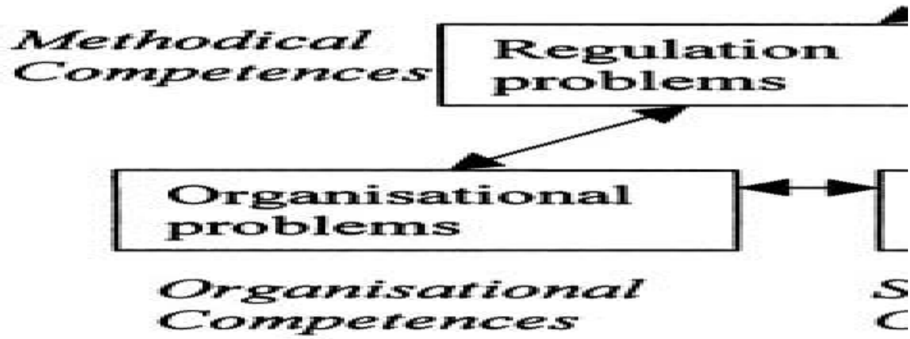

Figure 2.1. ***Core problems and broad professional competence. (Onstenk, 2001a, p. 30) (reprinted by permission of NCVER)***

Onstenk notes that core problems are characterised by uncertainty, complexity and conflicting considerations that require the exercise of judgement. They are important both for learning and for the acquisition of competence. Production problems stem from the object of work activity, from the tools and equipment, and depend upon the nature of problem solving permitted by an organisation (Onstenk, 1999). However work activities are carried out within the regulatory organisational and power framework (in keeping with relevant legislative frameworks), and so need also methodical and organisational competencies to deal with planning and solving of routine and non-routine problems arising in production — increasingly so with changing business policies such as flatter management structures which embody a socio-technical model of responsible autonomy, contributing to an ever-increasing number of regulation problems to be solved. Onstenk (2001a, p. 31) describes socio-cultural problems as stemming from the fact that "the work is done within a specific community of practice at group, company and/or professional level, which is characterised by specific and sometimes competing cultural norms, practices and espoused theories." Membership problems refer to organisational structures and rules, such as labour conditions and relations. They also apply within the local community of practice, where there are formal and informal rules governing the specific work-team, as well as relations with other external individuals and groups. Strategic competencies are needed here and demand a situationally adequate choice. Core problems occur regularly as part of occupational practice (specific to each task and workplace in their balance and intensity), and choices and decisions must be made involving the application of knowledge and skills with the appropriate actions at the optimal time and speed.

Most vocational mathematics curricula, in Australia at least, appear to be focused solely on the technical competencies associated with production problems[1] in manufacturing, trade, or symbolic-analytic services; yet workers are confronted daily with problems arising from the lack of appropriateness, quality, and maintenance of the tools and equipment used in production within the overall physical environment for the specific task(s) at hand. The complexity of Onstenk's model provides an indication to vocational course developers that specific disciplinary skills such as mathematics need to be located within problems that encompass the entire range of 'key' competencies and, indeed, broad occupational competence. This is in order that meaningful communication might take place, especially under flatter management structures.

Onstenk (1998) adds a further competence as a necessary element in broad professional skill: learning competence. Workers are always learning although not necessarily from formal training or in the manner (or matter) intended. This last competence, so critical to projects of lifelong learning, is more often than not taken for granted; it refers to metacognitive skills which need to be consciously developed and, I argue, requires the expertise of professional educators working in collaboration with workplace personnel. Onstenk (2001b), drawing on the work of Alan Brown in the UK, argues that learning through core problems contributes to the development of transfer skills.

In this section I have attempted to outline the complex nature of workplace competence, but I have not addressed the changing nature of the workplace. The next section will focus on the technologies of management as they impact on the workplace competencies identified above.

2.4. TECHNOLOGIES OF WORK IN PRACTICE

Technological development is imbricated in social and economic developments in a dialogical formation. A joint report by National Board of Education, Employment and Training and the Employment Skills Formation Council in Australia (NBEET/ESFC, 1995) traces a brief history of the organisation of work and its management. Until the turn of the 20th century these had developed haphazardly from past practice and conventional wisdom. In the early part of that century Frederick Winslow Taylor, an engineer, amplified and codified the practice into a system — which still prevails in some areas of industry today. In a hierarchical structure with central control and command, skills are analysed and stratified into finite divisions of labour, removing decision-making powers of operators. Taylorism

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[1] Here, I am using the term *problem* in the sense of a matter in which thought needs to be given to decide the best course of action, in the full context of demands and urgency at the site of work rather than in the classroom sense of task to be completed to satisfy teacher, text, examiner, etc.

reflects the level of technology generally used at that time, when standardised mass production was the goal of industry. From the 1960s the system began to change for a variety of reasons, including the influence of pragmatic developments of devolution in Japanese industry based on the quality control work of W. Edwards Deming. Other influences are now being exerted by the development of computerised technology and global competition, affecting the previously secure markets held by standardised products with high obsolescence and poor service. The report claims that "concepts of consultation, devolution and participation have emerged as the means of securing commitment from those who use distributed technology and for the achievement of quality assurance and high productivity" (p. 26). Adopting a broad view of 'distributed technology,' I believe that many Australian workers today, especially operators, would be surprised by the sentiments of workplace democracy expressed in this statement (see, for example, Hopkins & Maglen, 1999).

The NBEET/ESFC (1995) report observes that networked communications have the potential to lead to either the "greater centralisation, control and supervision of individual workers through the use of technology; or giving people the skills in using technology and devolving greater authority and greater responsibility down to operational staff" (p. 26). It contends that it is generally agreed that the latter position prevails — in contrast to the views of surveillance and control expressed by Farrell (1996, 1999, 2000) and others — although acknowledging that devolution tends to require stronger accountability arrangements. In addition, the move to flatter management structures and team-based work organisation has removed a layer of middle management formerly operating to bridge the gap between junior and senior staff, requiring new staff to adjust quickly to the workplace.

Not surprisingly the concept of lifelong learning — "*learning how to learn across the life span*" (NBEET/ESFC, 1995, p. 11) — figures prominently as an issue of great importance in this report. Reflecting the shift to neoliberal ideologies, the report — written under the auspices of the previous Labor federal government — rather candidly admits that the new emphasis is now "on lifelong employability rather than on lifelong employment" (p. 12). Thus it signals, as a technology of power in official rhetoric, the shift in responsibility to the (would-be) employee as a self-managing subject. I believe that the report's observation of the shift in favour of consumer self-service functions as implying a greater need for consumer knowledge (including that of technology itself) should be interpreted in an instrumental rather than a critical sense.

This imperative of lifelong learning was reinforced in another joint NBEET report with the Employment Skills Council [ESC] into the convergence of education and technology (NBEET/ESC, 1996). It observes that the information society we now inhabit is based on a global knowledge economy, which places a premium on the development of human capital throughout a (working?) lifetime and across multiple career paths (see also Gee, 1994). Unlike the Taylorist model, global organisations are said to value the relationship between people's skills, their culture (values and norms) and their processes. Team work, communication, continuous learning at both the organisational and the individual level are sought, together with the competency of information literacy:

> a literacy that combines information collection and analysis and management skills and systems thinking and meta-cognition skills with the ability to use information technology to express and enhance those skills. In a society of information 'glut' the ability to detect 'signal' from 'noise' will become increasingly valued. (p. 74)

As stated, this competency is resonant with international goals for senior school and post-compulsory mathematics (e.g., Cohen (Ed.), 1995; NBEET, 1995b; National Council of Teachers of Mathematics [NCTM], 1989), together with the Australian Key Competencies (Mayer, 1992). In a post-Taylorist era it could reasonably be required of workers at all classificatory levels, from operators to management. John Stevenson (1997) proposes that capacities needed for the workplace of the future included innovation, creativity, flexibility, and collaboration. He claims that they not only transcend the Mayer Key Competencies, but also cognitive, behaviouristic and affective divisions of knowledge.

Victoria Marsick (1997) supports the development of human resource capabilities in her discussion of the *learning organisation* which, in order to be successful, must be proactive in keeping pace with and adapting to changes in the external environment. She claims that it is the learning of individuals, and subsequently the entire system, which serves to make the creation and use of knowledge meaningful. In knowledge management, the concern for people and the development of an appropriate workplace culture are much more important than, yet inseparable from, the transfer of information alone or the installation of technology for greater efficiencies. This observation is echoed by a study on innovative business practices, cited in the NBEET/ESFC (1995) report, which recognises that science and technology are vital tools to be applied effectively and developed selectively, but that innovation is more a matter of flexible, productive and focused employee relations. In other words, technological competence is not an end in itself, as is often the case in vocational educational programmes. Employers are requiring higher initial skills, but value and would like to see improvements in generic skills such as problem solving and communication (Brown & Keep, 1999; Marsick, 1997; NBEET, 1995a) — although Marsick cautions that there are studies which suggest that employers' perceptions about skill needs are often normative rather than accurate descriptions of current practice.

The requirement for systems thinking as an integral part of information literacy has been recognised in the recent trends towards cross-disciplinarity (e.g., Gibbons et al., 1994) and teamwork. Drawing on the work of Salner (1986, cited in NBEET/ESC, 1996), systems thinking is context-oriented and context-dependent. It involves the following competencies:

- the ability to see parts/wholes in relationship to each other and to work dialectically with the relationship to clarify both similarities and differences. In effect, this means the ability to balance the processes of both analysis and synthesis;
- the ability to abstract complexity so that organising structures (visual, mathematical, conceptual) are revealed rather than imposed;

- the ability to balance flexibility and real world change against the conceptual need for stable system boundaries and parameters;
- command of multiple methods for problem solving as opposed to employing a limited range of algorithms to the widest variety of situations; and
- awareness that the map is not the territory, and the ability to act accordingly in the use of systems models.

(pp. 75-76)

These competencies can be readily identified with the projects of the institution of mathematics, as described in chapter 1 (see also Davis & Hersh, 1980/1983). The fourth dot point (the command of multiple methods for problem-solving) is the most concrete and speaks directly to vocational (and other) mathematics educators. How might mathematics education be developed according to the principles of contextualised learning to support competencies such as these? The knowledge economy, widely accepted as the successor to the industrial economy, will demand a competency that links information literacy, systems thinking, and learning skills according to NBEET/ESC (1996). These will require, *inter alia,* “the ability to decode information in a variety of forms — written, statistical, graphic” (p. 77), together with critical evaluation of that information; Gibbons et al. (1994) even suggest that the notion of competence, in dealing with (re)arranging and connecting a plentiful supply of information, may come to define the meaning of ‘imaginative’. How might these be developed in a non-trivial manner — along with the sense of personal agency and repertoire of learning skills outlined in the report as being essential characteristics of a lifelong learner?

The specific inclusion of mathematics (or numeracy) within the key competencies in many countries, in addition to its interrelationship with all others, indicates that it is recognised as having an important role to play in the workplace. Characteristically, there is no critique of the social uses of mathematics or technology included in such competencies. However, the workplace itself is complex, multi-layered, and dynamic. In chapter 1, I outlined Yves Chevallard’s (1989) distinction between explicit and implicit mathematics, which have a bearing on its visibility — in this case to various stakeholders in vocational education (e.g., students, teachers, education and industry managers, etc.). According to Chevallard it is the explicit uses in business and industry that are valorised, generally held to be synonymous with school mathematics. On the other hand, implicit mathematics is ubiquitous in its penetration of social and cultural life, embodied, crystallised or frozen into social objects. I now address some of the literature that has focused on the explicit and implicit uses of mathematics *in* the workplace. In this brief review, I wish to keep in focus the questions: What are the boundaries for mathematics education research in the workplace? Who are constructed as knowers in and by the workplace? What are the objects of knowledge that define these subjects’ institutional existence as authorised knowers in relation to mathematics?

2.5. MATHEMATICS IN THE WORKPLACE

> The mathematical sciences are critical to Australia's economic competitiveness and quality of life, and will become more so. The mathematical sciences are generic and enabling technologies. They are essential to the prosperity of many value-adding industries in Australia. (NBEET, 1995b, p. x)

Internationally, there is a widespread belief that mathematics underpins and enables the technologies of industry. Although the relationships between mathematics and society are manifold and complexly interrelated, the prime focus of the vocational education and training sector is its relationship with industry. In this section I will consider a selection from reports that have enquired into the mathematical content and processes required in the workplace. Earlier reports appear to be based on a more or less static view of the workplace and to be responding to visibilities of explicit uses of mathematics from a traditional (school) mathematics perspective.

2.5.1. Early Studies

Over the last three decades there have been reports in many countries about the mathematics (or numeracy) skills required in the workplace. This period has also seen the development of glossy posters, designed to give encouragement to young students, listing mathematical skills deemed useful for various occupations. Writers in previous decades have focused on mathematics in the workplace from an unproblematic 'tool box' mentality, promulgating supposed correspondences with lists of school mathematics topics. These reflect, more often than not, the industry respondee's previous school mathematics experience (Harris, 1991) rather than actual mathematical practice in all its complexity. The atomistic, compartmentalised appearance of some posters in which the concept of transfer is completely unproblematic lives on in the ethos of many vocational mathematics curriculum and assessment documents.

The 1982 Cockcroft Report, although criticised for its overtly utilitarian bias (e.g., Noss, 1997) in adopting a narrower definition of numeracy than the 1959 Crowther Report, aroused much interest in the topic of mathematics in the workplace. It noted that because of the diversity of types of employment, the variety of mathematical demands within each, and the considerable differences found to exist within occupations which might be assumed from their titles to be similar, it was not feasible to produce definitive lists of necessary mathematical topics for each. It avoided the temptation of formulating a deterministic relationship between mathematics and any one occupation. Rather, its main emphasis was on the development of a feeling for measurement with or without the use of instruments — a skill still lacking in many school leavers of all ability levels. Perhaps not surprisingly for its era, it failed to address specifically the issue of transfer. However, it foreshadowed the situated cognition literature (e.g., Lave, 1988; Lave & Wenger, 1991), emphasising the importance of learning on the job, and use of out-of-school methods of calculation. It also observed that affordances to calculations are provided by the tools at hand, noting that the frequent repetition of mathematical tasks renders them as 'commonsense.' As a consequence they become invisible and unavailable for reflection. John Foyster (1988, 1990) observes that there are differences in mathematical requirements at various stages of any career path, and complex relationships between the worker's range of duties and degree of responsibility which could vary with the size of the enterprise.

A New Zealand study by Knight, Arnold, Carter, Kelly, and Thornley (1992) found evidence of the use of generic skills of problem solving, as well as the need for optimisation or determination of a "best strategy" for a task. In addition, the use of technologies such as calculators and computers were clearly becoming very common in the workplace. Peter Galbraith (1988), in a study using the Delphi technique, added graphical interpretation techniques and checking for reasonableness of results to the NZ skills list of number, measurement, statistics and formulae. In the UK, all of these skills have all been incorporated throughout the General National Vocational Qualifications (GNVQ) core skills units in Application of Number (Business and Technician Education Council [BTEC], 1995).

Paul Dowling (1991) is strongly critical of utilitarian reports where "mathematics is used both to define the essential nature of the practice and to assess the competence of the practitioner" (p. 97). He asserts that they actually demonstrate the existence of a discontinuity in signification of the practices between everyday and workplace mathematics. The result, according to Dowling, is paradoxically that the utilitarian notion of mathematics as a universal set of tools can no longer be supported. "It actually represents a pathologizing of everyday and working practitioners who do not see the toolbox or its contents" (p. 103). Instead, he suggests that researchers need to first problematise their own culture rather than attempting to define other cultures in terms of their own.

2.5.2. More Recent, Epistemologically-Grounded Studies

Recent years have seen the burgeoning of less positivistic, more culturally-oriented research reports into mathematics in changing workplaces — conducted from anthropological, sociological, and ethnographic perspectives. In a project designed to promote an informed view of the Key Competency, *Using Mathematical Ideas and Techniques,* the Australian Association of Mathematics Teachers [AAMT] (1997) collected about thirty reports of mathematics used in the workplace. They were based on accounts collected from mathematics teachers who shadowed workers, paid and unpaid, for about half a day. These work stories, as they were called, indicated that in fact all of the key competencies (Mayer, 1992) came into play in complex ways. In approaching a practical task it appears that workers bring to bear a range of skills, attitudes, and knowledges which include: (a) situational (vocational and other) knowledges and skills (in particular, mathematical); (b) meta-cognitive skills and strategies (e.g., critical thinking, planning, problem solving, and evaluating); and (c) personal skills (e.g., communication, working with others, and understanding the culture), together with certain attitudes and dispositions toward the work and the workplace. The AAMT report summarises the key elements of using mathematics for practical purposes as:

- Clarifiying the outcomes of the task and deciding on what has to be done to achieve them.
- Recognising when and where mathematics could help and then identifying and selecting the mathematical ideas and techniques to be used.
- Applying the mathematical ideas and techniques, and adapting them if necessary to fit the constraints of the situation.
- Making decisions about the level of accuracy required.
- Interpreting the outcome(s) in its context and evaluating the methods used.

(p. 59)

The report concludes that although many practical situations require an understanding of some mathematics, this would always be specific to the particular work context. However, it was unable to determine any criteria for making a difference between good and poor performance. The aim of the project was to make recommendations concerning the incorporation of the mathematics key competency into general education. However, as can be seen from the text above, there are indications of a 'tool-box' mentality, and certain aspects have be criticised for their tendency towards essentialism (Kanes, 1997b).

Other recent studies of mathematics used in the workplace include the following: operators in the light-metals industry (Buckingham, 1997); front-desk motel and airline staff (Kanes, 1997a, 1997b); landless peasants in Brazil (MST) (Knijnik, 1996, 1997, 1998); carpet layers (Masingila, 1993); commercial pilots (Noss, Hoyles, & Pozzi, 2000); merchant bankers (Noss & Hoyles, 1996a, 1996b); nurses (Noss, Pozzi & Hoyles, 1999; Pozzi, Noss, & Hoyles, 1998); draughtspersons (Straesser, 1998); semi-skilled operators (Wedege, 1998b, 2000a, 2000b) and swimming pool construction workers (Zevenbergen, 1996). Collectively, these reports highlight not only the breadth and depth of mathematical concepts encountered in the workplace, but underline the complex levels of interactions in the broad range of professional competencies as outlined above, where mathematical knowledge can come into play — when permitted by (or in spite of) management. I will now discuss findings from some of these.

Elizabeth Buckingham (1997) studied the relationship of specific and generic numeracies in the workplace. Consistent with Ellström's (1998) concept of adaptational and developmental competencies, Buckingham argues that there is a need for recognition of a broader generic approach to workplace mathematics education in addition to specific procedural skills.

> Specific numeracy was taken as the capacity to use the procedural skills associated with demarcated and specialized work roles. Generic numeracy was taken to include higher order thinking skills which imply a capacity to use the techniques of mathematical modelling to control, plan and predict with a critical appreciation of the many factors that make up a production environment. (p. vii)

She observes that, unlike school mathematics, mathematics in the workplace is operational, expressing a diversity of knowledge interests, and supporting a capacity to work in a variety of ways for a range of purposes. These skills are needed to support monitoring, planning and operational activities of production (cf., Onstenk, 1998, 1999, 2001a). Buckingham continues that although there are commonly held views of mathematics as generic, mathematical techniques must be specific to each workplace site and relevant to the operation at hand. In the past, mathematical ways of working were usually associated with specific work roles, such as trades and professions, embedded in a multi-tiered traditional management system. Skills were taught in formal education as tools-of-trade, and supplemented by experience on the job. In the new work organisation management approaches are changing, especially with the advent of new technologies which require skills of a different order — rather than deskilling. As a capacity to act, she claims that workplace mathematics (or numeracy, in her words) is part of an extended and developing knowledge system within communities of learners.

In order to meet the new workplace competencies, as described in the preceding section, Buckingham (1997) asserts that negotiation is needed between company personnel and practitioners, accommodating traditional skills and the readiness of workers to adjust and contribute to the new order. However, problems may arise if the ways of working with mathematics are modelled on practices that no longer serve to make industry viable. The traditional concept of minimal numeracy skill levels is based on a mechanistic view of human resources, whereas the new work organisation requires higher order thinking. She claims that there needs to be shift from the 'one right way' of doing things to the use of multiple strategies, including a review of the direction the work is headed.

Pushing the boundaries of Australian mathematics education research in the workplace, Buckingham's study emphasises the importance and enduring power of workplace discourses in mediating and driving workplace processes (see also Farrell, 1996, 1999, 2000). However, she concludes that access to these discourses depends on organisational philosophy and the possibility of training to negotiate spaces for participation. In other words, organisational technologies of workplace management can be used to enhance or to limit workers' participation in vocational education and training. Within the training environment, participation is impacted by the discourses of training, recontextualised through auricular texts and the pedagogical practices of teachers or workplace trainers — possibly in tacit compliance with management agendas that are not necessarily in the best interests of the workers.

In Denmark, Tine Wedege (1998b, 1999a, 2000a, 2000b) followed the AAMT (1997) research data-gathering technique of 'work shadowing,' providing graphic examples of the broad range of mathematics-related competencies required in the workplace; she asserts that quantification skills are required in every so-called 'unskilled' job (Wedege, 1999a). Several contextualised examples illustrate that simplistic conceptions based on school mathematics topics fail to capture the full complexity of any job role. Wedege, (1998a) also asserts the Danish view that adults' need for mathematics-containing qualifications must be perceived from both a subjective and an objective point of view — that is, from the point of view of individual workers as well as of the labour market (see also, Onstenk, 2001b). Mathematics is not only used to make the workplace more efficient; it can be used for democratic purposes within and beyond the workplace, as illustrated by the use of graphs to monitor sick leave within teams (Wedege, 2000b) — not to mention the widespread use of statistical control measures for surveillance of workers. Workers lacking in appropriate mathematical skills are unable to participate in the full range of workplace communications, thus their contributions as authorised knowers are reduced. Drawing on the work of Ole Skovsmose, Wedege (2000b) also includes reflective knowledge as within the scope of her broad definition of technological competence necessary for the workplace — reflection on technology will be discussed further below.

My own teaching experience in the pharmaceutical manufacturing industry (see chapter 4) provides support for the notion of the often invisible complexity of the workplace. In Australia this healthcare industry is highly regulated from a legal point of view; every procedure must follow strict guidelines, set down for workers in Standard Operating Procedures (SOPs) which are constantly updated. Accountability is of the essence and is policed by regular and random audits. At each stage of the production process every item — including packaging, leaflets, raw materials, creams, and tablets — must be recorded, counted or measured, checked and re-checked by designated operators. In the case of any discrepancy, at the very least the immediate production process is halted, and in the worst case the manufacturing licence is under threat, or product recall takes place with possible loss of consumer confidence. After a discrepancy is discovered, if non-trivial, problem solving activities ensue calling upon a broad range of competencies from workers until a solution is found. Using Onstenk's (1999, 2001a) model of workplace competencies it is possible to provide an illustration of the kinds of questions which may be asked by a line manager following a (hypothetical) breakdown in production processes:

Technological: Was the machine functioning correctly according to specifications? Were the raw materials as specified in amount and quality?

Methodical: Were the controls set appropriately (accurately, in-time, etc.)?

Organisational: Were the appropriate staff (e.g., the optimal number, sufficiently qualified) performing their allocated tasks?

Strategic: How am I going to deal with this problem? How serious is it, and what are the implications of my decision?

Socio-normative: Which are the most appropriate staff to help find the most efficient and productive solution? (N.B. union demarcations, availability of staff)

Social-Co-operative: How will I seek help without alienating the workers concerned? Can I 'borrow' workers from another task? Is the delay period in waiting for the engineer, maintenance person, etc. negotiable?

Breakdowns of any kind mean time and money to an enterprise. In the allied food-processing industry the worst case scenario of product recall is becoming commonplace internationally. Working in a situation of economic contingency requires not only explicit mathematical knowledge but also a broad base of implicit knowledge together with higher order skills associated with systems thinking. The case study in chapter 4 offers a critique of the 'official' mathematical knowledges required by workers in the food/pharmaceuticals manufacturing industry.

Richard Noss (1997) argues that sophisticated mathematical skills are required for interpretation of results as well as error detection or retrieval from catastrophic technological breakdown situations. He observed that, although in many work situations there is less reliance on traditional school mathematics skills which can be carried out more efficiently by computers, there is a greater reliance on an ability to think in a mathematical way. Noss, Celia Hoyles, and Stefano Pozzi (1998) and Pozzi, Noss and Hoyles (1998) found that there are complexities in relations between professional and mathematical knowledge, and workplace decisions are based on an interplay of these. Communication is critical, and in non-routine situations workers may draw upon underlying models which are rarely articulated, and which may indeed not have a mathematical orientation. Studies of nurses, commercial pilots, and bankers (see also Noss & Hoyles, 1996a; Noss, Pozzi, & Hoyles, 1999; Noss, Hoyles, & Pozzi, 2000) indicate that in the workplace a mathematics far broader than basic numeracy (i.e., arithmetic and measurement skills) is required when decisions become contested or problematic. Their studies also reveal that workers rarely make decisions without the use of artefacts, described as 'crystallised operations' (cf., Chevallard's, 1989, crystallised mathematics), whose successful operation often depend crucially on a lack of awareness by the worker. Noss, Hoyles and Pozzi (1998) conclude that the use of mathematics in the workplace depends on the nature of the activity (routine or non-routine) and the resources available (cf., Ellström, 1998, Onstenk, 1999), coining the term *situated abstraction.* They assert that workplace mathematics is characterised by a different discourse from established mathematics — in terms of language, also objects and relationships — and whose generality may be limited to specific and well-defined sets of circumstances. Thus, they argue, studies which confine investigations to visible mathematics are inadequate, as are studies restricted to the traditional situated cognition paradigm "which fail to discern the breadth and richness of mathematical models in use."

In his epistemological study of the workplace, Clive Kanes (1997b) analysed transactions taking place at an airlines check-in desk using the theoretical framework of mediating artifacts, and found evidence of language-games performing this function. An example is given where the language-games associated with the signs of 'difference' and 'additional' were quite dissimilar whereas, he claims, based on an essentialist account it would have been expected that they would be found within the same language-game — that is, representing "the inverse relation which exists between addition and subtraction within the domain of numerical knowledge" (p. 269). Based on his findings Kanes (1997b) makes the following suggestions:

1. … the workplace itself has primacy within the organisation and implementation of workplace knowledge — thus any approach to workplace task competency should proceed from a detailed knowledge of the particular occupational situation, not an abstract set of numerical knowledge statements.
2. … numerical knowledge does not enter the workplace as a pre-given entity.

3. . . . numerical knowledge is not used as a unitary mathematico-logical structure within workplace sites. Analysis … suggests that numerical workplace knowledge is better seen as a body of fragmented knowledge.

4. . . . the logic of this fragmentation is governed by the character of mediating artefacts within task performance. (p. 269)

These findings of Kanes, as part of a larger study on the Australian Key Competencies (see also Kanes, 1997a), emanate from a discourse analysis research paradigm and complement the comprehensive research carried out in the UK by Noss, Hoyles, and Pozzi. What are the implications of these findings for vocational mathematics curricula?

Consistent with the transdisciplinary nature of work (Gibbons et al., 1994), the boundaries of mathematics education research are transcendent in that mathematical knowledge used in the workplace is situated and contextualised, and cannot be essentialised. Rather, as the work of Noss, Hoyles and Pozzi indicates, it is built upon situated abstraction and imbricated with professional knowledge. However, the absence of essentialist qualities does not suggest that mathematics in the workplace should be ignored. (Nor should it be reduced to visible (school) mathematics topics!) Rather, a challenge is posed to vocational mathematics researchers to push the boundaries of mathematics education and vocational education research — as has the pioneering work described above — to identify the discourses of workplace mathematics as used by authorised knowers. A subsequent challenge, of course, is to transform these discourses into appropriate pedagogical discourses. Each of the studies mentioned in this subsection confirms the need to question the research basis (if any) on which vocational mathematics curricula of the past and industry-based competency standards of the present are grounded — ontologically and epistemologically.

"All knowledge is situated knowledge, and is governed by the perspective of those who are the knowers" (Yeatman, 1994, p. 19). Who are the knowers in workplace research for mathematics education? In this section, researchers (e.g., Buckingham; Kanes; Noss, Hoyles & Pozzi; Wedege) came to know about uses of mathematics in the workplace through deeply respectful enquiries into the practices and knowledges of workers on the job. At no time was functional analysis or a deficit model of the worker countenanced — in direct contrast to the manifestations of Australian CBT (mathematics) curriculum development (e.g., Johnstone, 1993). As Peter O'Connor (1994) indicates, the roles of knowers and learners are in a state of flux, both in the dialectical processes of communication about a work task (e.g., between nurse and doctor), and in the formal sense of the sharing of specialised expertise which can flow upwards, sideways or downwards in terms of the traditional workplace hierarchy (e.g., skill sharing between co-workers).

In summary, there is a burgeoning literature accounting for uses of mathematics in the workplace — nowadays grounded in explicit epistemological theories, as distinct from studies of earlier decades. It could be expected that industrialised countries wishing to improve their economic (and social) performance should both support and pay heed to empirical research of the kind outlined above. This fundamental research then needs to be operationalised, recontextualised into teachable material — normally in the form of curriculum and assessment documents — and supported through pedagogical implementation processes by ongoing programmes of professional development for teachers. Assuming that these *were* to be possible, what considerations might then be given to mathematics education *for* the workplace? In the next section I review general literature on education for the workplace, then subsequently return to focus more on issues related to mathematics teaching and learning.

2.6. EDUCATION FOR THE WORKPLACE

In this section I will firstly differentiate between on-the-job learning and training. I will then compare advantages and disadvantages of education in workplace settings. In considering the development of broad occupational competence I will review some general principles for considering the educational needs of workers, paying attention to their existing skills and the pluralist narratives operating within the workplace. Finally I will offer general reflections on teaching and learning in the workplace context.

Onstenk (1999) differentiates between learning on the job and on-the-job training. The former is not structured by specific pedagogical activities but by characteristics of the work itself, affording opportunities (or not) for learning dependent on whether the work situation constitutes a learning environment. He asserts that the likelihood of learning processes occurring in a particular job situation will depend upon: (a) the available skills and learning abilities of the employee, (b) the employee's willingness to learn, (c) the on-the-job learning opportunities, (d) the availability of on-the-job training, and (e) the relationships and mutual influences of all of these. On-the-job learning is structured only by the characteristics of the work activity itself, whereas on-the-job training is characterised by specific pedagogical structuring elements. Both the job content and the work environment can open up learning possibilities, according to Onstenk, however tensions may be experienced between work objectives and the achievement of qualifications and learning by workers. He notes that "management often still lacks an imagination for an integration of work and learning" (p. 14).

Billett, Cooper, Hayes, and Parker (1997) consider the issues of workplace learning as an alternative or complement to learning in institutional settings, noting that changing nature of work is demanding the ability to go beyond the routine and predictable. According to Billett et al., the strengths of workplace participation, in offering the possibility of authentic vocational experiences, include "goal-directed activities that press workers into learning which extends and reinforces their knowledge" (p. 9) as well as experiences which offer engagement in routine problem-solving. Its limitations are mat:

(i) not all forms of knowledge accessed in workplaces are desirable [or appropriate];
(ii) access to authentic problem solving of an increasingly complex nature is not always available;
(iii) access to expert others is limited by availability and credibility and reluctance;
(iv) expertise is sometimes absent;
(v) knowledge is possibly hidden (opaqueness); and

(vi) [there could be an] over-reliance on instructional media. (p. 48)

Regardless of how authentic institutional education tries to be it is always removed to some degree from the exigencies of the workplace. On the other hand, knowledge for workplace performance is often highly complex and takes time for robust construction to develop. As Billett et al. note, both trades and professions have mandated extensive periods of workplace experience as a requirement to develop vocational knowledge. They conclude that "it is the quality and combination of experiences and guidance that are furnished in each environment which are likely to determine the robustness of the constructed knowledge" (p. 47). The question arises as to how well mathematics might be incorporated into workplace education. This depends crucially on the quality of curriculum and teaching, and associated research and professional development. (See chapters 4, 5, and 6 for further discussion.)

Frank Achtenhagen (1994a) raises some didactic issues related to workplace education:

1. What are the advantages of learning in the workplace?
2. How can the systematisation of teaching-learning processes be achieved?
3. What is the best procedure for mastering the different levels of abstraction required by changing workplaces? (e.g., theory-practice-computer applications?)
4. How can workplace training be possible if production processes are cost-intensive or if sensitive data is involved?

He asserts that neither vocational institutes nor enterprises are prepared to adequately fit their procedures and arrangements to the new challenges — one reason is the very traditional structuring of content. Following 20 years of research on the workplace he makes the following points about vocational education:

1. Content (including goals) is defined by situational aspects, and thus should be operationalised at all possible levels. Most goals, as represented by tests and texts are at the lowest cognitive level of Bloom's (1956) taxonomy.
2. Content should be related to useability in industry — most is very general. Further, "there is not one content unit dealing with students' situations as a seller of himself as a worker. The practical needs of the workplace are neglected" (p. 218).
3. Content is not concerned with the abilities of the students. Very little teacher reference material is related to students; that which does is frequently in negative terms, and without any relation to content or other instructional variables.
4. Content (e.g., in textbooks) should follow modern structures of life.
5. Content units are linearised, compartmentalised, distant from economic, and personal needs and abilities, and wrongly mixed (in terms of order). They do not meet the characteristics of key qualifications (competencies) such as network-oriented thinking, problem solving, being able to work in teams and to cooperate, and so on.

One problem Achtenhagen (1994a) notes for students and apprentices arising from the linearised structure is that: "the organization of the content units and the corresponding linear teaching procedures very often lead to patterns of rote learning, while the intention of the goals and content is kept hidden from the students" (p.

220). A second problem is that teachers, trainers, and students are all geared to stay within these lists of goals and content units. Achtenhagen accordingly recommends that research on curriculum, teaching, and learning should satisfy five criteria: (a) the goals and content should be of importance for the workplace; (b) they should correspond to modern scientific research for the specific field of practice; (c) students should judge the goals and content as subjectively important and meaningful; (d) content must be conceivable and understandable; and (e) teachers and trainers must be prepared to accept the new practice (described further below) with its background theories, and be thoroughly trained to handle it effectively.

Llandis Barratt-Pugh (1997) observes the lack of congruence existing between systematic approaches to training design and the increasingly fragmented and diverse organisational world for which learners are being prepared (see also Mulcahy, 1998). According to Morrison and Collins (1995, cited in Barratt-Pugh, 1997) the ability of learners to construct knowledge, *epistemic fluency,* will be a critical skill in the postmodern organisation as workers move from role to role, actively choosing when and where they will apply their learning. In order to go beyond the simplistic processes of acquisition of knowledge for application, Barratt-Pugh calls for: (a) the generation of a symbiotic relationship between learning to work and working to learn, (b) learners to take more conscious control of the actual learning process, and (c) learners to be included in the design process and in the establishment of learning goals. On the surface, official rhetoric would generally appear to be consistent with these principles. Whether they are realised in practice is likely to depend upon supportive learning environments where, as Barratt-Pugh suggests, learners: (a) develop their knowledge through discourse and discussion with other workers, (b) recognise and build on past experiences, and (c) construct meaning according to their relationship with groups and other individuals (see also Beach, 1999; Brown, 1998; O'Connor, 1994; Onstenk, 2001b; Stasz, 1996). These are unlikely to occur in programmes using self-paced mathematics modules, particularly if they are lacking in authentic contextualisation.

Arguing against industry-wide narrow specifications of functional competence, O'Connor (1994) recommends consultation by the designers of educational programmes with those worker/learners who know most about the detailed and intimate workings and requirements of the particular context layer. Such analyses would then recognise context as a dynamic component of a larger system, as well as workers' ability to theorise, problematise, resolve, and modify work practices. The notion of workers as 'unskilled' needs to be consciously and explicitly rejected, according to O'Connor.

> Educational interventions need to start from a premise of existing skills, knowledge and ability, if they are to use those skills to assist in the development and the acquisition of new skills and knowledge. There is an increasing body of research which acknowledges and respects the fact that everyday or routine tasks or job performance reveal a deeper set of understandings of the complexity (physically or cognitively) of skills and knowledge brought to bear in the performance of work. (p. 278)

He continues that ethnographic studies "emphasise that the nature of work itself is collective, and almost always requires the informal collective interaction and action among individuals" (pp. 281-282). The communal model which operates has greater depth than any individual knowledge base; the group develops a communal memory of problems and solutions, and provides assistance to individuals — a valuable and relevant learning asset.

O'Connor's observations have implications for assessment, which should therefore focus on the various contexts in which workers interact, as well as on the relationships between them. He recommends that there be a shift from a traditional emphasis on individual needs towards assessing the needs and competencies of individuals as group members and the collective needs and competencies of the group. Noting that in many learning processes the roles of learner/mentor are often interchanged and seldom stable, O'Connor (1994) calls for a recognition and valuing of individual differences among workers, especially those most disadvantaged by previous educational experiences:

> The workplace as a site of formal learning, as all others, contains a plurality of voices and narratives, conflict and disunity, which must be incorporated into our understanding of the grounds on which human action is construed. Our theory and practice must develop to express and articulate the differences, as tools in extending learning opportunities to workers previously excluded or marginalised by education. (p. 291)

Accordingly, definitions of workplace numeracy (for example) based on a deficit model of the worker are inappropriate. As O'Connor remarks, often basic skills assessment exercises or techniques do not adequately assess what is actually occurring in the workplace, but instead gauge "something of an individual's ability to perform the allotted exercise" (p. 272).

As noted earlier in this chapter, the rapidly changing workplace places a premium on learning to learn — not only for current performance but also as an orientation on the future. Alan Brown (1998) asserts that most employers prefer workers to have highly developed core skills (transferable skills and the ability to transfer them) above the necessary occupationally specific skills (see also NBEET, 1995a, in the case of mathematics), recognising that training and skill development need to go beyond the narrow traditional industry confines. However, rather than decontextualised teaching and learning, Brown argues for the integration of core and occupational skills as providing a powerful learning tool. The increasing complexity of jobs through task integration is requiring greater breadth of knowledge rather than depth, underlining the importance of the ability to transfer knowledge. He stresses a need for learning contexts which draw attention to the significance of skill transfer, as well as providing a range of appropriate contexts. (Transfer will be discussed further below.)

Brown (1998) includes among critical learning processes the encouragement of workers to reflect upon their own learning, to see beyond the surface level, and to see their own practice as continually developing rather than "the acquisition of a fixed body of knowledge or a set of immutable competencies" (p. 169). He recommends techniques to develop thinking skills, such as cognitive apprenticeship (discussed below) and concept mapping, while noting the barriers imposed by current teaching and assessment practices and by the failure of other workplace personnel (in the UK, at least) to value these new techniques and problem solving skills. He stresses the importance of learner independence, teamwork and other collaborative learning, the linking of learning and assessment practices, and the development of a substantive knowledge base. The latter is fundamental to high level expertise and goes beyond the current requirements underpinning current occupational competence in order to inform future learning. These critical learning processes then require "a more integrated and imaginative concern for learning and assessment, drawing on, for example, group project work and problem-based learning and assessment" (p. 176). The dilemma for mathematics teaching is that these kinds of recommendations are often included in advice to teachers. However, they are extremely difficult to operationalise in view of the overwhelming constraints placed upon teachers by curriculum and assessment practices which do not allow for or encourage these, and, in addition, by the surveillance mechanisms designed to ensure compliance with prescriptive documents designed to control both teachers and teaching (see chapter 4).

Allan Collins (1997) addresses the problem of students' preparation for a changing workplace by recommending the adoption of cognitive apprenticeship methods. This system was proposed by Collins, Brown and Newman (1989, cited in Collins, 1997) and aimed primarily at identifying the processes experts use to handle complex tasks, exemplifying the ways that conceptual and factual knowledge are carried out in practice; in other words it has a dual focus of expert processes and learning in context. Cognitive apprenticeship differs from traditional apprenticeship in that it focuses on pedagogical concerns, not demands of the workplace, applying methods in diverse settings, and gradually increasing the complexity of the tasks. It also emphasises the generalisation of knowledge, rather than the narrow contexts of use, with articulation of the principles underlying the application of knowledge. The system is based on an amalgam of educational theories drawn from areas such as cognitive psychology, critical sociology, as well as practices of sports coaching. It aims to overcome the problems of situated and unsituated knowledge construction through goal-based instruction which incorporates principles of authenticity, interweaving, articulation, reflection, cyclical learning, and prudent use of multi-media. Although it is claimed that the principles of cognitive apprenticeship could be applied in workplace or institutional settings, it has been criticised by David Kirshner and James Whitson (1997) as not having a strong claim to theoretical legitimacy as an educational model.

Based upon extensive research which indicates that vocational education must be seen in the context of teaching towards self-directed learning, Achtenhagen (1994a, 1994b) provides a model of institution-based workplace simulation through extended project work. It involves multidimensional teaching-learning arrangements — presented in the complex interlinking web-like form of a concept map — as a means of overcoming the traditional linearity of curriculum goals and content. He argues that such a transformation would require a different approach, including having a global concept of evaluation "that covers not only the cognitive, but also the emotional and motivational domain and proves whether the curricular content and goals lead to adequate actions" (Achtenhagen, 1994a, p. 223). However, Achtenhagen's assertion of the necessity to develop complex vocational teacher training programmes would require a radical reconceptualisation of the tradition teaching and learning paradigms currently in operation. It also raises the question of initial and continuing vocational teacher education — an important issue for mathematics.

For effective work-based learning, Brown (1998) supports Billett et al.'s (1997) claim that there is no one best context of learning, nor an optimal mix between specialist expertise and broader vocationally oriented knowledge or on-the-job versus off-the-job training. The environment needs to be challenging and varied, and a balance needs to be struck between learning for work and learning through work — especially when the work is undemanding. One positive aspect suggested by Brown is that work-based learning has the potential, especially through group projects, to address a range of issues (including quality control) not currently carried out due to limitations such as time and money). There are documented case studies of these theories in practice in the automotive industry (e.g., Sefton, Waterhouse, & Deakin, 1994; Sefton, Waterhouse, & Cooney, 1995; Waterhouse, 1996). Mathematical knowledge and skills are totally integrated into the programme of work-based learning, with successful outcomes for a range of workers including several from non-English speaking backgrounds. However, this integration presupposes that workplace educators are cognisant of the overlapping domains of andragogy and mathematical pedagogical content knowledge as well as a thoughtful apprehension of total work environment — from the macro level of the organisation and its management to the micro level of the particular work site in its technical, communicative and other practices. The common practice of walk-in, walk-out delivery of off-the-shelf training modules is an anathema to this mode of operation (Mulcahy, 1998; Waterhouse, 1996).

In summary, there is no definitive statement on the optimal site of learning for work, nor on whether specialist or generalist expertise is needed. Linear, hierarchical models of curriculum, unrelated to students' lives, are not satisfactory. The research points to integrated curricula, problem-based pedagogies, and the need for development of epistemic fluency through communication and reflection, as well as thinking and transfer skills. But what might the research reviewed in so far in this chapter mean for mathematics education? What kinds of mathematical knowledge might be generated through workplace discourse?

2.7. THE DEVELOPMENT OF MATHEMATICAL OCCUPATIONAL COMPETENCE

This section will focus on findings from research more specifically related to mathematics in the workplace. In particular it will review the concepts of agency, mathematisation, mathematics education for democratic competence, and the production of mathematical knowledge by workers. It will then address issues associated with transfer, essentialism, and the mediational role of artefacts within the workplace culture.

Clearly there is an important role for mathematics education to play as a fundamental core skill. At the same time the development of the complex abilities of learning to learn and of recognising opportunities for transfer suggests the need for qualified, reflective educational practitioners. Normatively, mathematics education for the workplace may be intended to enhance the knowing of workers both subjectively and objectively, so that as individuals they may be empowered as 'knowledge producers' as well as 'knowledge consumers' — that is, to be technologically, socially, and/or democratically numerate (in the broadest sense of the term, cf., 'literate'). Pragmatically, the ultimate gain, however, is generally expected (by employers and governments at least) to flow to the economy at the micro- and macro-levels (and hopefully to society also) through the success of the workplace in a capitalist economy. This sub-section will focus on research with an emphasis on mathematics education *for* workplace learners with implications for teachers and trainers in the VET sector.

Buckingham (1995) considered the purposes of workplace education from the perspective of social agency. Facilitation of creative solutions in the changing workplace requires the educator to locate, use, and build upon the knowledges of workers. Sensitivity to teaching the types of mathematics needed by workers could be enhanced by an understanding of three orientations towards mathematics, based on concepts of social agency identified by Buckingham. The first is a *personal agency orientation,* reflected in the view that learning mathematics is a means to achieving promotion, and as such is recognised as a legitimate form of ambition. The second is a *masked agency orientation,* where mathematics is remembered as a subject enjoyed at school and which provided a sense of achievement. However the sense of social agency may be masked, especially among minority groups, because of the perceived risks of appearing to be too competent in the workplace. The third is described as a *group agency orientation,* where the group can critically appraise the usefulness of mathematics in the workplace, and is likely to help others to see the value of the subject. Buckingham noted that this orientation is also associated with personal agency, and is an expression of views about the social interdependence of groups within the workplace. She concludes that the interest shown in workplace numeracy education will depend on workers' sense of personal agency. However, as Wedege (2000a) notes, technological competence — a mathematics-containing competence — is the goal of workplace education rather than the acquisition of mathematics as an end in itself. Accepting Wedege's proposition would seem to imply that a different kind of mathematics education is required to address this different teleological goal.

Pozzi, Noss, and Hoyles (1998, p. 107) describe *mathematisation* in the workplace as "a complex set of relations (including mathematical relations) between resources, activities and settings as they are operationalised to achieve a particular goal." In order to avoid the problem of restricting their research to assessment of culturally biased notions of content, Noss, Hoyles, and Pozzi (2000) draw on the work of Terezinha Nunes (1992) to focus on what is epistemologically invariant between academic (i.e., school) and workplace mathematics in their respective sub-cultures. According to Nunes:

> understanding cultural influences on mathematics learning must involve both the analysis of the differences among particular solutions to mathematizing reality and the recognition of logical invariants underlying these differences. . . . Within a culture, practices of mathematics vary depending on their purpose.… Research may show that

> two varieties of mathematical practice within the same culture differ in some ways but are similar in others. The similarities are likely to relate to the logical invariants of mathematical knowledge. Any variations are likely to relate to the representations and the uses of the invariants in the mathematical applications. These differences are peripheral to the conceptual structure but central to the skills displayed by the subjects. (p. 558)

Noss, Hoyles, and Pozzi identify an assortment of methods and algorithms used in three diverse professions (banking, commercial aviation, and nursing), including 'tricks of the trade,' which were quick and efficient at achieving particular workplace goals. However the term 'efficiency' is not taken in the same sense as 'mathematical efficiency' because a mathematical orientation is not part of the work, and the methods used are generally unavailable to scrutiny. Some of the practices match with their recognised professional textbook methods, others differ.

In contrast to the literature on changing workplaces, Noss (1997, p. 10) observes that bank workers and customers remain trapped within Fordist and Taylorist ideas that the "effective management of the labour process demands the separation of conception from execution, the removal of human intellect from the working process, and the fragmentation and gradual removal of skills and craft knowledge." However, in increasingly computerised workplaces, he asserts that people need to gain access to underlying models; for this they need tools (e.g., graphs, variables, parameters) and means of expression (e.g., numerical, algebraic, geometric tools). He concludes that new cultures of work are redefining the boundaries for mathematics education towards holistic approaches rather than teaching sets of isolated skills.

While on the surface it appears that fewer and fewer mathematical skills are needed in a technological society, the ability to critically evaluate their uses requires greater sophistication (Ernest, 1998c). Modern computer technology plays a dual role in the process of using mathematics in the workplace (Noss & Hoyles, 1996; Straesser, 1998). The use of sophisticated software hides the mathematics and speeds up its disappearance, yet "the very same technology can be used to foster understanding of the professional use of mathematics by explicitly modelling the hidden mathematical relations and offering software tools to explore and better understand the underlying mathematical models" (Straesser, 1998, p. 434). Rudolf Straesser is critical of the type of pedagogy which teaches mathematics as a separate body of disciplinary knowledge: "applying it to work via modelling may come second, sometimes never or inappropriately" (p. 435), recognising that appropriate modelling of vocational problems by applying mathematics (according to an essentialist paradigm) presents major difficulties for the (future) worker. However, a totally embedded model of legitimate peripheral participation, such as on-the-job training, tends to obscure the mathematical relations. The solution, he claims, lies in the exploitation of the interplay between the professional concrete situation and the structural mathematical model — as elaborated by Noss and Hoyles (1996a, 1996b).

Christine Keitel, Ernst Kotzmann, and Ole Skovsmose (1993) contend that, as an integrated part of technology, mathematical competence forms a major part of democratic competence. The type of knowledge used for developing technology "is different from the type of knowledge necessary in analysing and evaluating technological constructions" (p. 270), and so a reflective knowledge is necessary. But just as reflective knowledge has no epistemological basis in technological and pragmatic knowledge, neither can technological knowledge be reduced to mathematical knowledge. In other words, they say, knowledge of mathematics does not imply knowledge of its application. Keitel, Kotzmann, and Skovsmose (pp. 272-273) distinguish analytically between six levels of reflective thinking and knowing. I believe that these could apply to workplace mathematical practice (and possibly already happen at an intuitive level) as well as to school and vocational mathematics —in keeping with systems thinking referred to earlier:

1. Has the calculation been done correctly, the algorithm used accurately, and checked in different ways? (The underlying assumptions presuppose the true-false ideology incorporated in school mathematics, they say.)
2. Has the appropriate algorithm and method of calculation been used? Is the algorithm sound, valid and reliable for the range needed?
3. Is the result useful for the specific context, taking into account the non-mathematical constituents? (The reflection has moved from the use of mathematics as a tool to the technological aspect of contextualising mathematics.)
4. More generally, how appropriate is it to formalise the problem mathematically? "Is the mathematically obtained result more reasonable and reliable than one derived from intuitive or global considerations?" Mathematical tools per se are neither necessary nor useful.
5. Reflecting on broader perspectives of the use of the special techniques of mathematics in problem solving: questioning the influence of algorithms on the perception of (a part of) reality, the conception of mathematical tools when used universally, and the general role of mathematics in society.
6. Reflecting on this evaluation process as a whole, through the different foci — addressing the status of reflective thinking it becomes reflective knowing.

To develop this reflective thinking Keitel, Kotzmann, and Skovsmose (1993) propose starting from a meaningful problem context, where "mathematical concepts, theoretical frameworks and modelling activities should be used to become able to understand the problem, formulate alternative solutions and negotiate with others about their acceptability" (p. 275). This starting point accords well with Onstenk's (2001a, 2001b) problem-based model of developing broad occupational competence.

Although their work was not focused on the workplace but the school classroom, the following summary by Keitel, Kotzmann, and Skovsmose (1993) may be closely compared with findings about mathematics in, and for, the workplace. For example, it shows strong resonance with the quotation above from Kanes (1997b, p. 269), in terms of contingency, specificity, and creativity of knowledge.

> 1. The knowledge produced within and for the local environment is not only a reconstruction of existing knowledge but is partly and potentially "new" knowledge. It may provide information on issues which were not available so far. This gives a special and additional value to this produced knowledge.
> 2. The knowledge is specific knowledge generated in specific contexts. It is potentially valid in this context but not necessarily in other contexts.… [I]t could have a generalising potential which should be explicated and evaluated.

3. The knowledge is potentially useful for a specific audience. [If access is provided to others it may increase their] ability to understand their social situations and to cope with certain demands as well.
4. For the students the generation of locally useful knowledge implies an integration of experience-based judgement with generally available and other forms of socially valuable knowledge. (pp. 275-276)

In this quotation the emphasis is on learners (or workers in our case) as knowledge producers — a far cry from the experience of most people in school and vocational mathematics classes as knowledge consumers. Might forms of knowledge production such as these be valued as mathematical competence in the vocational education sector? If so, how might this happen? The work of Keitel, Kotzmann, and Skovsmose suggests a possible way forward for future curriculum development in vocational mathematics education — especially when linked with Onstenk's (1998, 1999, 2001a) model of broad occupational competence, and with the development of personal and group agency identified by Buckingham (1995).

Rudolf Straesser (1998, p. 436) concludes that "mathematics learned in a specific context is part of a subjective domain of experience … and cannot easily be isolated, taken away, transferred and applied in a different situation." The issue of transfer in vocational contexts is of particular importance in the case of an abstract discipline such as mathematics.

2.7.1. Transfer

Stephen Billett (1998) defines transfer as the process of disembedding knowledge from one situation and transforming it to have utility in another. He describes analytically five levels of the social genesis of transfer:

1. Socio-historic (phylogenetic) — a product of the evolving history of species: guiding concepts and procedures (e.g., calculations and a number system); for example, Key Competencies.
2. Socio-cultural practice — historically derived knowledge transformed by cultural needs; goals, techniques, and norms to guide practice and expectations of transformed socio-historic knowledge (e.g., particular uses and methods of counting); for example, national curricula.
3. Community of practice — particular sociocultural practices shaped by a complex of circumstantial social factors (activity system), norms and values which embody the community (e.g., a classroom or particular workplace).
4. Microgenetic development — individuals' moment-by-moment construction of socially derived knowledge, derived through routine and non-routine problem solving.
5. Ontogenetic development — individuals' personal life histories, socially determined, which furnish knowledge with which to interpret stimuli; includes participation in multiple overlapping communities.

In order to help explain the paucity of transfer between two different communities of practice — the classroom and the workplace, Billett (1998) suggests that

> vocational knowledge has its genesis in different levels of social development, each with its own characteristics and potential for transfer. In current vocational curriculum frameworks, goals for vocational education often relate to the disembedded socio-cultural level of knowledge, yet there is an expectation of that knowledge being transferable across communities of practice, such as workplaces with their own sets of embedded norms and values. Yet, not only are these communities distinct, but that transfer is from one type of community of practice to another (e.g., a workplace to a particular classroom). This makes the prospect of transfer across different kinds of settings 'far' (transfer to circumstances which are novel), something which does not readily happen. (p. 1)

When applied to vocational education (mathematics) curriculum in the fullest sense of intended, implemented and achieved (Robitaille & Dirks, 1982), Billett's (1998) work illustrates the distinctions between types of social practice and the unreasonableness of expecting the situational factors, which he claims are key determinants of knowledge construction and transfer activities, to operate at one level yet satisfy the requirements of another. For example, it explains the apparent discrepancy between the rhetoric of generic competencies and the actuality of many vocational mathematics curriculum texts, or between vocational mathematics curriculum texts and actual workplace practices. (This analysis will be developed in chapter 4.) At the same time, Billett's model underlines the dialogical relationships between each of the social levels. In addition, it highlights a further dialogical relationship between the ontological influences exerted by each teacher's and student's identity and their ongoing pedagogical (re)formation.

Paul Ernest (1998b, p. 21) helps to develop this analysis further by providing a model with six categories on the transferability of knowledge. Between the two (hypothetical) poles of *universal applicability* and *fully situated knowledge* he inserts four other perspectives, which he terms *applications, cognitivist, problem solving,* and *situated cognition;* each accompanied by related views of knowledge and transfer. The six are as follows:

1. Knowledge is universally applicable, abstract and unrelated to context; there is no transfer. General knowledge has the specific variables of the concrete situation inserted for full applicability (universal applicability).
2. Modelling dialogically links abstract with concrete knowledge. Knowledge is fully portable and can be applied in any situation through modelling (applications).
3. Explicit knowledge is transferable. In its tacit form, knowledge must be made explicit and abstract before it becomes transferable (cognitivist).
4. Personal problem solving skills are transferable. Tacit knowledge, including strategic problem solving knowledge, cannot all be made explicit, but is transported with person and made relevant by experience via immersion in context of application (problem solving).
5. Knowledge is partly situated; some cannot be divorced from context. Some elements of explicit knowledge can be recontextualised and further developed as new situated knowledge is created (situated cognition).
6. Knowledge is fully situated, and cannot be divorced from context. Individuals must be apprenticed in each new context to master situated knowledge (fully situated).

With the fifth, situated cognition perspective, Ernest asserts that transfer can take place from one social context to another through the development of new capacities of the self which has multiple but connected facets. However, many vocational mathematics courses appear to operate at the theoretical level of applications-based teaching, where the assumption is one of fully portable knowledge to be applied unproblematically.

In addition to highlighting the distinctions between aims and practices of generic competencies and mathematics curriculum, these two models of transfer (i.e., Billett's & Ernest's) help to explain the enduring problem of vocational (and other) students failing to transfer supposedly contextualised mathematical knowledge from one classroom to another (e.g., FitzSimons, 1996a), let alone to the workplace. Billett (1996) proposes that knowledge transfer is not simply based upon object similarity where, for example, the same mathematics could be taught and applied in any relevant context — as is often the underlying assumption of adult and vocational mathematics curricula. Rather, it is dependent on the way knowledge is "constructed, valued and utilised in different communities of practice" (p. 21). Specifically in relation to mathematics as an abstract discipline unlike other vocational studies, Billett observes:

> The prospect for transfer is likely to be based on the ways in which mathematical activity is interpreted by individuals as being similar to another form of mathematical activity. Compounding the transfer issue is that mathematical contexts are not determined by physical factors or objectives, but how they are perceived by individuals. (p. 26)

Billett then makes a series of general recommendations for educators, to aid in transfer, including: enhancing connections, assisting students to embed and disembed knowledge, encouraging reflective learning, and utilising authentic experiences. These kinds of activities have been espoused by mathematics education researchers and practitioners, especially over the last decade. However, their widespread dissemination is dependent upon specialised professional development — something which cannot be taken for granted in vocational education.

King Beach (2000, p. 2) proposes an alternative to transfer in the concept of *consequential transition.* Based on the cultural psychology work of Michael Cole, consequential transitions involve: (a) "the reconstruction of new knowledge, skills, and artefacts, or transformation, across time and through multiple social context[s];" (b) "a change in identity: a sense of self, social position, or becoming someone new;" and (c) changes in the relationship between the individual and the social context, recursively linked. Based on his research, he claims that "it is more productive to think about differences in school and work as presenting opportunities for mathematical learning and development, rather than boundaries to be overcome" (p. 3). He also suggests that change in identities should be a legitimate topic among adult learners of mathematics.

In the literature, transfer appears to be linked with the concept of situated cognition, and it is to this I now turn.

2.7.2. Essentialism, Socially Situated Cognition, and Mediating Artefacts

Developing an argument against essentialism, Kanes (1997a, 1997b) identifies examples of a burgeoning literature which suggests that mathematical knowledge is comprised of sets of socially organised beliefs and practices (see chapter 1), and is not mind-independent, made up of pre-given essences. Rather, conventionally labelled as *mathematics,* mathematical knowledge is made up of norms. He continues that mathematical reasoning does not embody the truth, but provides tools which enable correct conclusions to be reached; mathematical knowledge is nevertheless fallible, and can be replaced when necessary. Whereas an essentialist perspective renders the assumption of transfer from classroom to worksite unproblematic (cf., Ernest, 1998b, above), viewing mathematics as a construction of some kind opens the possibility of synthesis of knowledges at the site of use. According to Kanes (1997a), one approach to mathematical knowledge, as distinct from information processing and constructivist models, is as socially situated — although the term *situated* and the notion of situation can take on different meanings according to context such as time, location, place, even relationships or perspectives (Engeström & Cole, 1997). Kanes's (1997b) summary of the literature sees mathematical knowledge as "distributed within collective practice relating to a particular set of work or other culturally related tasks" (p. 264). Jean Lave and Etienne Wenger (1991) propose that learning is a process of participation in communities of practice, gradually increasing in engagement and complexity — legitimate peripheral participation. Knowledge use then, according to Kanes, is equivalent to such participation, rather than either far transfer of specific content and procedural knowledge, or individual construction of local knowledge.

In order to gain a deeper understanding of mathematics in the workplace Kanes drew on the work of Activity theorists (Vygotsky, Leont'ev, and Engeström) and their expositions on the use of mediating actions and tools which allow humans to control their behaviour from the outside, by external means. Yrjö Engeström (1994, cited in Kanes, 1997a) describes the Activity system as characterised by multiple mediations in a complex environment, where task production, or knowledge use, is distributed socially, instrumentally and temporally. To overcome the problem of duality in units of analysis for situated, practice-bound cognition (individual and collective), Engeström expanded Vygotsky's model of a mediated act (Figure 2.2).

According to Engeström (1999), the uppermost sub-triangle may be seen to represent an individual artifact-mediated action and group actions embedded in a collective activity system. This collective aspect is then represented by the bottom part of the diagram. The connections with Onstenk's (1999, 2001a) conceptual diagram of broad occupational competence (Figure 2.1) are evident in the integration of community with organisational and technical aspects.

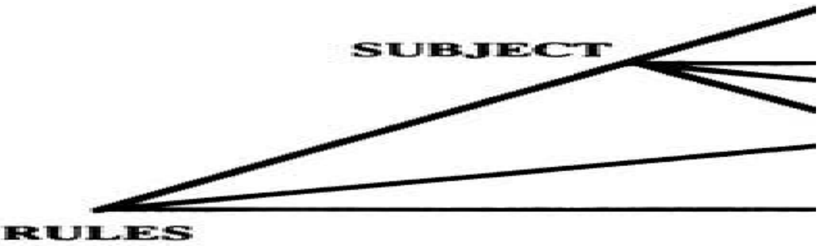

Figure 2.2. *The structure of a human activity system (Engeström, 1987, p. 78). (reprinted by permission of the author)*

Engeström (1999) reinforced and built onto this work on Activity Theory, summarising it with five principles (discussed in the *Prelude)* used to develop a theory of what he termed *expansive learning* at work. Discussing the possibility of expansive transformations, he noted that, in comparison to traditional models of education, learning in work organisations has to face issues around the instability of knowledge and skills, which may not be even defined or understood ahead of time. Workers are constantly learning new forms of activity, sometimes literally as they are being created; in this scenario there can be no 'competent' teacher who has a priori knowledge of all subject matter. He claims that standard learning theories have little to offer in the understanding of these processes. Expansive learning activity, as described by Engeström, has as its object the entire activity system in which the learners are engaged (e.g., a public hospital), and produces culturally new patterns of activity (see also Kanes, 2000). I believe that Engeström's work may point directions for workplace education, reinforcing the complex social nature of this form of endeavour (e.g., multi-voicedness, historicity, the role of contradictions), and highlighting the creative essence of both the workplace itself and those who are committed to the education of its workers. I assert that it also reinforces the need for workers to have appropriate underpinning mathematical knowledge in order to participate in the creative processes of development — in the workplace as in civil life.

Besides Kanes (1997a, 1997b), several other mathematics education researchers have documented the integral use of mediating artefacts in the workplace for the solution of mathematical problems embedded in practical tasks, and the frequent lack of isomorphism with the practices of school mathematics (e.g., Masingila, 1993; Noss, Hoyles, & Pozzi, 2000; Zevenbergen, 1996). However, Guida de Abreu (1998) provides a theorisation of the social relationships involved. Abreu's perspective on mathematics learning seeks to: (a) view learners as participants in multiple social practices, (b) acknowledge the influence of ‘significant others,’ and (c) acknowledge the mediating role of social identities and individual positioning. She asserts that although there is extremely relevant and informative research on how cultural artefacts (e.g., counting systems, measurement systems, calendars) mediate cognition and the use of knowledge, its account is partial. It is also important to take into account the relative valorisation of the artefacts by social groups and the individuals who use them. Abreu notes that valorisation involves the concepts of relative status of specific social groups (or understandings of status) and individual recreation of social identity, including positioning. In addition, within a learning situation it cannot be assumed that experts are ‘willing teachers,’ nor novices ‘eager learners’ (cf., Billett et al., 1997) — social relationships are not neutral or conflict-free. In summary, workplace education researchers and practitioners need to take account of the social mediation between a culture (in this case the workplace) and the individual with respect to: (a) the individual’s unique use of cultural tools, (b) the individual’s dialogical relationships between cultural and social values of tools, and (c) the individual’s agency or identity (cf., Buckingham, 1995). And, accordingly, teaching and learning for work should be an integrative construct recognising, utilising, and developing the interconnectedness of the knowledge of worker/learners at the personal, social, and cultural levels.

2.8. IMPLICATIONS FOR CURRICULUM AND TEACHING

What might be a role for vocational mathematics educators in the context of rapid economic and social change impacting on workplaces of all kinds?

The mathematics used in the workplace context is arguably application-driven and more socially accountable and reflexive than traditional mathematical knowledge, as it emanates from a broad range of considerations. However, vocational mathematics education cannot be allowed to dissipate into an essentialist set of skills and knowledges (tools) and thereby lose its epistemological force. Rather, a different orientation is needed. It appears that there will be a need for a more sophisticated kind of mathematics education.

Based ideally on a combination of research-based theory of mathematics education and pragmatic experience of teaching in adult and vocational education, educators will need to work in collaboration with curriculum designers and vocational teachers and trainers, in educational institutions and workplaces. John Stevenson (1998a, 1998b) calls for continuity to overcome polarisations of knowledge. The thrust of his suggested conversations across practice is: (a) a broadened conception of vocation as a calling (following Dewey, 1916); (b) acceptance of the unpredictable nature of economic activity which must be seen in connection with wider societal goals; and (c) a reconstructed perception of the relationship between knowing and doing so that these constructions are no longer polarised but linked with the individual and society.

Related to agency and the valorisation of artefacts, and their implication with social relations, is the valorisation of mathematics itself. Gelsa Knijnik (1996, 1997,

1998) addresses the issue of valorisation of mathematics in her work with peasants in Brazil — the Landless People's Movement (MST). In her case education and political struggle are mutually reinforcing. Education in settlement camps seeks to provide for those previously denied access and those who have not had their intellectual needs fulfilled or their culture valued in previous schooling. However, in this approach to teaching there is no exacerbated relativism between popular and academic knowledges; neither is there valorisation of one over the other. In her pedagogical work she has sought to interpret and decode native knowledges, stressing their internal coherence within their own context without glorifying them. In addition she has also sought to examine power relations produced in the confrontation between popular knowledges and the socially legitimated culture of academic mathematics. In a further development of her ethnomathematical approach Knijnik has broadened her outlook to investigate *different* native knowledges as they confront technical knowledges (old and new), in recognition of the differences *among* and *within* cultural groups (cf., Abreu, 1998; Nunes, 1992). Her starting point comes from three of the MST principles: (a) reality as a base of production of knowledge, (b) organic connections between educational processes and economic processes and (c) organic connections between education and culture. Here the school and its educational work are an integral part of the culture, in the same way that workplace education might — to reiterate the pleas of Butler (1989) and O'Connor (1994), in recognising and valuing the plurality of needs and knowledges of all participants.

Ernest (1998c) and FitzSimons (200la) observe that in technology education there is a distinction between developing capability and an awareness of the social significance, import and value of technological artefacts. In order to critically evaluate the uses of technology and the role played by mathematics in society, there is a need for an inclusive, bigger picture (cf., Noss's 1994a; 1994c, delineated meanings) of mathematics. According to Ernest (1998c), an appreciation of mathematics by all (school) students might include elements of awareness such as:

> 1. Having a qualitative understanding of some of the big ideas of mathematics such as infinity, symmetry, structure, recursion, proof, chaos, randomness, etc.;
> 2. Being able to understand the main branches and concepts of mathematics and having a sense of their interconnections, interdependences, and the overall unity of mathematics;
> 3. Understanding that there are multiple views of the nature of mathematics and that there is controversy over its philosophical foundations.
> 4. Being aware of how and the extent to which mathematical thinking permeates everyday and shopfloor life and current affairs, even if it is not called mathematics;
> 5. Critically understanding the uses of mathematics in society: to identify, interpret, evaluate and critique the mathematics embedded in social and political systems and claims, from advertisements to government and interest-group pronouncements.
> 6. Being aware of the historical development of mathematics, the social contexts of the origins of mathematical concepts, symbolism, theories and problems.
> 7. Having a sense of mathematics as a central element of culture, art and life, present and past, which permeates and underpins science, technology and all aspects of human culture. (p. 50)

Although these ideas seem like an anathema to current purely instrumental vocational ideologies, they are consistent with the convergence of general and vocational education as suggested by Brown (1998) and the more global perspective of education held by Stevenson (1998b). They could contribute to the substantive knowledge base of the community as a whole and could be taught within general adult (lifelong) education. Personal experience (e.g., FitzSimons, 1997a) shows that adults returning to study are well able to cope with these different, socially critical and historical perspectives on mathematics and mathematics education, at a variety of intellectual levels. However, I do not wish to suggest that vocational classes should become 'mathematics appreciation' classes — as might be possible in adult general education. Rather, at the very least, these ideas should underpin curriculum development and pedagogical practice in vocational mathematics education; they should form part of a conscious knowledge of VET mathematics practitioners — perhaps through organised professional development, even for those whose teaching is at low levels academically. In the professional development it would not be necessary to pursue the mathematics to high academic levels; perhaps the level of mathematics offered to intending primary school teachers (a vocational course in itself) might be appropriate. The question arises as to whether these seven elements could be integrated within workplace education. However, consistent with earlier calls for systems thinking, reflectiveness and mathemacy, I assert that they should be woven into curricular and pedagogic texts for vocational students as part of broad mathematical competence.

The traditional image of the mathematics teacher delivering 'theory and applications' from the front of the class would appear to have an uncertain future if integrated, simulated or workplace problem-based studies, as described above, were to become the norm. Already in Australia formal mathematics subjects (or calculations) have been discontinued in many vocational areas, no doubt due in part to their unpopularity and apparent lack of relevance. Herein lies another paradox: just as more broadly-based generic mathematical knowledges and skills as well as higher-order thinking skills are required to meet the changing needs of the workplace, including the ability to continue to learn as well as to be more information literate (NBEET, 1995a; NBEET/ESFC, 1995; NBEET/ESC, 1996), the trend, in Australia at least, is in the opposite direction. This is in contrast to at least two European countries of comparable demography.

2.8.1. Developments in Vocational Mathematics Education in the Netherlands and Denmark

Stieg Mellin-Olsen (1987, p. 77) observes that: "the conception of the learner as one who possesses much more mathematical knowledge than we have foreseen opens up new conceptions of the *dialectics of the classroom* and the teacher's direction of learning." As discussed above, it is likely that at least some of worker/students' mathematical knowledge is stored in codes other than the standard authorised system. How can vocational mathematics educators come to learn more of workers' actual and potential knowledges to develop meaningful programmes for their students?

An institutionalised attempt to bring meaning to vocational mathematics classrooms took place in the Netherlands with the *TWIN* (1999) project. The project arose because mathematics as an independent subject was about to disappear from vocational courses due to its failure to support vocational subjects (Goris & van der Kooij, 2000). Its main objective was to develop and implement a new curriculum, working investigatively at both teacher and student level so as to optimise implementation. Other objectives were to develop information technology as a structural component, using previously developed robust tools as well as new ones that were integrated with the curriculum. The project was supported by a new approach to assessment within boundaries set by vocational education, and a strong, network-based teacher training programme. It was run in partnership with several educational institutions, including the Freudenthal Institute, a commercial publisher, a network of 40 out of 53 Regional Education Centres (ROCs), and participating schools. The funding, raised from whatever sources were available, was then doubled by the government on a year-by-year basis (Tom Goris, personal communication, October 14, 1999). All mathematics teachers of participating schools met with project personnel three times a year, when they were updated on the project, introduced to new materials (e.g., TWIN, 1997, 1998a, 1998b), discussed issues such as examinations, and exchanged experiences. The intention was to: (a) offer only subjects relevant to the future profession, (b) develop in students the flexibility to use different strategies rather than one (formal) technique, and (c) use real-life contexts of the student's field of interest to learn mathematical concepts and to develop a mathematical attitude. Most important, add Goris and Henk van der Kooij (2000), was the focus on seeing relationships as about entities, including units of measurement, rather than solely as abstract and formal structures. (See also, van der Kooij, 2001.)

As may be surmised, the TWIN project was influenced by the Realistic Mathematics Education (RME) approach of the Freudenthal Institute in Utrecht. Freudenthal (cited in van den Heuvel-Panhuizen, 1998) notes the focal point should not be on mathematics as a closed system but on the activity, on the process of mathematisation. Marja van den Heuvel-Panhuizen discusses Treffer's formulation of two types of mathematisation, horizontal and vertical. In the former, students develop mathematical tools to help organise and solve a problem located in a real-life situation. In the latter, they reorganise their thinking within the mathematical system itself, finding shortcuts and discovering connections between concepts and strategies and then applying these discoveries. Freudenthal stressed that they were to be of equal value. Thus, in contrast to traditional mathematics education, the use of context is very significant as a source for the learning process to constitute and apply mathematical concepts. Another significant difference is the alternative conception of teaching and learning; students are considered as active participants in the teaching-learning process, and offered opportunities to share their experiences with others. As noted in the title of van den Heuvel-Panhuizen's paper, the RME project has always considered itself as a work-in-progress, and new questions are continually being formulated (see also de Lange, 1996). Goris and van der Kooij

(1998) observe that students generally like the approach, but have to get used to the idea that they are expected to become producers instead of consumers of knowledge (cf., Klein, 1998, 1999a, 1999b). In order for the students to develop self-awareness and self-confidence they need to be given enough room to explore concepts and skills at an intuitive, informal level. It is at this point that the teacher's role is critical to the learning process. However, this represents a great change from the traditional role and these changing goals may hold some confusing aspects for teachers: (a) a loss of certainty as to exactly what students should learn, (b) a loss of control engendered by student (re)invention and (re)construction of mathematical concepts with freedom and flexibility in classroom activities, and (c) a possible loss of the teacher's mathematics-related belief-system where, to use Ernest's (1991) terminology, they may have to shift from holding philosophies of Absolutism to those of Progressive Absolutism or even Fallibilism. To overcome these possible difficulties, Goris and van der Kooij recommend the recognition and discussion of beliefs, as well as the critical action of close collaboration between researchers and practitioners.

As described above, the work of the TWIN project is an attempt to link school and workplace mathematics from the perspective of the educational institution. It is a concrete example of research and practice which meets many of the theoretical criteria outlined in this chapter. A different kind of example is given by Tine Wedege (1998b) for the Danish *Fagmat* (professional mathematics) project, which she instigated, gaining the support of the Director General for Employment (T. Wedege, personal communication, June 15, 2000). The project provided a teachers' guide to industrial uses of mathematics, illustrated with photographs and facsimiles of workplace artefacts, and was made available free of charge to educators (teachers and planners) in the Danish adult education system. Wedege (1997) also discusses a Danish project *Profile in Mathematics* designed to develop appropriate guidance material for students and teachers, enhancing capacities in everyday and working life. Future projects include adult literacy and numeracy programmes in education and teacher training; however, according to Wedege, official interest (e.g., *Uddannelse* [Education] *No. 5*) appears to be directed strongly in favour of literacy — as is the case with the recent Australian review of research into adult literacy and numeracy (Falk & Millar, 2001; Watson, Nicholson, & Sharplin, 2001).

2.9. CONCLUSION

There are ongoing calls to develop a workforce that is flexible, literate and internationally competitive, whether in symbolic-analytic, service, or production industries. The information society, as well as the industrial society to some extent, is based on a global knowledge economy, pursuing organisational and product innovation, and thereby placing a premium on human capital development. Such a knowledge economy demands a new form of literacy encapsulated in, but going beyond, the generic competencies. Research has shown that in the workplace more is required than the simplistic choosing and using of school-type (usually arithmetical) algorithms: decisions are made by workers at all occupational levels, particularly in the case of contestation or non-routine problem solving. As the concept of the learning organisation takes hold in industrialised countries, higher order thinking and metacognitive skills will be required to meet the demands of the new millennium.

As outlined by Ellström (1998), there are many interpretations of the meanings of competence. Employers may use tests of mathematics — even archaic ones (Cockcroft, 1982; Foyster, 1988) — often inappropriately, as sorting mechanisms in times of over-supply of labour, rather than as a reflection of the actual job requirements. However, research (e.g., Brown, 1998) has shown that many employers prefer a good general education on which to build specific on-the-job training. But, even here, there are silences about mathematics as content apparently remains unproblematised. Onstenk's (1998, 1999, 2001a) conception of broad occupational competence suggests possibilities for an elaborated view of workplace practices where mathematical knowledges, whether explicitly recognised or tacit, operate within complex, multi-layered environments. These require sociocultural, socio-normative as well as technical competencies, although it is only the last that is generally recognised in curriculum and pedagogic texts for vocational mathematics students. Mathematics education research into the workplace indicates that its use is contingent, fragmented and unable to be totally determined in advance for any occupation, let alone individual work site. The non-linear development of workplace knowledge means that it cannot be aligned with linearly organised mathematics curriculum frameworks or any assumed hierarchy of mathematics learning, problematised by Ernest (1991). On the other hand there is an over-riding importance attached to mediating artefacts situated in social and cultural contexts. So what might this mean for vocational mathematics education?

Because there is no unique vocational structure, in either form or complexity of tasks for any one occupation (Ellström, 1998; Foyster, 1988, 1990) it is not possible to formulate in advance a general set of mathematical procedures that will cover all eventualities. The solution, from a mathematics education perspective, appears to lie in the direction of holistic approaches, thoroughly grounded in mathematics and vocational education research, integrating curricula across disciplines with judicious use of technologies of education, incorporating artefacts appropriate to actual practice (where possible). The education of adults, whether in vocational or general education courses, needs to address aspects of democratic participation in and out of the workplace, including uses of and reflection on technology itself, and incorporating critique of the role of mathematics in our society. In other words, the traditional practice of conducting generalised functionalist occupational analyses, essentialising selected mathematical tasks, and reworking them as 'contextualised' applications at low skill levels with predetermined answers is no longer appropriate. Higher order thinking skills, involving broad reflective and metacognitive skills, together with complex communication skills, or systems thinking, are required.

The simulation model proposed by Achtenhagen (1994a, 1994b) breaks the mould of linearity currently associated with vocational curricula and attempts to provide meaningful contextualised tasks (albeit under different conditions from the exigencies of the immediate workplace). However, there appears to be a danger that higher order mathematical thinking and the development of metacognitive skills may be overlooked if the workplace-oriented tasks focus only on the localised 'maths you need' for a specific job. The seminal work of Keitel, Kotzmann, and Skovsmose (1993) and Ernest (1998c) is focused on school mathematics, with mathematical development as an end in itself rather than technological workplace competence. A synthesis of contributions from mathematics education research and vocational education research is needed. This requires the contribution of expertise by reflective, informed mathematics educators and vocational education researchers — as well as support from policy-makers or industry bodies. First steps towards such a project are underway in the Netherlands, with the authors of the TWIN project linking with Jeroen Onstenk (H. van der Kooij, personl communication, June 28, 2001). Is this a Utopian vision for vocational mathematics education worldwide?

This chapter has briefly addressed some theorisations of globalisation, and technologies of management in the workplace. It has reviewed studies of mathematics in use, together with mathematics education in and for the workplace. It has suggested a broader view of occupational competence and the possibility of a different role for mathematics education in post-compulsory, vocational education and training. It has argued for the development of broad mathematical competence, and for the maintenance of an educational perspective in what has come to be regarded as a commodified training market (see chapters 5 and 6). No less than children, adults have the right to a mathematics education which respects their integrity, promotes equity and inclusivity, and enhances their personal empowerment within the workplace as well as in society generally. Chapter 4, a case study, will illustrate and critique examples of what counts as mathematics in adult and vocational education in Australia.

However, in the next chapter, *Interlude,* I propose to introduce more theoretical perspectives on technologies of power. These will be followed, for the sake of completeness, by an exploration of the comprehensive theorisations of Basil Bernstein with respect to symbolic control, pedagogy, and identity in education — encompassing all structural levels. The written text here is dense and complex; from Section 3.2 onwards may be omitted by readers unused to this style of writing. However, the salient ideas are reviewed in chapter 5, under the heading *Competence and Performance Pedagogic Models.*

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CHAPTER 3

INTERLUDE

Theoretical Frameworks

3.1. TECHNOLOGIES OF POWER

How are technology and power related? In this section I begin to tease out some theorisations of the term *technology* and its complex interrelationships with *power.* From the *Prelude,* Barnes (1988) comments that, strictly speaking, power should be taken as referring to distributions of capacity, potential, or capability. Technologies of power impact multifariously upon all stakeholders involved in activities of teaching and learning of adult and vocational mathematics: as citizens participate in their social, cultural, and civic activities; as workers and employers labour in the workplace; as students and teachers located in various educational settings teach and learn together; as teachers and their managers as employees of educational (and other) workplaces perform managerial tasks; academics as researchers and teacher educators carry out intellectual and pedagogical work; and as government policy makers, bureaucrats, and educational planning officers legislate for and enact political imperatives.

3.1.1. The Concept of Technology

The concept of *technology* is central to this monograph. Firstly, from an industrial perspective it is integrally linked with mathematics in production in the manufacturing, service, and symbolic-analytic sectors. Secondly, it is utilised as a tool of management, both in industrial settings and throughout the Australian VET sector—although, as will be argued in chapter 6, the education sector itself is being transformed from a public good to a competitive industry. Following the work of Jacques Ellul, George Grant understands technique as "the systematic utilization of the most efficient methods of producing and distributing desired goods" (Andrew, 1988, p. 303); technology is seen as the bringing together of *techne* and *logos* (our making and our knowing). Grant asserts that technology is not a set of instruments, nor a world of things, but rather is a worldview, present in attitudes to things and people, embodied in an integrated system of procedures, languages, and purposes. Minds and bodies are exploited by and attuned to the systematic control of nature. He claims that just as the subject-object split in technological research submerges subjectivity, so values are denied cognitive status in a technological world predicated upon facts, but return as products of autonomous human will — as standardised and 'ready-made.' These theses resonate with those raised in earlier chapters.

The primary meaning and the publicly accepted interpretation of the Australian post-compulsory vocational education acronym *TAFE* was, and remains, Technical and Further Education — despite numerous attempts to replace it with more politically expedient alternatives. However, in recent years derivatives of the term *technology* have become more prevalent (e.g., Universities of Technology), various adjectivally qualified department and School (faculty) titles (e.g., Engineering Technology), and subject titles (e.g., Biotechnology). There has been a slippage of terminology in the progression from the low-status technical skills and knowledges to technological know-how — reflecting at one and the same time changes to industry sectors in modern society and the perceived need by the education industry for astute marketing of its products.

Andrew Feenberg (1995) argues that technology is one of the major sources of power in modern societies; the power wielded by masters of technical systems largely overshadows political democracy in the control they exert over, inter alia, experiences of employees and consumers. However, rather than accepting a thesis of technological determinism, Feenberg asserts that technology is but one important social variable. He claims that technological determinism draws its force from an attitude that the essence of technical objects lies in their explainable functions. Instead, he suggests that there are two hermeneutic dimensions: their social meaning and their cultural horizon. The first extends beyond the concept of 'goal' which strips technology of its social contexts; the second holds that technological development is constrained by cultural norms — for example, the assembly-line technology of production was specific to a certain form of capitalist economics and social context. According to Feenberg, "social meaning and functional rationality are inextricably intertwined dimensions . . . not ontologically distinct" (p. 12), as 'double aspects' of the same underlying technical object. Functional rationality isolates objects from their original contexts, contributing in an apparently neutral way to what he calls the 'bias' of technology in support of a hegemony. Feenberg continues that modern technology can only be understood against the background of the traditional technical world from which it developed. However, rather than a generic shift, he claims that there has been a significant shift in emphasis of features such as the use of precise measurements and plans, and the technical control over some people by others. Bureaucracy is one example.

3.1.2. Bureaucracy and Rationalisation: The Contribution of Max Weber

The work of Weber relating to the development of rationalisation in Western civilisation offers an insight into the processes of bureaucratisation prevalent in the institution of vocational education and training, in Australia at least. The sector derives its primary political and social importance from the initial preparation and continuing education and (re)training of actual and potential members of the workforce. A secondary but not insignificant role is to provide an alternative, politically pertinent in statistical terms, activity to the personal void and the public liability of unemployment. In other words, a major but generally tacit goal of governments internationally is to be seen to be minimising unemployment figures. The management of the public funding and educational outcomes for 1.7 million Australian students (approximately 10% of the population), whilst being seen to be responsive to the electorate in general and to industry in particular, requires an efficient and effective bureaucracy.

Anthony Giddens (1972, p. 32) notes that contrary to liberalism and Marxism, a key theme in Weber's writings is "his emphasis upon the independent influence of the 'political' as opposed to the 'economic'." According to Weber, the relationship between democracy and bureaucracy in the modern social order creates a profound source of tension. While the development of democratic government necessarily depends upon the further advancement of bureaucratic organisation, the reverse is not true. The essential character of capitalism is in the rational orientation of productive activity. This process, such as the separation of workers from their means of production which gives rise to bureaucratic specialisation, is irreversible. Bureaucratic specialisation of tasks is, in Weber's opinion, first and foremost the characteristic of the legal-rational state; this affinity between capitalist production and rational law derives from the factor of 'calculability' intrinsic to both.

As will be elaborated in chapter 6, bureaucratic specialisation is reflected in the shifts that have taken place in ultimate responsibility for the Australian VET sector, particularly over the last two decades. Under the influence of political ideologies of neoliberalism (or economic rationalism) there has been a transition from departments headed by experienced professional educators to ministries headed by bureaucrats — in the newly legitimated structures. Calculability is of the essence, together with accountability. The influence of bureaucracy has been so pervasive in the adoption by many Australian educational institutions of the International Standards Organisation (ISO) quality assurance model — a model designed not for educational institutions but for commerce.

In contrast to the contestation over, and eventual transfer of, responsibility for secondary mathematics curriculum from the profession to the bureaucracy of the state (Horwood, 1997), mathematics teachers in the Australian VET sector have, historically, operated under different conditions of professionalism. They have never received the support of powerful universities and at best a tokenistic support from industry, and appear to have ceded their responsibilities without any sign of a struggle. It could be surmised that one explanation lies in the massive nature of bureaucratic changes which have overwhelmed teachers during the last two decades and which met with little, if any, organised resistance. In fact, the bureaucratic task was made easier in the 1980s by the actions of mathematics teachers associated with the TAFE Mathematics Common Interest Group, in the state of Victoria, who proposed and received state funding for an audit of the plethora of extant courses. (This will be further discussed in chapter 4.)

According to Giddens (1972, p. 13), "Weber recognised an absolute dichotomy between the validation of 'factual' or 'scientific' knowledge on the one hand, and of 'normative' or 'value' judgements on the other." Hence politicians' factual knowledge can never validate their value-laden goals. The correlate to Weber's epistemological proposition that rational analysis cannot validate or disprove judgements of value is the sociological approach that "rationalised systems of social organisation do not create values, but instead only function as a *means* to furtherance of existing values" (Giddens, 1972, p. 52). The assessment of rationality takes moral objectives or ends as givens; the rational cannot evaluate competing ethical standards.

Education, through its contribution to rationalised human conduct as exemplified in the manifestation of the bureaucratised division of labour, cannot avoid specialisation. Thus, seeing intellectualism as bound up with the rationalisation of human conduct, Weber concludes that professional education has come to replace humanism (Giddens, 1972). Here Weber's theorisation helps to explain the shift towards instrumentalism in vocational mathematics education, as will be illustrated in chapter 4, and the apparent lethargy by politicians and bureaucrats towards engagement with issues such as those raised by John Stevenson (1996, 1997) and others concerning the worthwhileness of vocational curricula in general for individual students, not to mention current and future industrial and societal needs.

Although Claus Offe (1972) was writing about a late capitalist welfare state, contrasting it with the liberal capitalist society where the economic system was institutionalised as a domain beyond the authority of the state, his observations may yet be pertinent to neoliberal political regimes. He notes that social processes, almost without exception, no longer take place beyond politics. Following his argument, an alternative explanation may be found for the apparent lack of political interest in day-to-day educational practice as compared to the managerial aspects of the Australian VET sector. Considering the need by ruling parties to maintain mass loyalty, state intervention would only be justified if there appeared to be consequences arising from the current situation that would jeopardise the immediate stability of the system as a whole. In any case, teachers in the Australian VET sector have now been placed in a severely weakened political situation — as evidenced by their replaceability by trainers with minimal qualifications or (potential) technologies of education — discussed in chapter 5. Their students, with reduced powers of student unions and few financial resources to back them, have not the collective voice that employers have (Anderson & Hoare, 1996). Yet, Australian employers like their British counterparts (Stuart, 1999, 2000), traditionally reluctant to countenance the funding of initial vocational education and training have, through representatives of big business and industry, still managed to influence government policy in the direction of deregulation. Collectively, they show little evidence of concern to ameliorate the declining quality and quantity of vocational mathematics education (as evidenced in the following chapters) — in fact, just the opposite.

The growth of what Weber termed *technical rationality,* as evinced in social relationships in the form of bureaucratisation, is closely tied to the development of legal-rational norms (Giddens, 1972). From Offe's (1972) discussion of a *technocratic* concept of politics, with decision-making processes designed to maintain stability with the political focus away from the *status quo,* I now turn to the work of Jürgen Habermas, a member of the Frankfurt School of critical sociologists along with Offe, to develop further the discussion of technology and values.

3.1.3. Technical Rationality: The Contribution of Jürgen Habermas

According to Paul Connerton (1976), the idea of critique is a product of the Enlightenment, extended and reformulated by the Frankfurt School. He describes the methodology of Critical Theory as being related to "the idea of critique as reflection on the conditions of knowledge in the social world" (p. 37). Its proponents argue that no system of basic concepts, such as those found in the natural sciences, is in principle possible for the study of society; reality can only be perceived through certain a priori categories embedded in the human subject. From a political perspective Critical Theory "is related to the idea of critique as an analysis of constraints imposed by the historically variable structures of the social world" (p. 38). The argument here is that our world is increasingly dependent upon science and technology, but then scientific criteria are used to determine whether or not the social world is rationally ordered. Habermas addressed several human interests: the technical, the practical, and the emancipatory (linked respectively to empirical-analytic, hermeneutic, and critical paradigms). However, Connerton notes that in the case of the interest in possible technical control this is not an empirical, demonstrable interest, but an interest in the *condition of the possibility* of natural science. In other words, not only its emergence and continued existence need to be explained, but also its procedures and methodological structure.

Habermas (1963/1974) argues that science, technology, industry, and administration are interlocked in the continual expansion of technical control over nature and concomitant refinement of administration over human beings. The social potential of science is reduced to technical control, and "emancipation by means of enlightenment is replaced by instruction in control over objective or objectified processes" (pp. 254-255). Industrialised societies are now unable to distinguish between practical (hermeneutic or interpretive) and technical power. Rather than attempt a rational consensus on the part of the community, technical control is attempted through ever-improving administration. There is a paradox in that people are externally bound to the functionally interdependent technological systems in the social order while personally being denied knowledge and, even more so, the ability to reflect on them. Rather than improved systems of manipulation, Habermas suggests a possible solution in a persistent critique.

Distinguishing between the exercise of *technique* in its former sense of guiding artisans and the modern use of the term *technology,* Habermas (1963/1974) relates the function of modern science to the social division of labour. In addition to its monopolisation powers of technical control, the other critical achievement of positivist science has been to reject all competing claims to a scientific orientation other than purposive-rational action. These are blocked out through slogans of ethical neutrality or value-freedom, according to Habermas. In fact, even this sole admissible 'value' of economy of means in the form of technical recommendations is not seen explicitly as a value because of its coincidence with rationality as such.

Thus, according to these principles, only empirical questions which can be posed and solved in the form of technical tasks are acceptable; others which require self-understanding go beyond the parameters of the positivistic paradigm which is not capable of investigating them rationally. Under this ideology practical (or interpretive) questions are not able to be discussed cogently and a ‘decisionistic thesis’ is employed to make a decision one way or another. As subjective value qualities are filtered off they become agglomerated, and respective claims cannot therefore be evaluated. Even the highest level goals can be thus treated as value-free decisions.

Habermas (1963/1974) continues that, with the denigration of the subjective philosophy of value, the decisionistic complement to positivist science can be found in non-cognitive Ethics. Fundamental value judgements are posited as axioms, based on decisions or commitments, with a deductive chain of statements following from them; yet these principles are not accessible to rational consideration and comprehension. There cannot be a rationally substantiated consensus. In a desperate attempt by authorities to secure socially binding commitments, Habermas posits “a return to the closed world of mythical images and powers” (p. 267) — a complementing of positivism by mythology (see chapter 7 for further discussion).

Even though Habermas was writing four decades ago and had not witnessed the technological revolution of recent decades, his theorisations are far-sighted and remain relevant to the situation of the institutions of mathematics and of vocational education and training in Australia. The imbrication (or recursive embeddedness) of mathematics in science and technology has been explored by several commentators. By contrast, a mathematics education research conference held in Australia under the theme of technology in mathematics education (Clarkson (Ed.), 1996) failed to produce a single published paper offering a serious critique of the uses to which technology is put. In the Australian VET sector the use of technology in mathematics curriculum documents, when mentioned at all, is unreflective — contrary to the critical approach in some computing units (see chapter 4). From a pedagogical perspective there has been little evidence of any Australian VET sector research (original or synthesised from the literature) into an evaluation of the teaching capabilities for mathematics afforded by technology (or the consequences!), beyond the technicalities of pasting traditional materials onto CD-ROMs or the World Wide Web (albeit with fancy icons, moving images, and multiple-choice tests) and of student management protocols (e.g., Computer Managed Learning, CML). Such a hiatus suggests support for Habermas’s theory of technical rationality, concomitant with diminishing opportunity and encouragement for student reflection in the form of metacognition or considered value-judgements on the uses and abuses of technology. This applies across the spectrum of courses, from base-level operators to high-level applied science courses for technicians, and is a missed opportunity, particularly in the case of mathematics.

The rejection of competing claims to rationality and consequent curtailment of rational, ethical debate as proposed by Habermas may be evinced in the policy formation and implementation at all levels of management in the Australian VET sector. Decision-making in the absence of consensus-seeking debate among all stakeholders has been rife for well over a decade, and resultant policies not only fail to meet their own intended objectives, but are often internally inconsistent. Supposedly value-free technological recommendations/demands to TAFE institutes and other providers (e.g., for ever-increasing accountability or to achieve targets in the face of further reductions to central funding) issue forth on a regular basis.

Allied to the technologisation of policy and planning, from which experienced educators have been systematically excluded, is the technologisation of the educational process itself as evidenced in the marketisation of 'products' such as prepackaged curriculum, assessment, and teaching materials, as well as in 'delivery systems' such as online courses. The epitome of technical rationality in education lies in the very marketing strategies, such as the lifelong learning campaign and the burgeoning glossy brochures (discussed in chapter 7) and creative Web pages on Internet sites. It is here that the myths and images posited by Habermas can be seen in full colour, literally and metaphorically. Even the government-funded research, as discussed in chapter 6, provides little opportunity in the parameters set (officially or unofficially) for any serious debate of issues other than within the same technical decision-led agendas, sympathetic to current neoliberalist ideologies.

3.1.4. Technologies of Power: The Contribution of Michel Foucault

Alec McHoul and Wendy Grace (1993) describe Foucault's contribution to the history of ideas as involving a rethinking of three central concepts: power, knowledge, and discourse. Moving beyond Marxism, they claim that Foucault saw power in terms of relations in the flows and practices of everyday life rather than as something imposed from the top down, or a thing to be wielded. Foucault drew attention to the specific epistemic and discursive conditions necessary for authorship of ideas; noting that meaning and intentions are historically contingent. He saw power as both reflexive, producing subjects who reproduce it, and impersonal. McHoul and Grace observe that Foucault was also interested to examine *subjection*: "the process of the construction of subjects in and as a collection of techniques or flows of power which run through the whole of a particular social body" (p. 22). Discourses, taken as well-bounded areas of social knowledge, are connected with politics through the field of power and the positions it generates for subjects.

In what McHoul and Grace (1993) describe as his *critical* phase Foucault turned his attention, among other things, to subjugated or marginal knowledges, or the local popular knowledges of 'unruly' subjects. Official knowledges tend to work as instruments of normalisation, providing correct, functional forms, and occluding other knowledges or pathologising them. Foucault's writings on power are linked with the production of 'truth.' In his study of the imbrication of subjection within power relations, his conception of discourse in the production of knowledge, including self-knowledge, is crucial for an understanding of power, according to McHoul and Grace. Caputo and Yount (1993, p. 6) note that "disciplines introduced the power of the norm, and from that point forth power has demanded the productions of truth that its new techniques make possible." At the same time that normalisation imposes homogeneity it also makes possible individualisation and differentiation.

Foucault applied the term 'institution' to "all the field of the non-discursive social" (Foucault, 1980, quoted in Caputo & Yount, 1993, p. 20). Situating institutions within the web of power relations he sees them as means that power uses and not its sources or origins; however power itself is multiple, multiplied, scattered and disseminated, not concentrated at a central point. Institutions attempt to reform those who stray beyond the limits of normalisation. For Foucault, knowledge is produced by power relations in order to more effectively disseminate themselves. Thus, Foucault recommends critique of institutions as a means of exposing lateral forms of power which have become embodied in techniques and multiple forms of subjugation (Caputo & Yount). Although Foucault challenged the status of the conditions necessary for the production of truth in natural sciences while admitting a certain epistemological rigour in subjects such as mathematics, his main interest was in the systems of social sciences which produce less stable conditions for the production of truth. My interest is in the institutions of mathematics and adult and vocational education, their respective productions of truth, and the intersections of these.

Gilles Deleuze (1986/1988) describes Foucault's power relations, deriving from the multiplicity of forces extant within the social body, as differential relations. They are actualised through an integration of forces, although not globally. Rather, there is a multiplicity of local and partial integrations making up institutions which presuppose power relations and therefore cannot be its sources or essences. State control appears to have captured many power relations which are in fact produced in other domains (e.g., pedagogical, juridical, economic), but which have themselves encouraged global integration. Institutions have the capacity to integrate power relations which establish contact between unformed matter (receptivity) and informalised functions (spontaneity) by constituting various forms of knowledge, using respectively visible or articulable elements or statements to reveal formed substances and finalised functions, which actualise, modify, and redistribute these relations. (Examples of forms of mathematical knowledge which function to give effect to differential power relations through teaching texts will be given in chapter 4.)

In asserting that modernity is linked with power in being primarily a matter of administration of life, including realisation of the demand for fulfilment, Foucault challenges Weber's conception of modernity as the evolution of a rational but depersonalised system of bureaucracy with its alienating instrumental rationality (McHoul & Grace, 1993). Foucault sees four methods for exercising disciplinary power over society, through: (a) spatial distribution — mostly enclosure, but also partitioning; for example in schools and factories; (b) control over activities through extracting 'time;' for example intensifying the use of bodily movements in the workplace (e.g., Taylorism); (c) organisation of segments or stages of training, through pedagogical practices, arranged hierarchically and codified, to monitor progress and to differentiate or individualise people; and (d) a co-ordination of all elementary parts of training in order to achieve the integration of the human body into a more general 'machinery.' According to McHoul and Grace, Foucault's conception of an institution was of opposing, agentic forces rather than excessively functional or anonymous — as argued by critics. Thus Foucault links training with techniques of power; certain forms of knowledge are developed according to norms, and the instruments and procedures needed to harness the accumulation of knowledge involve some form of unequal intercourse between participants such as surveillance or normalising judgements. Discipline can also be practised upon populations through interventions, or other regulation of aspects of life.

In his work on *technologies of the self,* Foucault (1988) analyses human sciences including economics as specific 'truth games' related to the specific techniques that humans use to understand themselves. He identifies four major types of technologies, each of which he claims is a matrix of practical reason, and which hardly ever function separately. "Each implies certain modes of training and modification of individuals, not only in the sense of acquiring certain skills but also in the sense of acquiring certain attitudes" (p. 18). They are:

> (1) technologies of production, which permit us to produce, transform, or manipulate things; (2) technologies of sign systems, which permit us to use signs, meanings, symbols, or signification; (3) technologies of power, which determine the conduct of individuals and submit them to certain ends or domination, an objectivizing of the subject; (4) technologies of the self, which permit individuals to effect by their own means or with the help of others a certain number of operations on their own bodies and souls, thoughts, conduct, and way of being, so as to transform themselves .... (p. 18)

This government of the self allies itself with the practices used in the government of others, and is termed by Foucault as *governmentality*.

Foucault's work, in its linking of power, knowledge, and discourse with special focus on social sciences, has been used by many writers in their theorisations of the Australian VET sector, from the perspective of truth games (e.g., Dwyer, 1995; McIntyre & Solomon, 1998, 1999) and discipline through technologies of the self (e.g., Butler, 2001). As discussed in chapter 6, the rhetoric on lifelong learning (ANTA, 1999, n.d.-b; DfEE, 1998a, 1998b, 1999) could well be linked to technologies of the self, in its message of self-discipline and self-fulfilment through further education.

Although Foucault paid relatively less attention to the natural sciences including mathematics, his work on discourse analysis has been utilised by Maggie McBride (1989), to look at discursive practices, rules, and roles in mathematics education with respect to textbooks, teaching methods or styles, examination processes, and the use of space in the university classroom. Margaret Walshaw (1999) also draws upon Foucault's philosophy to critique self-understandings of mathematics teachers. A Foucauldian analysis of the disciplinary structures of space, time, training organisation, and institutional control could be pertinent to adult learners and mathematics curriculum and teaching; the work of Thomas Popkewitz (1988, 1997), for example, has clearly been influenced by Foucault.

Foucault's depiction of power relations as immanent in society, often state-controlled but not state-generated, presents one means of conceptualising the institutions of vocational education and training and of mathematics education in schools, but not necessarily the more strongly hierarchical discipline of mathematics itself. Following a Foucauldian line, although power in the Australian VET sector appears to be overtly top-down it is actually constituted by the technologies of the self in the self-discipline which arises from the surveillance techniques such as competency-based training (CBT), ISO, and other quality control measures to which VET teachers must submit.

Foucault's theorisations of local popular knowledges and unruly subjects have been taken up by writers concerned with workplace education in general. They may well be pertinent to the sites of 'resistance' — which Foucault claims are more effective when directed at a technique of power rather than power in general. As discussed in chapter 2, there are mathematics educators/researchers who struggle to have workers' mathematical knowledges valued. Official mathematical knowledges in the Australian VET sector may be seen to have a normalising effect, and to reinforce the subjection of people who are likely (but not necessarily) to be positioned as relatively powerless upon entry to the sector.

In summary, there is much that a Foucauldian analysis could offer in terms of linking power, knowledge, and discourse with respect to mathematics, mathematics education, and the Australian VET sector, but there is a certain fragmentation. Foucault's generic conception of institution as an instrument of power rather than a source makes it difficult to theorise the three substantively different but imbricated entities of mathematics, mathematics education, and vocational education and training under the one framework. A more integrative framework is needed. This can be found in the work of Basil Bernstein which presents a unifying but complex theoretical framework.

3.2. BERNSTEIN'S MODELS OF SYMBOLIC CONTROL, PEDAGOGY, AND IDENTITY

The remainder of this chapter presents a complex theoretical framework which some readers may find unnecessarily confusing and abstruse. It may be omitted without loss of flow of arguments. The main ideas will be summarised in chapter 5.

The work of Basil Bernstein (1996) appears to offer a coherent set of principles for linking the institutions of mathematics and vocational education. It systematically encompasses and connects different contexts of experience and different levels of regulation (Bernstein & Solomon, 1999). Although Bernstein acknowledges the importance of political implications, these are secondary to his work on the "long process of understanding and describing agencies, contexts and practices through which we are both constructed and constructing ourselves and others" (Bernstein & Solomon, 1999, p. 275).

Bernstein's work which, according to Solomon (Bernstein & Solomon, 1999, p. 278), sets the basis for "new theoretical and empirical work on contemporary powerful agencies and practices of control and regulation" arising out of recent changes in technology, the economy, and culture, linked with the growing interest in 'training', appears to provide a foundation for the analysis of mathematics provision in the Australian VET sector. The analyses will range from the macro-, institutional level of knowledge production and distribution in mathematics, mathematics education, and vocational education and training, through the meso-level of knowledge recontextualisation for transmission, to the micro-level of knowledge reproduction at the classroom/worksite level.

Bernstein (Bernstein & Solomon, 1999) acknowledges Foucault's work on technologies of normalisation, discipline, and the construction of the subject in relation to identity formation. However he claims to provide a more dynamic theory in relation to the struggle for appropriation, design and distribution of these technologies as well as the conditions for change.

The work of Bernstein on institutions, pedagogics, and the formation of identities offers a powerful framework for substantial analysis of the case study within this monograph. It is necessarily very complex — made more so by overlapping uses of some terminologies. The following subsection begins to address these with two important concepts at the macro- or institutional level.

3.3. CLASSIFICATION AND FRAMING

In this section I will outline a theoretical framework for the macro level technologies of power acting through institutional texts — in this case upon mathematics education in the Australian VET sector; other sections will address meso and micro levels (the recontextualising field and recontextualising texts). Clearly these are interrelated and the distinction is for analytic purposes only.

Bernstein (1996) distinguishes the concept of *power* — as establishing legitimate boundaries *between* forms of interaction — from the concept of *control* — as establishing legitimate boundaries *within* forms of interaction. In his interpretation the term *classification* is then used to examine the relations of power, which he claims are arbitrary, between categories — be they agencies, agents, discourses, or practices — which construct the nature of the social space in the form of stratifications, distributions, and locations. The strength of a power relation is related to the degree of insulation from less specialised forms of knowledge, and is indicated by uniqueness of discourse, identity, and voice, together with specialised rules. Chapter 6 will argue that there is a weakening classification of mathematical knowledge in the Australian VET sector. This argument is supported by the virtual disappearance of mathematics curricula, combined with the lack of career pathways for recognised TAFE mathematics teachers — as illustrated in chapter 4, the Australian case study.

Bernstein (1996) uses the term *framing* to examine means of control over communication in local, interactional, pedagogic relations. He interprets framing as a means of regulating the realisation rules for the production of discourse, as a means of acquiring the legitimate message, of *how* (compared to *what,* in classification) meanings are made, their forms and social relations. It is related to the internal logic of pedagogical practice, in terms of control over the selection, sequencing, pacing and criteria of communication, and control over the social base which makes this possible. Bernstein distinguishes analytically two systems of rules regulated by framing. The first is the *Regulative Discourse* which establishes the social order in terms of the forms hierarchical relations may take and expectations about conduct, character, and manner; implying a potential for labelling the acquirer of knowledge. The second is the *Instructional Discourse,* which establishes the discursive order in terms of the selection, sequencing, pacing and criteria of knowledge. The instructional discourse is always embedded in the regulative discourse. According to Bernstein, strong framing leads to visible pedagogic practice, while weak framing leads to invisible pedagogic practice where both regulative and instructional discourses are implicit, largely unknown to the acquirer, and are associated with 'progressive' education (see, for example, Ernest, 1991).

Bernstein (1996) notes that classification can have internal value (e.g., dress, posture, position) and may refer to the arrangement of space and the objects within it (e.g., seating, images, tasks). On the other hand, framing can have external value in the form of controls on communication outside the pedagogic practice entering it, based on the classification between others' knowledge (i.e., official discourse) and the otherness of knowledge (i.e., local pedagogic practice). Together classification and framing provide the rules of the *pedagogic code* (i.e., practice but not discourse), but there is always a struggle over the nature of symbolic control, according to Bernstein. They act selectively on what Bernstein terms the *Recognition Rule* — which enables the appropriate realisations of what meanings are relevant to be put together — and the *Realisation Rule* — which determines how meanings are put together and made public, in order to produce legitimate text. Text, in Bernstein's interpretation, is anything which attracts evaluation, and there can be a dynamic relation between text and interactional practice.

Discussing pedagogic codes and their modalities of practice, Bernstein (1996) distinguishes between discourses as singulars and discourses as regions. Those which are singulars are only about themselves, with very few external references, and create the field of the production of knowledge. Bernstein's description resonates with the *Mode 1* typology of knowledge production of Gibbons et al. (1994), as a disciplinary, homogeneous model where "problems are set and solved within a context governed by the, largely academic, interests of a specific community" (p. 3). The discipline of (pure) mathematics appears to fall within this classification; hierarchical, with strong external boundaries (see chapter 1; see also Buckingham, 1999; Davis & Hersh, 1980/1983; Kline, 1980, 1987). On the other hand, Bernstein describes regions as those discourses where there is an implication of the recontextualising of singulars and an interface between fields of knowledge production and practice; he claims that this in an index of the technologising of knowledge. Classification is weaker here, and resonant with Gibbons et al.'s *Mode 2* form of knowledge production, a heterogeneous, transdisciplinary model where problems are defined and solved collaboratively in specific and localised contexts. The field of education, in particular mathematics education (including adult and vocational education subfields), appears to come under this weaker discursive classification — as do many other professional fields, although strengths of classification will undoubtedly vary within each.

At the level of the educational institution, Bernstein distinguishes between classifications. Strong classification can exist with respect to external knowledge with a special quality of otherness. That is, there is a hierarchy of knowledge between so-called common sense and its opposite. In the case of the educational institution of the VET sector, as described in chapters 4, 5, and 6, there appears to be an ever weakening classification of knowledge. For example the introduction of the concept of *Recognition of Prior Learning* (Vocational Education, Employment and Training Advisory Committee [VEETAC], 1993) could be seen as a determined effort to break down the boundaries or the insulation of formal, institute-based knowledge by giving recognition to knowledges and skills acquired on-the-job or through other life experiences (see, for example, Hager, 1998).

3.4. MODELS OF COMPETENCE

Bernstein poses the question: In whose interests are these changes in classification taking place? As suggested in chapters 4, 5, and 6, it is neither teachers' nor students'; rather it appears to be the members of dominant social groups such as neoliberalist governments and their business and industry supporters. One of the most powerful means of establishing stronger central control, steered at a distance, over the VET sector has been the implementation of competency-based education and training (CBT). This has not been unproblematic yet it remains entrenched after a decade in Australia and other English-speaking countries. (See chapter 5 for further discussion.)

Bernstein addresses the concept of *competence* as part of his theorisation on pedagogising knowledge. According to him, this concept evolved and passed through the major social sciences in the 1960s and 1970s. In his analysis competences are intrinsically creative, and tacitly acquired in informal interactions. Their acquisition, but not their forms of realisation, in practical accomplishments are beyond the reach of power relations. In this sense their constitution may be regarded as social, but independent of any particular culture. Bernstein summarises the features of the social logic of competence theories as having an inbuilt procedural democracy, creativity, and virtuous self-regulation. Even if not inbuilt, he claims that "the procedures arise out of, and contribute to social practice, with a creative potential" (p. 56). However he cautions that this idealism/celebration is bought at a price: the abstraction of the individual "from the analysis of distributions of power and principles of control which selectively specialize modes of acquisition and realizations" (p. 56). The concept of competence resonates with liberal, progressive, and even radical ideologies. Bernstein also makes the observation that early competence theorists (e.g., Chomsky, Hymes, Garfinkle, Lévi-Strauss, Piaget) had little or no concern for education; there were even oppositional epistemological roots, probably united by anti-positivist sentiments.

In a manual on developing competency-based curriculum modules, Porter (1993) elaborates the official Australian rhetoric on CBT as follows:

> Competency standards set down the knowledge, skills and behaviour required to perform jobs. They are comprehensive descriptions of what a person needs to know and do to be considered a competent worker in a job or position. They describe how well and under what range of conditions a competent person should be able to perform the roles and functions of a job, and the criteria against which their performance of these competencies can be assessed.

> A competency based curriculum is a curriculum based on competency standards developed by industry, and enterprise or the community. It specifies the expected learning outcomes, the assessment criteria for those learning outcomes, the knowledge, skills and behaviours to be developed, and the methods and strategies for assessment of the learners' achievements, (p. iii)

These quotations illustrate 'procedural democracy' in terms of openness, but only at a superficial level. As will be illustrated in chapter 4, there are silences not only about the knowledge workers actually possess; also about understanding and critique of power relations in the workplace.

'Virtuous self-regulation' is apparent not only as a projected outcome for students but also for the very curriculum developers who are the specific audience for this text. The manual is true to its own principles in that the following pages, addressed to the "TAFE teachers and consultants who complete this program," are complete with one Program Outcome, seven Learning Outcomes (expressed in behaviourist language), and headings stating the Purpose, the Relationship to Standards, the Entry Competencies and/or Prerequisite Programs, Concurrent and Complementary Programs, and Recognition of Prior Learning. Not only does this rhetoric 'abstract the individual' (both curriculum developer and student) as Bernstein predicts, but they also limit any creativity beyond the selection of exemplars (in the case of curriculum developers) within the tight constraints of CBT. Mulcahy (1996) gives a cogent example of the dilemma confronting hospitality teachers between the demands of CBT and the creativity required in the making of polenta. What dilemmas in the realm of creativity (e.g., Polya, 1957) face vocational mathematics teachers?

The discussion up to this point has been concerned with the macro level of institutional discourse. I now wish to use the work of Bernstein (Bernstein & Solomon, 1999) more specifically with regard to pedagogic relations, which he claims shape pedagogic communications, and may be distinguished as explicit, implicit, or tacit by the visibility of the transmitter's purposeful intentions toward the acquirer. Whereas explicit pedagogy is highly visible to both parties, implicit pedagogy signifies an invisibility of intention to the acquirer, and tacit pedagogy implies that neither may be aware. Pedagogic communication may occur formally or informally, with or without request (e.g. via the mass media); but pedagogic acts are distinguished by information being specifically recontextualised in order to meet the needs of the requester, indicating the specific and limited nature of the pedagogic relation.

3.4.1. Competence and Performance Pedagogic Models

By producing two contrasting general models of practice and context, *competence* and *performance* models, Bernstein (1996) shows how recontextualised 'competence' constructs a specific pedagogic practice. The performance model "places emphasis upon a specific output of the acquirer, upon a particular text the acquirer is expected to construct, and upon the specialized skills necessary to the production of this specific output, text or product" (pp. 57-58). In his broad differentiation between models, Bernstein refers to six features of recontextualised knowledge which both models share: (a) categories of discourse, space, and time; (b) pedagogic orientation and evaluation; (c) pedagogic control; (d) pedagogic text; (e) pedagogic autonomy; and (f) pedagogic economy. Bernstein's analysis is focused essentially on early learning but my intention is to relate his analysis to the discourses of vocational education and training and of mathematics as it is realised through the conservative mathematics education which appears to prevail in the Australian VET sector. The following is drawn from Bernstein's elaboration, contrasting these six features as more or less dichotomous between competence and performance models. I suggest that the competence model has much in common with the institutional discourses of vocational education and training and the performance model with the institutional discourses of mathematics education. The subsequent section will address some implications of such an alignment at the institutional level.

First, the categories of discourse, space, and time are weakly classified under the competence model and strongly classified under the performance model. With respect to the category of discourse, each of the following qualities is a feature of the performance model but not the competence model: specialisation of subjects, skills, and procedures; explicitness of recognition, and realisation rules; lack of control over (content) selection; grading and stratification. With respect to the category of space, similar distinctions can be made for the clear marking and explicit regulation of pedagogic spaces as well as restricted access to and movement within facilitating sites (e.g., workplace, classroom) under the performance model, although local sites may be clearly bounded under the competence model. In addition to the characteristics associated with space, time is differentiated insofar as the present tense is the temporal modality in competence models, with weak and implicit sequencing and pacing, based upon the needs of the acquirer. Relative to competence models, performance models emphasise the future.

Second, concerning the category of pedagogic evaluation, competence models emphasise what is present in the acquirer's product; although the criteria expressed through the instructional discourse are likely to be implicit and diffuse, those of the regulative discourse are more likely to be explicit. By contrast the performance model emphasises what is absent in the acquirer's product, with criteria explicit and specific so that the acquirer is made aware of how to recognise and realise the legitimate text.

Third, the category of pedagogic control is intrinsically related to the preceding categories. Thus, under the competence model positional control is a low priority strategy. In any case such control militates against the notion of the acquirer as self-regulating and the transmitter as facilitator. Control, then, is likely to operate at the individual level and to be realised "in forms of communication which focus upon the intentions, dispositions, relations and reflexivity of the acquirer" (Bernstein, 1996, p. 60). Positional and imperative control modes may occur, but are less favoured. The performance model uses and in turn legitimises the structures and classifications of the previous categories as constituting and relaying order. "The mode of the instructional discourse itself embeds acquirers in a disciplining regulation where deviance is highly visible" (p. 60). Personalised modes of control are less favoured in the economy of performance models with their highly explicit rules.

Fourth, with regard to the category of pedagogic text, in the competence model its production represents something other than itself, revealing the acquirer's cognitive, affective and social development. Judgement rests with the teacher's professionalism, recontextualised from elsewhere, not able to be made totally explicit — if at all in the early years and not necessarily in the VET sector, especially in the case of skilled trades. While the present is continuously visible, the future is known only to the teacher (and/or employer in the case of the VET sector). In the performance model, however, the pedagogic text is the acquirer's production/performance, objectified by grades. "The professionalism of the teacher inheres in the explicit pedagogic practice and in the grading procedures" (p. 61). Grading gives rise to potential diagnosis and remediation, and distribution of blame. Although the future is made visible, it is constructed from a past invisible to the acquirer, based upon rituals which have produced the instructional discourse and which position the acquirer invisibly in the past. Mathematics education, in the Australian VET sector at least, appears more clearly aligned with the latter model.

Bernstein's fifth category of pedagogic autonomy is particularly complex to interpret within the central concerns of this monograph: vocational education and training and 'progressive' education have many similarities but also differences. According to Bernstein, competence models require a large degree of autonomy. However, the autonomy of teachers regarding their pedagogical practice may be reduced due to the necessity of conforming with the required homogeneity of practice (as is the case with the hegemony of CBT). At the same time any particular context and practice will require a degree of autonomy in order to meet the particular needs of the acquirer. According to Bernstein's theory, resources in the form of textbooks and teaching routines are less likely to be pre-packaged, although the trend in Australia's VET sector is towards self-paced learning supported by and embodied within a module production industry — print-based, audio, video, CD-ROM, on-line, and so forth. Perhaps autonomy lies in the acquirer's and facilitator's selection of available resources. Bernstein also suggests that competence models are relatively less open to public scrutiny and accountability relative to performance models as their products are more difficult to evaluate objectively — although this would be hotly contested according to the rhetoric of certain interest groups promoting CBT. Finally he claims that they are less dependent on specialised futures and less regulated. With regard to performance models Bernstein distinguishes between what he calls *introverted* modalities, where the future is the exploration of the specialised discourse itself (as in the case of higher mathematics), and *extroverted* modalities, where the future is likely to be dependent upon external regulation such as the economy (as would be the case for mathematics applied to other areas). In spite of, or perhaps because of, their autonomy of discourse, introverted modalities in particular strongly regulate curriculum selection, sequence, pacing, and criteria of transmission; extroverted modalities may have more flexibility over financial and discursive resources and hence less regulation.

In the final category of pedagogic economy, Bernstein proposes that competence models attract higher costs in terms of specialised teacher training and stricter student selection processes. This is definitely not the case for the Australian VET sector. However, his identification of the hidden costs of teacher time in planning, monitoring, networking, constructing resources, and providing feedback on the acquirer's performance, and so on, is most appropriate. In addition he recognises that these hidden costs are rarely explicitly recognised, and may lead to ineffective pedagogic practice caused by excessive demands on the practice and hence the fatigue of teachers. Applying complementary logic to the performance models (which appear to be confounded in this case with the Australian VET sector competence model), Bernstein claims that costs are less; teachers in training need a less elaborated theoretical base and the explicitness of transmission, facilitated by packages and algorithms, reduces restrictions on supply of teachers. Accountability is supposedly facilitated by 'objectivity' and outputs are measured and 'optimised.' Thus Bernstein's (1996, p. 63) claim that: "In general, performance models are more susceptible to external control and to the economies of such control" is not entirely appropriate. However, in the performance model hidden costs are considerably reduced because of the explicit structures of transmission and progression. He concludes with a comment on the importance of the teacher's commitment, motivation and personal attributes within each of the particular models.

3.4.2. Implications for Vocational Mathematics Education

It could be argued that Bernstein's competence model applies in large part to the institutional discourse and pedagogic practice of the Australian VET sector as will be described in chapters 4, 5, and 6, while his performance model applies largely to the discourse and traditional pedagogic practice of mathematics education as described in chapter 1. I suggest that this divergence of models of recontextualised knowledge offers a significant explanation for the rupture between the two institutional discourses, those of vocational education and training and of mathematics, as played out in the day-to-day experiences of VET mathematics teachers and learners whose institutional history is grounded in performance models but who must now operate under the dominant competence model with its restrictions on curriculum, teaching, and assessment. This dominance of weak discursive and locational classification, implicit pedagogic codes, and high autonomy for the acquirer (not infrequently, vicariously meeting the needs of the employer rather than the student) also provides a possible explanation for the ever-dwindling curricular content of explicit mathematics subjects or components, for the dearth of discipline-based professional development for VET mathematics teachers, and the near total absence of research into mathematics teaching and learning. (Of course mathematics is not alone in this situation; its trajectory is closely matched by that of communication skills, and to a lesser extent all other subjects weighted towards theory rather than practice.) It must also be taken into account that there is an increasing tendency towards the deskilling and de-professionalisation of VET teaching staff as they come to be replaced by lower cost education workers and industry-based trainers whose main occupation is other than teaching — and who might be considered to be more compliant with bureaucratic changes to pedagogy.

Having looked at institutional discourses at the macro level as well as general pedagogical models, I now turn to the meso level of what Bernstein (1996) terms *the recontextualising field,* although he subsequently adopted the metaphor of *arena* in preference to field (Bernstein & Solomon, 1999).

3.5. THE RECONTEXTUALISING FIELD

According to Bernstein (Bernstein & Solomon, 1999):

> . . . pedagogic modalities are crucial realisations of symbolic control, and thus of the process of cultural production and reproduction. Symbolic control, through its pedagogic modalities, attempts to shape and distribute forms of consciousness, identity and desire. (p. 269)

He distinguishes between official and local modalities, where the former give rise to institutional forms of regulation while the latter operate in less formal contexts. In particular, he notes the potential for "colonising/complementary/conflicting, privileging/marginalising relations" (p. 269) between the two modalities.

In Bernstein's (1996) theorisation, control over pedagogic modalities and transmission is contested: the activities of the *Official Recontextualising Field* (ORF), representing the interests of the state regulate to varying degrees the activities of the *Pedagogic Recontextualising Field* (PRF), representing the interests of practitioners and teacher educators. Legislative changes enacting educational reform may be organisational or curricular — with only the latter directly affecting pedagogic discourse. However changes in organisation may open up or close off spaces for appropriation by the Pedagogic Recontextualising Field.

In the Australian VET sector, as elsewhere, new discourses of economic rationalism and managerialism in the Official Recontextualising Field have weakened the autonomy of the Pedagogic Recontextualising Field particularly, but not only, through the curriculum and assessment regulatory mechanism of CBT. At the same time, the organisational changes allowing the deregulation of entry-level educational qualifications for VET teaching staff have further eroded the professionalism of existing staff, with consequent impact on morale.

Within both competence and performance models Bernstein (1996) further differentiates three distinct *modes;* within the Pedagogic Recontextualising Field there can be oppositions among each of the various modalities.

3.5.1. Competence Modes of the Recontextualising Field

Bernstein's three competence modes, located in the field of symbolic control, are predicated upon 'similar to' relations, emphasising differences between acquirers rather than stratification and deficit.

The first is the *liberal/progressive* mode, where relations are located within the individual. Associated with the development of consciousness, it was developed, sponsored and institutionalised in schools by the new middle-class of the 1970s in the UK, Australia, and elsewhere. (These progressive connotations helped CBT to gain initial credibility among certain groups.)

The second is the *populist* mode, where relations are located within the local culture (e.g., class, ethnic group, region). Associated with the recognition of consciousness, the validity of communicative competences is intrinsic to a local, usually dominated, culture. It presupposes an opposition between official and local pedagogic practice and contexts; a silencing of the latter by the former. Its sponsors attempt to show the ignoring or repression by members of official pedagogic fields. Relevant examples here are ethnomathematics and the unofficial workplace discourses, as discussed in chapter 2.

The third is the *radical* mode, related to the second, but focused upon inter-class/group opportunities, material and symbolic, to redress objective dominated positioning. It is associated with a change of consciousness, and presupposes an emancipatory potential in pedagogic practices and contexts, actualised by members' own exploration of the source of their imposed powerlessness. This mode is often found in informal adult education, and connected with the work of Freire (see Coben, 2000b). It is notably absent from the ORF and its presence in the PRF depends upon the autonomy of that field.

3.5.2. Performance Modes of the Recontextualising Field

According to Bernstein (1996) performance modes are located in both economic and symbolic control fields. Based on 'different from' relations, they are empirically normal across all levels of official education. Importantly, Bernstein notes that competence modes "may be seen as interrupts or resistances to this normality or may be appropriated by official education for specific and local purposes" (p. 65).

The first mode, described by Bernstein as *singulars* (see subsection on institutional classification above), has its "own specialized discrete discourse with its own intellectual field of texts, practices, rules of entry, examinations, licenses to practice, distribution of rewards and punishments" (p. 65). Singulars are protected by strong boundaries and hierarchies. They have an ambiguous identity construction; sometimes autonomous, sometimes introjected. This mode may be related to the discussion of the institution of mathematics in chapter 1.

Describing the second mode as *regions* constructed by the recontextualisation of singulars, Bernstein notes that they are the interface between disciplines and the technologies they make possible. The shift to modular format of educational courses weakens the autonomy of the discursive and the political base of singulars, and facilitates changes in the organisational structure of institutions towards greater central administrative control. Their greater autonomy over content helps them to be "more responsive to, more dependent upon, the market their output is serving" (p. 66). With the weakening of strength of classification of discourses, identity construction has shifted from introjected to projected; towards greater external dependency. Bernstein notes that while school education is firmly based in singulars, higher education is moving towards regionalisation. This mode may be related to the discussion of de-institutionalisation in chapter 6.

Bernstein (1996) indicates that the third performance mode in the recontextualising field, *generic,* is a recent construction with complex identity. It has four distinguishing features: (a) the recontextualising location, (b) the focus, (c) the location, and (d) misrecognition. "Generic modes are constructed and distributed outside, and independently of, pedagogic recontextualising fields" (p. 66). In the UK Bernstein claims that they originated with the Manpower Services Commission (see also Williams & Raggatt, 1998), and the distinctive 'competences' methodology was realised through the use of functional analysis (see also Blackmore, 1999). Their focus is essentially directed to extra-school experiences of 'work' and 'life.' These modes are predominantly, but not exclusively, located in the Further Education sector in the UK, and in the VET sector in Australia. Produced by "a functional analysis of what is taken to be the underlying features necessary to the performance of a skill, task or even an area of work" (p. 67), in appropriating resonances of the competence model they silence the cultural basis from which they were derived, "and give rise to a jejune concept of trainability" (p. 67). Bernstein concludes that the generic performance modes share fundamental features with competence models, that is 'similar to' relations, but not with respect to their common humanity, culture, or position and opposition. Instead they specify a set of general skills underlying a range of specific performances. They are directly linked to the instrumentalities of the market, to the construction of what are considered to be flexible performances. Despite their superficial resemblance to competence models, their identity is constructed by processes of projection, according to Bernstein.

Finally, Bernstein notes that the preceding models and modes are not necessarily discrete nor distinct in practice. Various insertions of modes may give rise to opposing practices. In the case of mathematics education there is an opposition between the singular-mode performance model and selection from the field of discourse production theories of learning of the behaviourist type, atomistic in their emphasis — now commonly associated with the recently constructed generic mode, prevalent in the VET sector. In the 1970s school mathematics instruction programmes, in the USA and Australia at least, were heavily influenced by behaviourist advocates such as Gagné. However in the 1990s mathematics instruction in schools moved on to be influenced to some extent by the rhetoric of problem-solving, constructivist, and ethnomathematics intellectual movements — an insertion of the liberal/progressive and/or populist modes of the competence model. Australian school textbooks now include focus statements, outcome checklists, key competency-related extension work (often on CD-ROM), blackline masters, and test banks — another swing back to the performance model, but this time (re)inserting singular *and* generic modes. This last swing reflects an approach both more conservative and increasingly regulated by the (neoliberal) state, and illustrates the symbiotic relation between the ORF and the PRF. Similar insertions and oppositions may be found in the VET sector mathematics pedagogic discourse.

At the recontextualising level within the pedagogic field, Bernstein's (1996) work suggests that vocational education and training recontextualising and eventual reproduction might actually belong in the generic mode of the performance model, but that its construction might rely heavily on its appropriation of liberal/progressive and populist modes of the competence model — in the rhetoric of the ORF at least. Clearly radical modes, in their emancipatory potential offered by opportunities for understanding and critique leading to a change of consciousness, are eschewed. As will be demonstrated below, the ORF (e.g., ANTA, 1998c) posits relations of individualism and self-interest rather than those of shared goals for a common humanity (Stevenson, 1996), even if these may be subverted by individual practitioner members of the PRF within the space of their own classrooms.

In summary, within Bernstein's conceptualisations, areas of control have been contested by the Official and Pedagogic Recontextualising Fields (ORF & PRF). Bernstein identifies three modes within both competence and performance models: liberal/progressive, populist, and radical as modes of competence models; and singulars, regions, and generic as modes of performance models. Neither models nor modes are necessarily discrete nor distinct in practice, and this is exemplified in the case of mathematics education in the Australian VET sector which inserts elements of several modes, drawn from both models, into the texts for teachers and students. These texts necessarily impact upon the identity formation of both groups.

3.6. RECONTEXTUALISING TEXTS

The nexus between the recontextualising field and the formation of identities is made, in part, through recontextualising texts. In this section I will focus at the sociocultural level on texts for teachers and students, as an example of the didactical transposition (Brousseau, 1997), emanating from the project which produced the National Vocational Mathematics Curriculum Framework (ACTRAC, 1993). To provide a theoretical basis I turn to Bernstein's (1996) work on codes and content.

3.6.1. The Concept of Code

Bernstein (1996, p. 111) defines code as "a regulative principle, tacitly acquired, which selects and integrates relevant meanings, their form of realization and evoking contexts." However the pedagogic discourse itself is contingent upon the activities within the pedagogic arenas (or fields). Relevant meanings (or Recognition rules) arise from institutional discourses, translated from the classification principles of power. Forms of realization (or Realization rules) arise from transmission discourses, translated from the framing principles of control. Evoking contexts arise from organisational discourses, translated from both classification and framing principles whose values may each be strong or weak. Bernstein (Bernstein & Solomon, 1999) stresses that the rules are not the codes but the resources for the codes, realised differentially. "Thus, codes transform distributions of power and principles of control into pedagogic communication" (p. 270).

In earlier work Bernstein generated two basic principles of pedagogic practice: *visible* and *invisible*, sponsored by what he termed different fractions of the middle class. One fraction, located in the field of production, carry out functions directly related to the economic base (circulation and exchange) and dominate production codes. The other, located in the field of symbolic control, carry out specialised forms of communication (e.g., regulators, repairers, reproducers — as in education, shapers — as in research institutes, and executors — as in civil service, central and local government); and these could be said to control discursive codes. Both fractions could be located in either public or private sector, and both impact directly upon teaching and learning in vocational education.

According to Bernstein (1996), the process of recontextualisation entails the principle of *de-location,* that is the "selective appropriation of a discourse or part of a discourse from the field of production and a principle of *re-location* of that discourse as a discourse within the recontextualising field" (p. 116). Thus the original discourse undergoes an ideological transformation (see, for example, Kanes, 1999, who poses the question as to whether the mathematics teacher observed is actually teaching the discourse of mathematics). In Australia, as in the UK, over the last 25 years there has been an increase in state regulation in the three fields of production, recontextualising, and reproduction, and in state control over pedagogic discourse and its range of practices and contexts.

Bernstein emphasises the crucial distinction between what he called a *pedagogic device* — a symbolic ruler — and its various realisations in pedagogic discourses and practices. Symbolic control is materialised through this device, "which is the condition for the construction of pedagogic discourses" (Bernstein & Solomon, 1999, p. 269). I reproduce here his figure indicating the key relations of his model of the pedagogic device and its structurings.

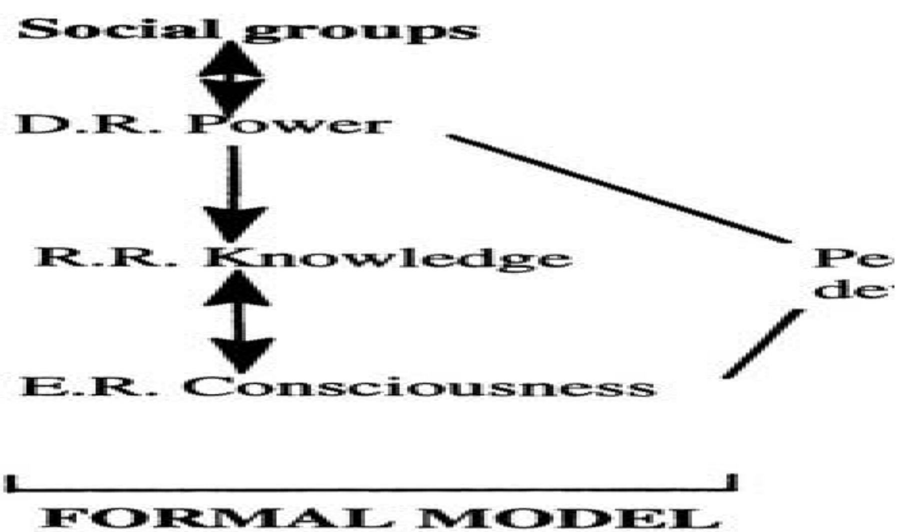

Figure 3.1. ***The key relations of the model of the pedagogic device (from Bernstein, 1996, p. 52). (reprinted by permission of Taylor & Francis)***

According to Bernstein, the grammar of this pedagogic device consists of three interrelated, hierarchically organised *Rules* which underlie the contexts for production and reproduction of pedagogic discourses.

1. Distributive rules: these provide different forms of knowledge or consciousness to different social groups; that is, access to the 'unthinkable' in the possibility of new knowledge, and the 'thinkable' in the form of official knowledge.
2. Recontextualising rules: these construct the 'thinkable' official knowledge; the 'what' and the 'how' of pedagogic discourse.
3. Evaluative rules: these provide the criteria to be transmitted and acquired through pedagogic practice.

Bernstein's distributive rules may be related to differences between forms of mathematical knowledge made available to students at university and those enrolled in the Australian VET sector. It is generally accepted that these enrolments are roughly classified along socio-economic lines (Ainley & Long, 1998; McIntyre, 2000). Although few university students seriously contemplate continuing their Mode 1 official mathematical studies into the 'unthinkable' territory of post-graduate study, there are likely to be others operating in Mode 2 using, and perhaps creating, mathematical knowledge in the pursuit of practical problem solving. By contrast, for vocational students Bernstein's recontextualising rules relating to the construction of official knowledge are well illustrated by the limiting structure of the Australian vocational mathematics framework of (eventually 94) permissible topics (ACTRAC, 1993) — the official mathematics knowledge for all vocational students, from whence binding selections were made, until curriculum no longer came to occupy a central position (see chapter 6). This official discourse would appear to preclude any possibility of entering into the unthinkable. This is not to say that workers at any level are incapable of solving novel problems; rather that they are more likely (as discussed in chapter 2) to use non-formal or even non-mathematical methods. As will be demonstrated below, official VET knowledge does not encourage mathematical creativity; in fact, just the opposite! The evaluative rules, which underlie the contexts for vocational mathematics knowledge reproduction and acquisition, are to be found within the overall regulatory framework of CBT. It constrains how mathematical knowledge may be recontextualised in textual forms, specifying curriculum and assessment (or at least guidelines) in the regulatory form of Learning Outcomes, with their atomised Elements, and Assessment Criteria. To this extent, within the selected topics from the mathematical knowledge framework and the organising principles of CBT, constraints are placed on how teachers evaluate that which has/has not been acquired — confounding competence and performance models.

Associated with each of his three Rules, Bernstein then formulates three *Fields,* contexts for knowledge production, recontextualising, and pedagogic practice:

1. Distributive rules: these specialise access to fields where the production of new knowledge may legitimately take place. After knowledge production has taken place outside the field, the field's principles will determine whether such knowledge is incorporated into the field.

2. Recontextualising rules: these regulate the work of specialists in the recontextualising field who construct the 'what' and 'how' of a pedagogic discourse. Pedagogic discourse is more a principle for appropriating discourses from the field of production and subordinating them to a different principle of organisation and relation; passing them through ideological screens. The recontextualising field always consists of an ORF, created and dominated by the state for construction and surveillance of state pedagogic discourse. It usually also includes a PRF, in the form of trainers of teachers, writers of textbooks, curriculum guides, and so forth. Both may struggle for control of the field, and even be in opposition.
3. Evaluative rules: these regulate pedagogic practice at the classroom level, defining standards which must be reached. They act selectively on the contents, form of transmission, and their distribution to different groups in different contexts.

In Bernstein's analysis of fields, it would appear that the field of production of new mathematical knowledge (in the absolute sense) is external to the VET sector. This is to be expected given the sector's charter for the initial preparation and ongoing professional development of workers (in paid employment or otherwise), as distinct from the basic research focus which forms part of the charter of universities. However the recontextualising rules proliferate in the VET sector. The ORF demands a CBT format which places considerable restrictions on the recontextualising field for vocational mathematics teachers, not to mention the organisational constraints associated with time and money. The PRF has been dominated in the last decade by an industry of curriculum workers — consultants, writers, institutional managers, and so forth (none of whom necessarily have an educational background), identifying, producing and guiding the production of texts compliant with the ORF under the aegis of ACTRAC Products (Ltd.) (e.g., Johnstone, 1993; Porter, 1993). ACTRAC has also produced trainers' guides (e.g., ACTRAC/NFITC, 1995), while teaching and learning text material has been variously prepared by industry groups, classroom teachers, and commercial publishers. Evaluative rules operate individually with each classroom or distance education site (e.g., online), within the teacher's interpretation of CBT curriculum and assessment procedures together with their professional knowledge of the discipline area situated within the particular vocational context, if one exists.

3.6.2. The Arbitrary Basis of Content

Bernstein (Bernstein & Solomon, 1999) acknowledges the work of Bourdieu, finding his concept of field "immensely valuable" (p. 269), although he expresses the need to make Bourdieu's concept of habitus (durable patterns of disposition) "more transparent with respect to the manner of its specialisation and thus formation" (p. 272). In a critique of the earlier work of Bourdieu, Bernstein (1996) suggests that, as part of legitimate sociological phenomena for analysis, the symbolic system should be included as well as the activity of the field. Bernstein sees his task, then, as to focus on procedures of reproduction and to expose the arbitrary nature of content within a field (cf., Ernest, 1991). To achieve this his analysis focuses upon "the positional features of the field, the specialized practices that serve to reproduce its structure, the habituses which give access to it and are responsible for the cycle of change of texts" (p. 170).

In contrast to what he claims are Bourdieu's oppositions between formal and practical mastery, Bernstein (1996) points to their similarities with respect to their distributive rules of knowledge and their social relations. He distinguishes between what he terms *horizontal* and *vertical* discourses. Horizontal discourse, typified as commonsense knowledge, has the characteristics of being: "local, segmental, context dependent, tacit, multi-layered, and often contradictory across contexts but not within contexts . . . [its objects of knowledge] are likely to be volatile and substitutable" (p. 170). They are not composed of an explicit, systematically organised set of principles, except in the groups' regulative discourse (cf., Onstenk, 1998, 1999, 2001a), but there are distributive rules which regulate access, acquisition, and potential as distinct from actual practice. These strategies are designed to maximise encounters between persons and habitat.

Bernstein's description of horizontal discourse resonates with research into workplaces as described in chapter 2. He notes that meanings derive from social positionings within and across segments. There may be common operations across segments (e.g., counting, estimating) but that this need not be the case. Discourses are acquired, often tacitly, through local activities, and contextual transfer may be through a process of intuitive analogic recognition. "Horizontal discourse is an outcome of a cultural specialization and its modes of acquisition and production are embedded in that specialization" (p. 172). Thus, pedagogic relations may vary across contexts (Bernstein & Solomon, 1999).

Vertical discourses have a coherent, explicit, systematically principled structure, and are hierarchically organised — the institution of mathematics is an example. Different from that of the horizontal discourse which Bernstein claims has context specificity through segmentation, in vertical discourse the social units are structured in time and space by principles of recontextualisation. In other words, both have a different but arbitrary base. Their origins and development are likely to be found in the official institutions of the state and the economy, and their realisations depend upon who has power over classification and control over framing (Bernstein & Solomon, 1999). Performance-model school contexts are an example of vertical discourse; they are not consumed by their context and are linked to other procedures, organised temporally, and gaining their significance from the future.

In this section I have used Bernstein's work to theorise examples, to be illustrated in chapter 4, of the values and assumptions inherent in the recontextualising field, and to indicate some of the silences concerning populist knowledge held by workers in the case of the pharmaceutical manufacturing industry. The Learning Outcomes and Assessment Criteria for *Calculations A,* detailed in chapter 4, also give an indication of the confounding of the competence model of CBT with the performance model of mathematics education.

3.7. CONCLUSION

Over the years I have struggled to find an explanation for what appears as the paradoxical situation of mathematics in the Australian VET sector. That is, to understand the situation of mathematics being considered as publicly important, particularly in a sector which is premised on supporting technological developments in the workplaces of the 21st century, while it is simultaneously devalued as a teaching subject in the sector, in terms of both curricular content and professional teaching capabilities. To seek greater understanding I sought to gain a more theoretical insight into the complementary role played by technologies of power in this sector. The work of Bernstein ultimately provided, for me, a unifying set of principles for the interrogation of institutions, pedagogics, and the formation of identities (teachers' and students') taken up in the chapters which follow. To encompass such a range, his theorisations are necessarily very complex. Rather than attempt to summarise them here, I present instead my own diagrammatic interpretation.

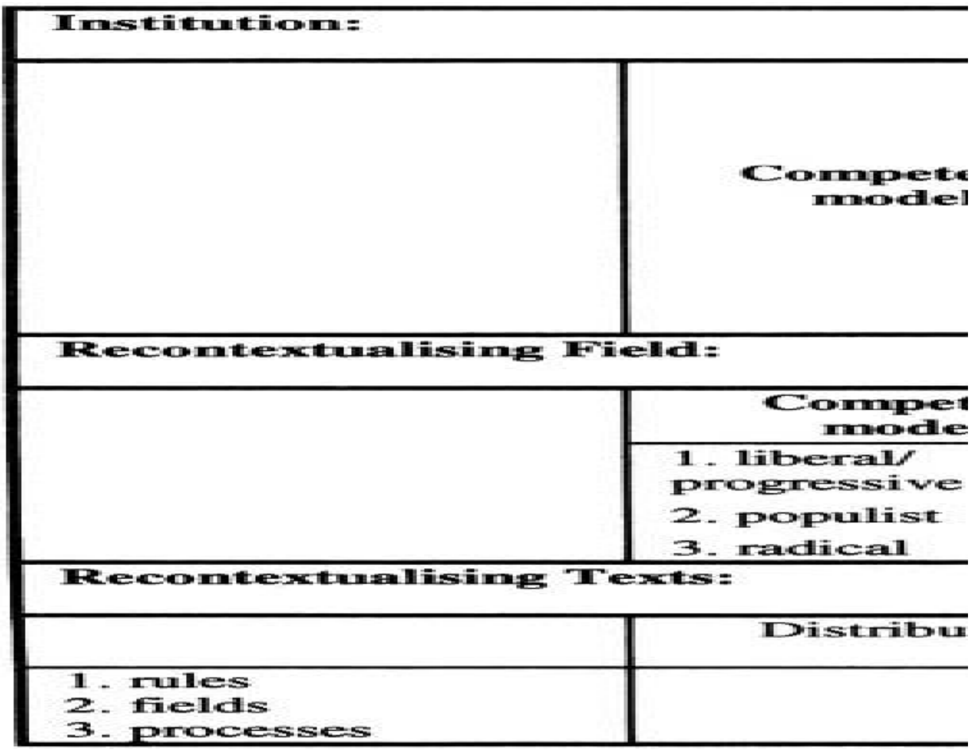

Fig. 3.2. *Diagrammatic summary of Bernstein's categorisations.*

In chapter 7, I revisit technologies of management with respect to public image in the Australian VET sector. This time I look for a way forward.

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CHAPTER 4

TECHNOLOGIES OF POWER: RECONTEXTUALISING TEXTS

An Australian Case Study

4.1. INTRODUCTION

In order to better appreciate and understand the current situation of mathematics curriculum and assessment, teaching and learning within vocational education in Australia, this chapter will briefly situate the monograph in its broad institutional setting. It will begin in the narrative mode with discussion of historical aspects of the development of the sector and the images which it conveys to the public and the education sector as a whole. This will be followed by an example of recontextualising texts (Bernstein, 1996). Here the analysis will focus on the reproduction and acquisition of mathematical knowledge, with consequent implications for students' and teachers' identities.

4.2. THE INSTITUTION OF VOCATIONAL EDUCATION AND TRAINING

In chapter 1, I discussed the institutions of mathematics and of mathematics education. Now I wish to shift the focus onto vocational education as a sector within the broader institution of education, as set in the Australian context. Discussing institutions such as education, Seddon, Angus, Brown, and Rushbrook (1998) assert that they are effects or outcomes of particular practices of organising which constitute contextual settings that shape behaviour and other social action — their regulatory norms constitute the social infrastructure as a social, discursive, and organisational medium. The impact of these regulatory norms will be in evidence throughout this chapter and the two which follow. Seddon et al. elaborate on the socialisation roles played by institution of education for the young and the (relatively) inexperienced in the transmission of the cultural heritage of society (see also Beach, 1999). They also draw on the work of William Connell in relation to the development of a collective capacity for learning and dealing with change. Vocational education, no less than school education, has a role to play in these developments. Seddon et al. also note the work of Claus Offe who observed that the outcomes generated by institutions both create and depend upon meanings, norms, and values in their production. In other words, cultural change cannot be brought about by administrative fiat alone; it may be resisted or contested by institutional actors. In the Australian VET sector it is the practitioners and their students who are the ultimate, albeit relatively powerless, decision-makers as they carry out their day-to-day tasks within the constraints and parameters set by their local managers, interpreted from conditions set by state and national bodies who are charged with operationalising policy deliberations of government. However, as Seddon et al. suggest, the efficacy of policy interventions is limited by their reduction of complexity and ignorance of significant social and cultural dimensions in economic discourse and rational actor theories.

In the Australian post-compulsory education sector (which includes both VET and higher education or university) the trajectories of change include the following trends: the growing role of government; the collapse of the youth labour market contributing to an increase in post-compulsory education participation rates by school leavers together with an associated rise of credentialism; and significant changes to work organisation in general. In the particular case of the VET sector, there have been changes to teachers' work and employment conditions associated in part with the declining status of teachers as professionals (see chapter 5) and in part with pervasive industrial reform agendas (see chapter 6). These trajectories shape and are shaped by changes to education and work embedded within changing social life, according to Seddon and Angus (1995), who observe that education is subjected to intensified pressures for change as it becomes repositioned globally and nationally. They claim that traditional arrangements are being problematised and the purposes of education redefined. For example, under the influence of neoliberal philosophies of government the cultural values associated with education are being reconceived in economic and vocational terms; self-management of the institution and the individual is being sought, and the investment in human capital has been reoriented from a social investment to self-investment. Government policies and interventions have been strategic to bringing about change.

4.2.1. A Brief History of Adult and Vocational Education

Vocational education and training has existed for as long as the novice, or newcomer, has sought to appropriate and even surpass the skills of the old-timer, to use Lave and Wenger's (1991) terminology. The practice of observation and imitation, often of an older family member, was formalised in concept of apprenticeship which has existed in Europe since the Middle Ages (Deissinger, 1994). Formalised institutional provision for adults originated in the 19th century with Mechanics Institutes in England. However, Copa and Bentley (1992) describe the institutional history of vocational education in the USA dating back to 1630. The 20th century saw the burgeoning of organised vocational education and training, in part because of rapidly changing skill requirements which could not be adequately met by the traditional apprenticeship system (Copa & Bentley, 1992; Williams & Raggatt, 1998). The purposes of vocational education for school children and adult learners alike appear to have been contested over its history (e.g., Copa & Bentley, 1992; Kangan, 1974/1979; Rushbrook, 1995; Stevenson, 1997). In addition there has been territorial contestation among sectors of education (discussed below), and within the Australian VET sector. In the following I will trace briefly the histories of the further education and vocational components; although the prime focus is on the latter. In policy terms there appears to be a convergence in both purpose and target population.

4.2.1.1. *Adult and community education in Australia.*

According to Des Fooks (1994), drawing on the work of Stephen Murray-Smith, the first Mechanics Institutes were set up in Australia within a few years of their establishment in London in 1823. Although they were not scientifically oriented, they provided the basis of genuine educational work. However, their usefulness diminished as they were overtaken by other historical developments in education (Senate Standing Committee on Employment, Education & Training, 1991).

Terri Seddon (1994a) observes that in the late 1980s students in the Adult Basic Education sector (as it was then known) began to be perceived as an untapped resource to aid in economic recovery. Education was now conceived of as a productive industry, aimed at preparing workers for the labour market. This shift in political gaze has resulted in the growth of the sector and radical changes to classroom experiences; there is now considerable overlap between adult and vocational education course structures.

In the past it was possible for adults returning to study mathematics to determine: (a) which content they wished to study, and for what length of time; (b) the manner of assessment (if any); (c) their level of participation in class; and (d) the use to which their mathematical knowledge was put. With increasing political interest in the adult education sector this is no longer the case, as funding mechanisms are closely tied to documented and audited performance statistics, based on prescriptive curricula. (See FitzSimons, 1997a, 2000d for further description of the impact of changes wrought upon mathematics teaching in the Adult, Community, and Further Education [ACFE] sector.

In 1993 the Certificates in General Education for Adults (CGEA) were introduced in Victoria, and re-accredited after review (ACFEB, 1996), as adult and vocational education moved into the competency-based training (CBT) era. (CBT will be discussed further in chapter 7.) There were five broad areas of mathematics content organised according to purpose. These were specified at three different levels of performance, and assessment had to be verified at moderation meetings. Although it could be argued that moderation meetings provide good professional development for beginning teachers, Peter Waterhouse (1995) describes the tensions in this process. These include experienced teachers feeling under threat in the meetings, as well as the restrictions to teaching practice which result directly from the imposition of such a regulatory framework.

But what has been the cost of these reforms? Whose interests have they served? From the students' perspective, the increasing levels of fees are certainly a disincentive to women returning to study, particularly as they often already experience a sense of guilt in doing something for themselves (FitzSimons, 1994b), aside from financial hardships often associated with limited initial schooling. The flow-on effect of lifelong education to children in such families cannot be quantified, and is therefore discounted by economic rationalists. Similar claims could be made for other groups identified as disadvantaged. (For further discussion of the issues associated with the technologising of equity through the identification of discrete target groups see Butler, 1998a.) Staff teaching in this sector remain less likely than others to have tenure, working as little as three- to six-month contracts for a few hours a week, year after year.

Increasing control and regulation of this sector of education have nevertheless brought some advantages. One is the recognition of qualifications gained by students; another is the serious attitude the sector has maintained towards professional development. In two states, Victoria and New South Wales, there has been extensive coverage for adult numeracy (Falk & Millar, 2001), especially necessary in view of the fact that many teachers of basic skills do not have strong mathematical backgrounds themselves. However, these are not mandatory, and uptake is patchy (D. Tout, personal communication, November, 2000).

4.2.1.2. *Technical education in Australia.*

Tracing the history of technical education in Australia, Gillian Goozee (1993) notes that

> although fulfilling a crucial role in providing post-secondary education and training for large numbers of people, [technical education] was consistently under-valued and under-resourced. The development of technical education has not been consistent but characterised by periods of rapid change followed by much longer periods of neglect. Thus, technical education has usually tended to prosper during times of national crises such as world wars and economic depressions. (p. 6)

According to Peter Kell (1994) the development of technical education has been shaped by working class ambitions for legitimation and institutionalisation of practices, demarcations and procedures, associated with political and economic struggles. It has experienced cycles of development in terms of financial support from governments and shifting educational emphases, from the narrowly instrumental to the broadly-based liberal (Kell, 1994; Rushbrook, 1995; Stevenson, 1995a; White, 1995). However there have been ongoing tensions between levels of government about jurisdiction. There have also been tensions between labour and capital over access to and responsibility for training, with evidence of restricted entry to trades along gender and race lines (Kell, 1994; Rushbrook, 1995).

The second half of the 19th century saw the beginning of a system of technical education for adults in Victoria: Abbott and Doucouliagos (1999) provide an historical review of the evolution of agricultural, mines, and 'Working Men's' colleges, as well as the establishment of junior technical schools. According to Kell (1994), prior to World War II the vocational education system across Australia was fragmented, and organised around awards and agreements with specific industries in an inconsistent and ad hoc manner. After 1945 the post-war shortage of labour was partly addressed by immigration policies, but it was not until the release of the Australian Committee on Technical and Further Education [ACOTAFE] (1974)

'Kangan' report that vocational education was established as an entity in its own right — coming to be known as the TAFE sector.

Over the last decade or so, the institutionally-oriented TAFE sector has been re-constructed — incorporated into the newly created VET sector (see chapter 6) — to accommodate formal learning which occurs at other sites (such as workplaces or community settings), often under the tutelage of private providers. The Australian Qualifications Framework (AQF) now encompasses occupational levels ranging from operators, through tradespersons and technicians, to paraprofessionals. Other terms for qualifications more familiar to European readers might be: *craft* (for trade and equivalent); *master-craft* (for post-trade supervisory type); and *technician* (for technicians and paraprofessionals) (Maglen & Hopkins, 1998).

There is a blurring of the boundaries at the upper levels where some vocational qualifications are recognised by universities. Even the term 'vocational education and training' is contested, as illustrated by one academic who included within its realm his university's provision "law, medicine, dentistry, optometry, veterinary science and pharmacy" (Maglen, 1996, p. 9) — an ironic touch given the highly prestigious nature of these professions and that particular university — thus signalling the trend towards de-differentiation of the two sectors (Nicoll & Chappell, 1998). This inclusion nevertheless reflects the history of universities as sites of professional preparation and underlines the sectoral contestation between the two sectors. Yet, Peter Rushbrook (1997) illustrates how fiercely the universities have opposed the introduction of competency-based education and training into their sector although, as Peter Raggatt (1998) recounts, it is now embedded in the UK system of teacher education. In the other direction, students in the final years of secondary school are now permitted to undertake certain accredited VET subjects.

The very concept of seamlessness across educational sectors, promoted in Australia, suggests that there should be some overlap or at least continuity in educational provision across sectors of education. Yet this is not generally the case — the debate over CBT is a prime example; the NBEET (1995b) report on mathematical sciences is another, highlighting the traditional pursuit of different purposes and orientations, especially with respect to mathematics, across sectors — the Australian VET sector was virtually ignored in the report.

In contrast to many universities, the VET sector historically has maintained a dual focus on both students and industry, albeit with fluctuating emphases. While students themselves have had very little voice (Anderson, 1999a; 1999b), from the mid-1980s the corporate sector has established an increasingly powerful presence in the determination of VET policy and practice, as did the trade unions until the election of a neoliberal federal government in 1996. However, it should be recognised that the voices of business and industry are not univocal, and that spokespersons can in no way represent the interests of the entire industry or vocation (Fisher, 1993; Hawke & Cornford, 1998). The trend towards globalisation of economies is also having diverse effects on industrial practices, including education and training programmes, although not in the deterministic manner suggested by some commentators (Butler, 1998b; McIntyre & Solomon, 1999) — impacting on the policy advice given in relation to vocational education and training.

Although TAFE institutes have managed to maintain a healthy public image this has been in the face of rapid organisational change (discussed below). In this period of economic uncertainty, particularly under neoliberal ideologies of government, there has been intense competition within and between sectors for student dollars as part of an ongoing history of contestation over course delivery and status. The notion of competition might be expected to generate attempts at raising the quality of educational offerings in each sector but, somewhat perplexingly, quality in the Australian VET sector is measured by simplistic measures such as student contact hours, reflecting the technical preoccupation with goals over social meanings, raised by Feenberg (1995).

4.2.2. Images of Vocational Education and Training

Complementing the discussion of the images of mathematics and mathematics education in chapter 1, I wish to compare and contrast images of vocational education. Unlike other sectors of education in Australia, the survival of the VET sector depends critically upon its public image. In turn, the status of mathematics education and what counts as mathematics within the sector depends upon its perceived purposes.

According to Peter Rushbrook (1995), institutionalised adult and vocational education has adapted itself to the needs of the local citizenry and local industry. Drawing on the work of Murray-Smith and Batrouney, Rushbrook identifies the Australian VET sector's purposes as being within the broad and enduring traditions that have distinguished it from other sectors. These include: (a) the fostering of nation-building philosophies, (b) the amelioration of social disadvantage, (c) eclectic relationships with local communities, and (d) the inclusion of liberal education courses as well as utilitarian job training. Rushbrook also adds what he terms the *structured silences* of traditions associated with patriarchy, the formation of sectoral identity, and the quest for private sector legitimacy, as defining characteristics. Damon Anderson (1998) notes that the sector's essence and identity have been defined by its capacity to adapt in a flexible and responsive manner to diverse needs and changing demands. Its survival, in spite of many changes in name, structure and organisation over recent decades, can be partly explained by its constant focus on the needs of its key clients — individual students, industry and the wider community — although these relationships have been ambiguous at times. However, as Rushbrook concludes, over time these strengths of flexibility and responsiveness have been mitigated by the wider economic and political forces which have colonised the system, notably in times of major social and economic upheaval (see also Kell, 1994).

Fooks (1994, p. 40) observes that, throughout its history in Australia, "technical education has suffered from problems of identity, image and status." These revolve around: (a) its lack of identity: being all things to all people, seen as an amorphous sector between schools and universities; (b) its lack of status: always viewed as working class and, prior to 1973, referred to as technical training rather than education; and (c) its lack of any effective lobby — among students, teachers, directors, employers, or trade unions. Rushbrook (1995, 1997) argues that this quest for sectoral identity and private sector legitimation led to the acceptance of scientific management discourse into vocational education curriculum, ultimately manifested in the adoption of CBT.

In comparison to both school and university sectors, the Australian VET sector generally has residual status in terms of media interest and among many students as a post-school destination. This is somewhat surprising given figures from TAFE graduate destination surveys published by the National Centre for Vocational Education Research [NCVER] which show high levels of graduate and employer satisfaction. However, a recent report on *Seamlessness* (OTFE, 1999) confirms that graduates from the ACFE sector are actually disadvantaged, presumably by perceptions of selection officers, in processes for admission to higher education courses — in spite of having gained superior scores on Tertiary Entrance Requirements. This second-class status may be attributable in part to the history of the sector, although the Australian National Training Authority [ANTA] has attempted to rectify the situation through its 1998-2003 strategy document, *A Bridge to the Future* (ANTA, n.d.-a), through the use of promotional materials including glossy brochures such as *The ABC of Vocational Education and Training* (ANTA, 1998c), and through its continually modified website [http://www.anta.gov.au]. Clearly these form part of an attempt to market the VET sector in a strategic attempt to increase participation in education. But it is a matter of concern as to the ultimate effects of brochures such as these on the public image of VET. For example, Pauline Robinson (1998) provides a critique of the portrayed images of teaching and learning as being overly simplistic and unrealistic, where learning is effortless and qualified teachers are of diminishing importance compared to on-the-job trainers. A more recent document, on a strategy for marketing skills and lifelong learning (ANTA, 2000) advocated a social marketing strategy of promotion to segmented markets, comparable to health awareness campaigns, appropriating the rhetoric of the recent the United Nations Educational, Scientific and Cultural Organisation [UNESCO] report on lifelong learning (Delors, 1996) as its conceptual basis.

John Stevenson (1998c) suggests that the low status in which the Australian VET sector is held is due in part to the unresolved issue of the relationships among work, knowledge, and education which, he claims, is leading to incoherence, constant change, and ambiguity in the purpose and direction. To overcome the perception of vocational education and training as 'other' to institutions such as school and university, or as not educating the whole person, for example, Stevenson argues for a convergence of general and vocational education. He suggests that the status of VET would be enhanced by adopting a Deweyan approach with less division between education for work and education for other social purposes. What might this mean for mathematics? In FitzSimons (1999b) I argue that, particularly in an era of transdisciplinarity (Gibbons et al., 1994), in the interests of workplace communication, the polarities between the mathematics taught to university undergraduates and that 'delivered' to VET students must be overcome. Otherwise how can effective communication in the workplace — congruent with that discussed in chapter 2 — be achieved? As is, or should be, the case in other sectors, VET students have the right to open and honest consideration of the values of mathematics in relation to society, in and beyond the workplace and the home. They are entitled to respect and empowerment to link their workplace mathematics with academic mathematics — yet from a critical standpoint — in full appreciation of the values entailed.

In summary, the Australian VET sector has been afforded an ambiguous public image. On the one hand, it is seen as generally being responsive to the needs of its key clients, individuals and industry — although this image has been attacked for political reasons, as will be discussed in chapter 6 — but, on the other, it has second-class status in terms of a post-school destination. As will be developed further, it is seen to be of political importance as an instrument of economic and industrial reform.

4.2.3. Reflections on Two Decades of Practice

Some issues which have been of serious concern to me as a practising TAFE mathematics teacher include: (a) the diminishing status of mathematics as a discipline within the sector and, allied to this, career pathways for TAFE mathematics teachers; (b) the isolation and stagnation of vocational mathematics teaching practices; (c) the failure of vocational mathematics curricula to respond effectively to changing industrial circumstances and student needs; (d) the dearth of knowledge generally about the ontogenetic status of vocational students with respect to mathematics education and the variable sociocultural circumstances in which these students may find themselves; and (e) the overwhelming disinterest by all levels of the sector (with the exception of some teachers) in research as it applies to the totality of mathematics curriculum and teaching practices, whether face-to-face in TAFE institutes, by distance education methods, or on-site in the workplace.

When I began teaching in 1982 employment conditions in the state of Victoria were generous; tenured positions were readily available, and the weekly timetable specified 18 hours teaching with 12 hours preparation and correction. There were few other demands on teachers' time. Collegiality thrived within and between colleges. Working conditions in terms of classroom and office space, however, varied greatly according to the timetable of massive building construction which followed the release of the 1974 Kangan Report (ACOTAFE, 1974). It was significant that 'access centres' for students were generally housed off-campus, in marginalised locations until these were deemed no longer financially viable. However, in some cases this was turned to advantage as some centres (e.g., Women's Education) could be made more homely and remain aloof, to some extent, from the exigencies of institutional life (see FitzSimons, 1994b). Over the years, collegiality has withered, employment conditions have deteriorated as has the morale of TAFE teachers. TAFE colleges have been renamed 'institutes' in a corporate-image form of 'credential creep,' and a succession of mergers and rationalisations has left teaching staff with perceptions of perpetual change and dislocation, rarely if ever for the benefit of students or themselves, or even industry for that matter. Within the last decade many have given up classroom teaching or left the education system altogether, heading for early retirement or more satisfying, higher-paid jobs elsewhere.

Internationally, there has been a burgeoning interest in the education of adults as nations strive for economic competitiveness, often acting upon the explicitly or implicitly held assumption of links, even direct correlation, between economic success and the level of qualifications of the populace. There is considerable variation among nations in the means and ends employed to achieve their goals for adult education in general, and for adult mathematics education in particular. Students enrolled in Australian vocational and further education courses have in general a weaker mathematical background than their peers who progress directly from school to university, particularly in the science and technology areas. That is, on the evidence from enrolment applications, they appear to have attained fewer formal mathematical achievements and qualifications. Many adult students, old and young, are surprised to be confronted by mathematics-type subjects or subject components at the post-compulsory level; this applies not only to vocational students but also to university students who may be required to study statistics — for example in psychology, social science and business studies courses (see, for example, FitzSimons 1996c; FitzSimons & Godden, 2000).

Once students have made it over the enrolment hurdle — sometimes an achievement in itself reflecting, on many occasions in the past, the extremely poor organisational efforts on behalf of (some) TAFE college management and administration, and sometimes no hurdle at all as 'bums on seats' were and continue to be a priority — they are generally placed together in the same mathematics class, regardless of educational background and/or time away from formal study (see also Foyster, 1988). In theory, self-paced learning can be a panacea for this kind of situation, although in practice it has often proved detrimental to those least able in terms of literacy skills and metacognitive abilities. Even if these cognitive considerations were to be recognised, the affective domain was and is rarely under consideration with respect to TAFE mathematics — except for occasional (now defunct) further education courses with titles such as 'Overcoming Maths Anxiety' (see FitzSimons, 2000d).

Although macro-level data has been collected on enrolment patterns, module completion rates, and so forth, at the micro-level there is a dearth of systemic knowledge on the salient cognitive and affective, social and cultural characteristics of students who enrol in mathematics or statistics classes or who undertake calculations components in vocational courses. Little consideration seems to be given to the sociocultural factors which cause otherwise successful students to disappear spasmodically or permanently; for example students who are torn between employer and/or family demands and sacrifice their studies to these, or those who live in poverty and must take whatever casual work is available. As Anderson (1999b) claims, students have been overlooked as key stakeholders in the sector. An irony exists here in that student services in TAFE institutes have been severely curtailed over the last decade, and may be even less accessible through private providers or industry-based training sites.

4.3. RECONTEXTUALISING TEXTS FOR VOCATIONAL MATHEMATICS

In the 1970s moves were taking place in the Australian school sector to make curriculum more relevant to students, as control of secondary curricula was wrested from the universities (Horwood, 1997). In a similar manner, prior to the 1990s, some TAFE mathematics courses were evolving to meet the needs of students in pre-tertiary, pre-vocational, labour market, and return-to-study courses which provided alternatives at the post-compulsory level of school education. These were under varying degrees of regulation, from complete teacher autonomy to statewide moderation of curriculum and assessment. More strictly vocational courses have had a history of prescription, where trades courses (predominantly male-oriented) have been subject to external regulation. The emphasis in apprenticeship trade calculations was on pragmatically-oriented basic skills of number and measurement. The higher level certificate classes for technicians, areas with a heavy commitment to advanced mathematics, had strictly enforced syllabi and sometimes external examinations conducted under the auspices of industry groups. Thus, while some TAFE courses were unique to the institution in which they were offered, others gained statewide recognition. However, even those which were more highly regulated operated differently across different Australian states; course codes were non-systemic, and there were national issues of recognition and transferability.

A 1985 grant from the Victorian TAFE Board to audit mathematics courses within the state (Foyster, 1988) was conducted by members of the TAFE Mathematics Common Interest Group (TMCIG), revealing a plethora of uncoordinated course offerings causing potential disadvantage to students in terms of recognition of credit across courses and states. No doubt it also caused confusion to employers. This rationalisation of courses on a national scale was achieved through the work of the National Vocational Mathematics Curriculum Project (NVMCP), awarded to two TAFE mathematics teachers from different states (Pantlin & Marr, 1992). The project had commenced when the legislation requiring CBT format was passed, to which it was then required to conform. The final result was that the work fitted neatly with the recommendations of the audit project of the previous decade for the modularisation of courses. The explicit intention was to develop a mathematics curriculum which was nationally consistent across all vocational areas. Each module was designated (arbitrarily) to be of three hours duration and designed for an 'average' group of students. A little surprisingly, the project research found that equity was not considered by mathematics teachers throughout Australia to be an important issue. Apparently neither gender nor non-English speaking background (NESB) were considered to be problematic areas. It should be noted that the project brief did not include an appraisal of the relationship between existing units and *actual* workplace needs (see chapter 2). Industry consultation generally appeared to reinforce the *status quo* in this regard (cf., Harris, 1991) — possibly due to the restricted nature of the questions asked.

The 94 topic packages devised by the NVMCP was mapped onto a complex network, linked by pathways showing preferred topic sequences, prerequisites, and co-requisites. The two baseline packages were *Introduction to Geometry* and *Fractions and Decimals* — but it is the latter which appears to have prevailed, especially in courses with minimal mathematics content. Mathematical modelling subjects are out to one side, requiring a strong algebraic background. Many of the higher package titles could be found in university mathematics or service courses. The network, very logical and detailed in appearance, consistent with the ideals of scientific management, formed the basis for selection into modules of accredited courses. The intention was to achieve uniformity of format, content, presentation and philosophy across each state and territory, and throughout each industry. However, this standardised, technicised approach to curriculum, ironically described as learner-centred, carries an inbuilt inertia.

During recent years I have been highly critical of the CBT mathematics curriculum and assessment framework in Australia (e.g., FitzSimons 1996b, 1997a, 1997b, 1998a, 1998c, 1999b, 2001a, 2001b), claiming that it serves neither the individual nor society at large, including business and industry. I now exemplify specific mathematics curriculum, teaching, and assessment materials (resources/texts) derived from the NVMCP framework for a course accredited between 1993 and 1999. This example is not intended to be representative but merely illustrative.

Even though curriculum, along with professional development and learning resources are no longer officially endorsed, I consider it is worthwhile to pursue this direction of inquiry. This is because pre-existing CBT-accredited documents provide historical antecedents to the current situation of vocational mathematics, both in terms of the theoretical aspects and in terms of the practical exigencies of teaching where reference material (usually accessible in print or on-line) is regarded as an essential tool (the "what shall I do on Monday?" problem).

Prior to their replacement by so-called *Training Packages,* the accredited curricula for base-level pharmaceutical manufacturing operators — coming under the auspices of the Food Processing Industry — specified generic core modules (e.g., calculations, quality assurance, and industrial communication), together with a range of pharmaceutical core modules (e.g., good management practice, basic computer skills) and specialised electives in production, packaging, and materials handling. Discussions with operators revealed these to be in ascending order of relevance to their everyday work. The following are examples of elements and learning outcomes of some of these modules:

Calculations A[2]:

Unit 1.1 Apply mathematical concepts

Element 1.1.1 Estimate, calculate and record workplace data

Learning outcomes

1. Estimate results from basic information used in typical workplace situations
2. Calculate results involving whole numbers used in typical workplace situations
3. Calculate results involving simple fractions used in typical workplace situations
4. Calculate results involving decimals used in typical workplace situations
5. Record estimates and calculations on standard workplace forms/documents accurately and legibly.

[2] Of these first three modules, only Calculations A is core.

Calculations B

2.1 Apply mathematical concepts

2.1.1 Use routine measuring instruments

2.1.2 Complete routine arithmetic calculations

2.1.3 Chart data

1. Explain SI measurements for mass, volume, temperature and length
2. Measure product weight and associated variations
3. Measure product volume and associated variations
4. Measure product temperature and associated variations
5. Measure product length and associated variations
6. Record data on standard charts

Calculations C

3.1 Apply mathematical concepts

3.1.1 Calculate performance measures

3.1.2 Convert imperial to SI measures

1. Calculate percentages, ratios and proportions
2. Use imperial and SI measures to calculate performance
3. Record data on standard charts

Basic Computer Skills

This module provides the learner with a basic understanding of computers and computing systems used in the pharmaceutical manufacturing process. The emphasis is on the ability of the person to manipulate the keyboard, respond to simple commands, and input data in their immediate work area.

1. Explain the purpose of computers and their components and the impact of computers on society
2. Describe the different computer and computerised control systems used in the pharmaceutical manufacturing/production industry and the differences between the systems
3. Input, store, and retrieve data following computer menus and commands, using a range of input/output devices.

Quality Assurance A

1.1 Apply basic quality assurance practices

1.1.1 Identify and monitor critical control points at work station

1.1.2 Sample product for off-line testing

1.1.3 Perform inspections and tests of own work

1. Identify the critical control points at the individual's work station
2. Obtain representative samples according to instructions
3. Prepare samples in format required for transfer to designated location
4. Perform inspections and tests required in the individual's work area to assure product quality.

Industrial Communications A

3.1 Communicate in the workplace

3.1.1 Express views verbally

3.1.2 Read non-routine text

3.1.3 Prepare written information to support groups and teams

1. Gather, collate, record and convey information
2. Use effective verbal and non-verbal methods to facilitate cross-cultural communication in the workplace
3. . . .

The *Assessment Criteria* for each Learning Outcome in *Calculations A* are as follows:

1.1 Estimate* whole numbers using addition, subtraction, multiplication and division processes.
1.2 Estimate decimals using addition, subtraction, multiplication and division processes.
1.3 Estimate variations to product weights and volumes.
1.4 Estimate metric measurements for temperature, mass, volume, length, time and pressure.
1.5 Estimate yield and loss amounts and percentages.

2.1 Add whole numbers.
2.2. Subtract whole numbers.
2.3 Multiply whole numbers.
2.4 Divide whole numbers.

3.1 Add fractions
3.2 Subtract fractions
3.3 Multiply fractions
3.4 Divide fractions

4.1 Add decimals
4.2 Subtract decimals
4.3 Multiply decimals
4.4 Divide decimals

5.1 Enter information accurately into the correct section of the workplace form/document
5.2 Record calculations legibly so that data can be read by users of the information
5.3 Convert metric units to other units

*Estimate — within the context of this calculations module refers to the ability to form an approximate judgement which is closely related to the formally calculated result.

(ACTRAC, 1994a)

To provide a theoretical basis for critique I turn to Basil Bernstein's (1996) and Paul Dowling's (1998) work on recontextualising rules which in turn constrain and shape the evaluative rules. Clearly there are weak classification boundaries between much of the textual content and primary (elementary) school mathematics, especially when 'decontextualised' by removal of the catch-all phrase "used in typical workplace situations." Whose knowledges do these learning outcomes represent? Certainly not those of a large majority of the workers engaged as operators in pharmaceutical manufacturing. Under what pretext are the workers' complex skills (cf., Onstenk 1998, 2001a) rendered as Other? What are the ontological and epistemological bases for this jejune, staccato depiction of the mathematical knowledges used and required by pharmaceutical manufacturing operators?

4.3.1. Workers' Perspectives

How would a typical mature-age pharmaceutical operator respond to this document? Bernstein (1996) argues that values and skills are actually part of the one discourse; their distinction in academic discourse acting as a disguise. In other words pedagogic discourse has a hidden voice. However, it will be useful to separate them analytically at present for the purpose of identifying the various messages carried in the *Calculations A* course. It is clear to anyone with a working knowledge of the industry that, unlike other modules, there is a discrepancy between most of the learning outcomes of *Calculations A* and what actually takes place on the job for Level I operators in any section of a pharmaceutical plant. How could these learning outcomes be even remotely considered as setting the foundation for higher order thinking skills? The most obvious feature is that the content selected is from the very bottom of the national vocational mathematics framework (ACTRAC, 1993). The epistemological implication seems to be that the skills needed for operators on the base level of qualifications are deterministicatly related to what has apparently been deemed, according to their location within the framework and their commonly used metaphorical description, *basic skills.* What is the justification for this assumption?

The mathematical skills listed are supposedly derived from a functional analysis approach (e.g., Blackmore, 1999; Johnstone, 1993). How could it happen, then, that adopting what Dowling (1998) calls a *mathematical gaze* on a tour of inspection of just one plant it is immediately obvious that each of Bishop's (1988) six pan-cultural activities — counting, locating, measuring, designing, explaining, and even playing — are apparent in the day-to-day activities of operators? Under what pretext is the only mathematical part of the certificate course which is core so limited and indeed so limiting in relation to the industry's needs, especially in view of the trend towards multiskilling? One interesting aspect of the onsite research is the critical importance of counting in the pharmaceutical manufacturing industry; due to legally-enforced codes of practice every element which is used in the production process (from ingredients to packaging and leaflets) must be accounted for, no matter how minor. Yet a skill which is apparently so elementary as counting is of the essence because any discrepancy could ultimately result in serious financial loss should there be a need for reworking or even product recall. Similarly for the continuous labelling and re-labelling processes involving code transcription and identification throughout each stage of the production process up to the point of despatch. Particularly evident when a discrepancy is discovered, these apparently simple mathematical activities of counting, reading and labelling are nested within the whole range of the Australian Key Competencies (Mayer, 1992) (i.e., problem solving, working in teams, communication of ideas and information, planning and organising activities, etc.), and professionally within Onstenk's (1999, 2001a, 2001b) concept of broad occupational competence. Links to the range of key competencies within the illustrated calculations text are largely implicit; research (e.g., Down, Fechner, & Lilly, 1997) indicates that these links need to be made explicit in teaching/learning activities. The important issue here is that mathematics (or numeracy) content for the workplace is generally not regarded to be of high academic standard; rather that applications are frequently complex in scope. As noted in chapter 2, it is conceivable that the production of new (local) knowledge is integral to many if not all jobs.

Considering the issue of reflection on mathematics and technology, under what pretext is there no hint of social critique of the uses to which mathematics is put — unlike Basic Computer Skills — nor of the judicious use or possible pitfalls of using a calculator? In other words why is there no reflection on the uses of technology nor of mathematics as a contributor to our technological society (cf., Keitel, Kotzmann, & Skovsmose, 1993)? Bernstein's (1996) theorisation of the recontextualising field as abstracting experiences from power relations, negating the possibilities of understanding and criticism, would seem to be apropos here (i.e., socially critical and industrial relations issues are not raised at all). The values which seem to be conveyed in this (typical) calculations text are that, despite the rhetoric, mathematics is largely unrelated to any of the complex range of everyday workplace activities; it is something procedural, instrumental and regulative, something value-free, a hurdle to be overcome.

In spite of the burgeoning of research into the actual uses of mathematical knowledge in the workplace and the creativity of workers in this regard (see chapter 2), the rules operating in the text above concerning the distribution of knowledge eschew these knowledge interests and preclude access of worker/students to what Bernstein (1996) classes as *unthinkable knowledge*. For example, workers often need interpretive statistical knowledge in order to deal with the numerical and graphical information they receive daily. And, given appropriate pedagogy, they are well able to construct this knowledge. Bernstein's assertion that those who have failed along the way are positioned and restricted to simple operations where knowledge is impermeable is vindicated by the text reproduced here. The large majority of VET students, especially at operator level, have been socialised into the pedagogic code and are unable to visualise alternative realities within this powerful yet mysterious discipline of mathematics. Under what pretext is this blinkered outlook on mathematics perpetuated?

In addition to issues of knowledge distribution, there could well be some kind of explicit or implicit coercion for potential or current workers to undertake such training courses in order to maintain or improve their employment status. What is the psychological impact on the individual? Bernstein (1996) gives special attention to the concept of *trainability*. Under a short-term worldview there cannot be stable expectations of the future nor of one's location in it: tasks, skills and areas of work undergo continuous development, disappearance, or replacement. It is therefore necessary to develop a new skill: trainability, "the ability to profit from continuous pedagogic re-formations" (p. 72). Is this curriculum a pretext? Is it that students engaged in the sorting processes associated with studying mathematical content come to 'know their place' — that is, to accept their fate in the employment/promotion stakes, accepting responsibility for their own lack of success in spite of past inequities and social injustices they may have suffered?

What messages does the text give the operators about what is valued in their work? Are they forever to be in need of more training as their own skills are devalued and others, more esoteric yet pedantic, are deemed to be worthy of pursuit? Following Dowling's (1998) concept of subjectivity in which the subject is inscribed within, or constructed by, social practices and relations, the question arises: What values are being transmitted to workers with respect to their subjectivities? What is the pretext for the essentialist notion which assumes that all operators should be required to have (only) a mathematical knowledge base of a given selection from primary school number work which may be readily reckoned on a supermarket-purchased calculator? What lies behind the failure to recognise, among other things, the store of knowledges and skills built up uniquely from the life experience of each person? What perpetuates the denial of workers' (populist) knowledges and reifies an arbitrary selection from a sector of education which operates under a different charter and, it appears, not particularly successfully for the majority of school leavers?

One possible answer is ignorance by those stakeholders in positions of power and control in the Australian VET sector. More sinister is the possibility that operators such as these are constructed as perpetually immature citizens and workers, forever in need of (re)training in the wake of continuous appropriation of new technologies of production, yet always under the tight control through technologies of workplace management. At what cost to the individual, the enterprise, and the community at large?

4.3.2. Teachers' Perspectives

Focusing on what Bernstein (1996) identifies as recontextualising rules, clearly curriculum developers in the Australian VET sector have been restricted by the necessity to comply with the mandated CBT model, adopting its behaviourist terminology and narrowness of focus to that content which can be easily assessed. From an ontological perspective, in this sector hierarchical notions of a definitive mathematics curriculum, starting always with whole numbers, fractions and decimals, seem to be immutable. Under what pretext does this fundamental premise remain unchallenged, particularly where other kinds of mathematical skills also prevail in the workplace? Personal experience of teaching adults supports the assertion by Ernest (1991) of the non-uniqueness of both discipline and learning hierarchies. When a thematic approach is pursued and underpinning knowledge is taught in a meaningful context, then adults are motivated and able to learn mathematics topics which cut across traditional hierarchies (e.g., FitzSimons, 1997a, 2000a, 2001a).

As teachers struggle for meaning in their interpretation of the pedagogic text in order to regulate pedagogic practice at the classroom level, there are many silences. Four learning outcomes mention 'typical workplace situations' but what determines a *typical* workplace? Each workplace is unique, not only in size, ethos, and focus, but in each of the problem areas identified by Onstenk (1999, 2001a, 2001b). On-the-job training may be construed as 'typical' in the immediate sense but does not necessarily prepare the worker for a different workplace, or even different worksites within the same enterprise, unless transferable skills are specifically addressed in the teaching and learning process. On-the-job training is also unlikely to develop any 'big picture' of mathematics (cf., Ernest, 1998c). In some situations it may be preferable or even necessary to employ techniques of simulation. How might typical workplace situations be simulated, given that a simulation by its very nature is something other than the real situation in terms of the exigencies of workplace (e.g., time and cost pressures, social competencies)?

What underlies the failure to address transfer? Could this omission be related to the de-skilling and de-professionalisation of vocational mathematics teachers? Is the failure to recognise the value of pedagogical content knowledge associated in some way with the deregulation of entry skills for teachers of generic subjects? Could it be related to the promotion of technologies, in the form of self-paced flexible learning materials, intended to increase the space of mediation between teachers and students, even to replace teachers? In other words, in the denial of the importance of pedagogy, is vocational mathematics teaching being portrayed as a low level skill, to be unproblematically delivered (i.e., transmitted) by workplace personnel or non-mathematics qualified teachers?

Because Learning Outcomes #2, #3, and #4 are so well known to teachers and trainers alike they may seem unproblematic, and have an innate quality of attracting the familiar sets of repetitive worksheets couched in the imperative language of the assessment criteria: "solve the following . . ." Otherwise they are pseudo-contextualised, as the mathematical skills sought to be demonstrated are wrapped within what are thought to be relevant settings and terminology for the industry — similar to the examples Dowling (1998) uses to demonstrate what he calls 'the myth of participation' which construct mathematics as a reservoir of use-values. However, here it is likely that once the kernel of the problem is arrived at, the contextual meaning (if any) is discarded by students and the numerical solution is dominant over any possible reality checks. What can teachers do if there is no typical workplace situation for Assessment Criterion #3.4 which calls for division of fractions? As indicated by Jeff Evans (1999), Lave (1988), Lave and Wenger (1991), and others, the mere substitution of adult dressmaking, supermarket shopping, or production-line narratives for the primary school-mathematics 'contexts' of popsicles, teddy-bears, and so forth, does not constitute situated cognition nor will it ensure transfer.

Learning Outcome #5 asks for the *accurate* entering of information and its *legible* recording. While 'accurate' has an absolute quality, 'legible' is more open to judgement. The issue of judgement by assessors is a major one for practical subject areas in CBT, but generally not an issue for vocational mathematics. However, Learning Outcome #1, *estimation,* becomes much more problematic. When is a numerical estimation close enough in industry? Must an algorithm always be followed for numerical estimates? Assessment Criterion #1.5, to estimate yield and loss amounts and percentages, seems to present a major intellectual challenge, given the complexity of actual workplace data sheets which could carry up to about 20 entries per page comprising multiple columns, with 'awkward' numbers — unless the exercise becomes reduced to an algorithm of repeated rounding and calculating. More realistically experienced workers know that there are certain expectations for these practices (e.g., up to ±5%), and that something would be seriously amiss if this limit were to be exceeded. In any case the story told by the visible surplus or shortfalls in consumable materials would be likely to cause some immediate concern to operators in the pharmaceutical manufacturing industry.

This leads back to discussion of the silences concerning the role of workers' experience in quantitative estimates. As Mary Harris (2000) points out, no-one undertakes a work task without some clear idea of the quantities of materials needed and the approximate time required. Surely the operators who work in receiving depots, for example, need to have a reasonable idea that the goods being unloaded are approximately the right quantity. In problem solving situations which are continuously novel, bulky pallets needed to be quickly and efficiently stored temporarily and their boxes counted and adequately labelled, even if not visible from the outside of the pallet. How can this, the workers' actual knowledge, be assessed meaningfully, and hence valued? To return to Bishop's (1988) six universals, there would seem to be glaring omissions in the calculation-based course given above: the most obvious is *locating.* Storage and warehousing (raw materials and finished goods) are crucial resources in this industry; entering information accurately and recording legibly are necessary but not sufficient workplace skills. Storage needs to be *planned,* locations for "picking" goods or materials need to be *explained* (albeit in code for experienced workers), as does temporal order (e.g., first-in-first-out). Pallets need to be unloaded and reloaded (*design*); orders need to be made up, with due regard for fragility and temperature sensitivity (*counting, measuring*), and records need to be made, checked, and re-checked at each point up to the point when the order is packaged and departs with the appropriate carrier.

Further questions arise in relation to Bernstein's concept of 'control' through the framing of how this nominated curriculum should be 'delivered' — to use the official terminology. Upon what assumptions of a 'typical' student was it decided that this module should occupy 20 hours teaching time? What if — and this could be more probable in food processing industry proper — the operator had little background knowledge in the skills listed? How far could a beginner go in 20 hours, and how long might it take to become competent in all learning outcomes? Clearly this is dependent upon each individual student's ontogenetic development in mathematics, and education in general, as well as their intentions and motivations. In the large majority of VET courses there is a wide range in the mathematics entry-levels of any one cohort. Could this arbitrary time limit actually coerce mathematics teachers to use self-paced learning packages or to encourage processes of Recognition of Prior Learning (RPL) among students, in lieu of teaching and learning interactions?

Silences for teachers also include psychological aspects such as the need to engender motivation and to address negative beliefs and attitudes developed by students as a result of previous mathematics education experiences. Other silences include social and cultural aspects, when it clear that not all operators have experience of a middle-class, English-language education — not an atypical situation in Australian manufacturing industry. Teachers and trainers need to be aware of the fact that a variety of valid notations and algorithms are used in different countries of the world, in and out of formal educational systems — and especially in workplaces — and address this issue, among others, with due cultural sensitivity (e.g., Knijnik, 1997, 1998).

4.3.3. Examples of the Arbitrary Basis of Content

As noted in chapter 3, Bernstein (1996) distinguishes between what he terms *horizontal* and *vertical* discourses. Horizontal discourse, typified as *commonsense knowledge* by Bernstein, has the characteristics of being: "local, segmental, context dependent, tacit, multi-layered, and often contradictory across contexts but not within contexts . . . [its objects of knowledge] are likely to be volatile and substitutable" (p. 170). Horizontal discourses are pragmatic, shared understandings in the local context, with their own rules of operation and internal regulation.

Bernstein's (1996) description of horizontal discourse resonates with research into workplace discourses, referred to in chapter 2. (King Beach, 1999, also discusses horizontal discourse in the workplace.) There may be common operations across different segments (e.g., counting, estimating) but that this need not be the case. Discourses are acquired, often tacitly, through local activities. They are an outcome of a cultural specialisation (i.e., the workplace), with modes of acquisition and production embedded in that specialisation (i.e., workplace practices). This means that pedagogic relations (e.g., in workplace education) are likely to vary across contexts (Bernstein & Solomon, 1999). This suggests that practices of delivering 'off-the-shelf' modules — even with the substitution of contextual clues, such as plumbing, bread-making, architectural drafting, and so forth, are unlikely to be appropriate.

By contrast, vertical discourses have a coherent, explicit, systematically principled structure, and are hierarchically organised — the institution of mathematics is one example. Both horizontal and vertical discourses have a different but arbitrary base. Their origins and development are likely to be found in the official institutions of the state and the economy, and their realisations depend upon who has power over what knowledge is recognised and control over how that knowledge is realised (Bernstein & Solomon, 1999). Unlike workplace mathematical contexts where the immediate priority is getting the task done and not the mathematics itself, school mathematics as an example of a vertical discourse is not consumed by its context, and is linked to other areas of study, gaining its significance from the future.

In the school sector, Paul Dowling (1998) observes that elements of horizontal discourse become resources regulated by distributive rules which limit the recontextualising field for students who are constructed as non-academic. That is, they are offered access to qualitatively different kinds of mathematics education. Although the Australian VET sector does not have officially sanctioned 'streaming' of texts as in Dowling's UK study, there appears to be a more subtle kind of positioning at work. This takes the form of requiring all workers at lower qualification levels to begin (and frequently end) their vocational mathematics careers with limited, but arbitrary, selections from the number work strand of primary school mathematics curriculum documents (as demonstrated above). These are then justified, a posteriori it seems, by the inclusion of so-called contextual examples. Although the learner may be given the impression that the context came first, this is not the case: curriculum writers and mathematics teachers have been given explicit instructions to 'find typical workplace examples' for the predetermined learning outcomes (e.g., ACTRAC, 1993, 1994). Because lower level courses are frequently taught by workplace trainers (without tertiary mathematics discipline or educational qualifications), trainer's guides often attempt to fulfil this task (e.g., ACTRAC/NFITC, 1995). However, there are few examples if any that deviate from the artificiality apparent in school texts as they promulgate what Dowling calls the 'myth of participation.'

An apparent irony exists in that Bernstein (1996) regards horizontal discourse as a crucial resource for pedagogic populism (as in ethnomathematics) in order to 'unsilence' voices to create conditions for participatory acquisition and empowerment. However, in the Australian VET sector it is usually manifested in what Dowling (1998) calls the 'myth of emancipation'. Here the 'mathematical gaze' recognises the mathematics in the work, but then the pedagogics serve to "pathologize the yet-to-be-schooled" (p. 15), using the superficialities of the workplace context to 'motivate' students to swallow what might be regarded as their 'elementary maths pill'.

Dowling's (1998) myth of emancipation is exemplified in a Calculations A worksheet, where operators are being taught the skills of estimation, using the pretext of "How can you estimate how much tax you pay?" (ACTRAC/NFITC, 1995). Given the algorithm: "Net pay = Gross pay - Tax and deductions" (p. 13), the learners are directed to Worksheet #1 (ACTRAC/NFITC, 1995; Appendix 3, unpaginated) — a simplistic facsimile of "John's payslip." *Gross pay* is shown to be $362.60 and *Net pay* is $ 310.85; with a blank space against *Tax and deductions*. Most (other) workers would simply read the required amounts off their (completed) payslip or else telephone the pay office to find the answer and demand an explanation for the incomplete documentation. What is the message for these workers? These worksheets provide evidence of the kind of artificiality and static view of what is normally a dynamic workplace. In another example, workers as students are required to read single temperatures marked on a contrived illustration or a sample thermometer, rather than to interpret rises and falls over time — a skill critical to normal workplace functioning, and with more meaning. The final pedagogic coup lies in the *Additional Materials* (ACTRAC/NFITC, Appendix 5) where, after nine examples of whole number and one-place decimal multiplications by 10, 100, and 1000, the learner is asked to:

> Fill in the spaces:
>
> If you multiply a whole number by 10 you put a .... on the end of the number.
> If you multiply a whole number by 100 or 1000 you put ...... or .... on the end of the number.
> If you multiply a decimal number by 10 you move the decimal point .... places to the right.
> If you multiply a decimal number by 100 you move the decimal point .... places to the right.
>
> Do these without a calculator
>
> 36 x 100
> 5.7 x 10
> . . .

Whose voice is heard here? How empowering is this text for the novice, either mathematically or industrially? On what mathematics education research is this recontextualisation and reproduction of mathematics in the workplace based? Similar examples of text may be found in 'exemplary' online mathematics courses for science technician students in the Australian VET sector.

Dowling (1995) argues that the kind of examples found in school mathematics texts mathematise everyday experiences with the implication that people's lives would be more efficient and effective if they operated as mathematicians. However, he notes that this assumption is not valid "because mathematised solutions always fail to grasp the immediacies of the concrete settings within which, as Jean Lave points out, problems and solutions develop dialectically" (p. 4). As the seminal work of researchers Richard Noss and Celia Hoyles among others indicates, mathematics actually used in the workplace is contingent and rarely utilises 'school mathematics' algorithms in their entirety, if at all, or necessarily correctly. As Bernstein (1996) observes, a segmented competency (e.g., actual workplace numeracy) operates in the present tense modality, is culturally localised, and is likely to evoke a range of realisation strategies leading to multiple correct strategies — in contrast to much school and vocational mathematics.

"How can you work out how much is produced per minute?" (ACTRAC/NFITC, 1995, Appendix 2, unpaginated) is a typical illustration of an algorithmic approach to a question which might well be answered more pragmatically by workers being told the answer (politely or otherwise) at production meetings. In any case, pausing to do the suggested repeated addition or multiplication calculations would severely downgrade the production rate! How many workers would actually perform these calculations in their coffee break or lunch-hour?

The subsequent problem, to be worked through with a trainer, states:

> The machine breaks down at 12 noon and starts again at 1.05 pm.
>
> The average amount produced is 20 items each minute.
>
> How much production was lost while the machine was stopped?
>
> You can fill in the second column of Worksheet 5 for extra practice at multiplying numbers.

This final instruction betrays the real agenda. Apart from the improbability of a breakdown on the stroke of 12 noon (and maybe an extended lunch-hour?) there is no consideration of the reality of the situation. For example, there may have to be a line clearance (complete cleanout) for certain products before the process can start up again. In any case what happens to products partly completed — are they to be discarded or reworked? How long will it take between the restarting of the machine and the resumption of full production? Is it the case that workers have repeatedly complained to management about poor maintenance processes or ageing machinery? And so on.

4.4. CONCLUSION

In this chapter I have offered a case study of the kind of vocational mathematics offered to Australian workers, set in a brief history of the institution of adult and vocational education. With few exceptions the impact on vocational mathematics curricular content of 20th century developments in applied mathematics and of continually evolving work practices, increasingly interlinked with technology, seems minimal (cf., Griffiths & Howson, 1974). That is, students are still spending much of their limited time practising mathematical skills which may be more efficiently carried out by electronic devices and are thereby being denied, in the limited hours available, potentially more useful and interesting applications of practical estimation, interpretation, evaluation, and workplace error detection and problem solving. From the USA, David Pucel (1995) warns that:

> most adults returning for education for employment will continue to be taught using standard mathematics courses that present the traditional range of mathematics. Such courses are often ineffective because students view many of the mathematics skills that are taught as irrelevant. . . . Such perceived irrelevance often causes adults to drop out of programs and forsake their occupational preparation. (p. 55)

The consequences of dropping out can be quite serious to the learner, both in terms of psychological impact on identity and in real threats to their security of employment (FitzSimons & Godden, 2000). At the macro level there are economic costs to society, among other things, in the educational opportunity foregone.

The issue of contextualisation also appears to have been treated superficially. Because the workplace and the classroom are two distinct communities of practice the strongest link between mathematics and its applications is broken (Mathews, 1991). Not all mathematical aspects of a job are observable or even perceived (Harris, 1991; Mathews, 1991), and textbook applications (whether in print or on-line) can never replicate the constraint-filled situation of actual practice (Masingila, 1993), nor the affordances (i.e., contextual clues and properties of artefacts) of the workplace (Wong, 1997). Provided that they do not replicate the pseudo-contextuality of many texts, the use of interactive CD-ROMs may offer more possibilities in future, although initial costs are likely to be high. There are situational differences between educational and workplace settings in motivation, objectives, focus on mathematical (and other) process, available data, precision, accuracy, language, and permitted levels of sociability (Hoyles, 1991). Regardless of whether students are school children or (potential) workers in the VET sector, Boaler (1993) expresses well the problems associated with contextualisation:

> [the strategy of] random insertion of contexts into assessment questions and classroom examples in an attempt to reflect real life demands and to make mathematics more motivating and interesting . . . ignores the complexity, range, and degree of students' experiences as well as the intricate relationship between an individual's previous experience, mathematical goals, and beliefs. (p. 13)

She continues that contexts cannot be assumed to offer a unique meaning, and may not be helpful according to whether or not students perceive the task as irrelevant or artificial. For contextualisation to have value, learners need to appreciate and understand the potential generalisability of what is learned, and this must come from reflection on structures and processes. Helme (1995) and Wedege (1999b) give compelling examples of the importance of appropriate context in adult learning situations.

The issue of extending learning opportunities to workers previously excluded or marginalised (O'Connor, 1994) must be taken seriously. I have used Basil Bernstein's work to illustrate some of the values and assumptions inherent in the mathematics recontextualising field in the pharmaceutical manufacturing industry, and to indicate some of the silences concerning populist knowledge held by workers. Although the Learning Outcomes and Assessment Criteria for Calculations A (as listed above) are supposed to be competency-based and learner-centred, they differ only superficially from those found in traditional elementary school mathematics. In any case, curricula such as these are arbitrary, not justified by workplace research, nor founded upon adult education research.

In addition, these curricula are accompanied by texts which would be regarded as inferior by the vast majority of mathematics educators around the world who have participated in any form of reflective practice. In Bernstein's (1996) terms, they give an indication of the confounding of the competence model of CBT with the performance model of mathematics education, discussed in chapter 3. How did this kind of curriculum and pedagogy come to represent what counts as mathematics in adult and vocational education? What effect do curricula such as these have on professional teachers' identities? Chapter 5 will address the impact of curricular decisions and changing working conditions on vocational mathematics teachers in Australia.

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CHAPTER 5

TECHNOLOGIES OF POWER: THE RECONTEXTUALISING FIELD

Curriculum and the Conditions of Teachers' Work

5.1. INTRODUCTION

The conditions of students' learning are inextricably related to the conditions of teachers' work. In this chapter I draw upon the work of Basil Bernstein for further theoretical perspectives on the Australian case study presented in chapter 4. I then relate these to broader aspects of teachers' work in the Australian VET sector in terms of the institutional constraints placed upon their professionalism.

5.2. VOCATIONAL MATHEMATICS CURRICULUM

Thomas Popkewitz (1997) argues that curriculum is a practice of social regulation, historically formed, inscribing systems of reasoning which are the effects of power, shaping and fashioning interpretation and action. Curricula not only regulate what content is selected, but also the construction of the student's 'self,' particularly in relation to labour market training (Farrell, 1999, 2000; O'Connor, 1994). Drawing on Foucault and feminist theories, he claims that the concept of an 'educated person' has shifted according to social and political conditions: teachers and students are re-visioned "as objects that are systematically classified, legislated, standardized and normalized" (Popkewitz, 1997, p. 148). Thus, curriculum and other policy documents should be read as expressions of classification of social problems and practices deployed to overcome them. How has vocational mathematics served to reproduce social relationships?

In Australia, since the late 1980s there has been a shift in control over school and VET curricula towards meeting the perceived needs of the economy (Marginson, 1997). Over a decade ago, Fitzclarence and Kemmis (1989) made the observation that mere had been changes in the social relationships of education, not confined to the new communication technologies but also appearing in the technologies of social and educational administration. They argued that this might undermine the very possibility of critical thought. Although the focus of their concern was distance education for Masters students, which they asserted should be able to "offer a theoretical alternative to narrow, consensualist, bureaucratic and technicist approaches to thinking about education" (p. 174), their critique applies equally to the Australian VET sector.

5.2.1. Mathematics Curriculum in the Australian VET Sector

What do TAFE practitioners believe about current mathematics curricula?

> The curriculum is wide open now & students, especially those from industry, prefer to select non-math related subjects & not the hard-core engineering subjects. . . . It is not easy to impress on people the value of mathematics in a technical environment when other soft options are readily available in similar environments. [Male, >5 years TAFE experience]

> Mathematics is not considered important by those responsible for TAFE course design and mathematics testing is a mere formality — a pass means nothing. . . .Mathematics teaching is declining. Electronic mathematics, I-IV was 72 hours each module. Now there is a 40 hour total. [Male, >10 years TAFE experience]

> But it amazes me, here, like I used to work in the Centre for Computing and Information Technology, and there's no maths in their courses. Now they need to know about binary number systems, and so on. They need to know a little bit of Boolean algebra; when they're doing spreadsheets they need to know how to use formulas. [Female, >10 years TAFE experience]

Vocational mathematics content is apparently considered by powerful stakeholders in Australia to be of diminishing importance. Why? How is it that the teaching of vocational mathematics is virtually disappearing from even the most technological courses, such as Electronics, Engineering, and Applied Science? And that which remains becomes 'watered down' to "numeracy" — a subject intended to be taught genetically (if at all) with literacy, as and when needed?

Clearly vocational courses are supposed to reflect the needs of the relevant industries as determined by their representative educational advisory bodies, so that certain branches of mathematics are more likely than others to appear in accreditation documents (e.g., calculations for trade areas, Boolean algebra for electronics technicians). Applied mathematical work in the academy and in industry appears to have had minimal effect on the actual content of the majority of Australian VET mathematics subjects which almost inevitably focus on a small subsection of teachable material from the discipline of mathematics, generally located in developments made well before the 20th century. Why did the curricula which were accredited until the last few years of the last century, free from the overwhelming influence that the universities had and continue to have on year 12 (final year), remain so dominated in form by the traditional mathematics education of earlier eras? Why does there appear to be an unquestioning acceptance of the tenet — not supported in the literature — of a fixed hierarchy of mathematical concepts and order in which they are supposed to be learned?

Why have certain generic content areas such as algebra (including concepts of rates of change, maximisation and minimisation) or statistics, even quantitative literacy, which are arguably of universal importance in industry — highlighted in chapter 2 as being of critical importance to workplaces of the future — been precluded for certain occupational groups? Does this reflect a failure to comprehend that many occupations require a broad spectrum of unrecognised — or unrecognisable to the layperson, and indeed some mathematics educators —

mathematical knowledges? Where are the visible signs of the influence of rapidly changing industrial and information technologies burgeoning in the last two or three decades?

Why are students enrolled in personal service industry and creative arts courses, for example, deemed not to need *any* mathematics? Is the diminishing mathematical content, even in technician courses, merely a pragmatic attempt at improving the completion rates? Above all, what consideration is given to the personal, social and civic development of vocational students as people who inhabit a mathematised, increasingly technological world, premised largely on economic goals and characterised by information saturation? Whose views actually inform decisions as to which mathematical content is worth knowing?

The introduction of the National Training Framework and its so-called Training Packages has seen a shift in control mechanisms from accredited curricula (as with the NVMCP framework topic packages) to assessment of outcomes according to sets of industry competency standards. In contrast to other sectors of education, curriculum no longer plays a central role in the VET sector, concomitant with a diminishing role for teachers, as all learning may now, in theory at least, take place on-the-job. With this non-endorsed model of curriculum the locus of power and control has shifted from the teacher — embodying the institution of education — to the 'user' — student or, most likely, employer — thereby making it more difficult to evaluate or to challenge. The question arises: What might be possible reasons for the elision and in whose interests are these changes? Chapter 6 will take up these questions from more theoretical perspectives.

Nerida Ellerton and Ken Clements (1994) have documented evidence of recent struggles over control of school curricula in Australia, especially mathematics. Yet over the last decade, there has been no visible evidence of any contestation by mathematics teachers in the Australian VET sector over mandated CBT curriculum and assessment regimes. One reason for this may be the widely engendered belief, accepted by TAFE teachers, that the curricula represent "what industry wants" (see, for example, Johnstone, 1993).

5.2.2. Goals for Vocational Mathematics Curricula

In the formation of curricula many goals need to be taken into account (Bishop, 1993; Niss, 1996; Stevenson, 1995a); it is not simply a matter of matching the curricula to the perceived needs of the employer which would serve neither the interests of individual students nor society at large (Ernest, 1991; FitzSimons, 1997b). Anna Sierpinska and Stephen Lerman (1996), building on Sal Restivo's case for a strong sociology of mathematics, argue that communities validate themselves, establish and retain power through their justification of socially valued knowledge. They claim that this applies to the investment that mathematicians have in the status of mathematics in society, "and it is certainly the case for mathematics educators and the status given to [school] mathematics curricula all over the world"

(p. 840). What effect might the support of mathematicians have on the public image of vocational mathematics, and with what consequences?

As noted in chapter 1, goals for school mathematics are based on the presuppositions of mathematics being able to make a contribution to the technological and socio-economic development of society at large, to its political, ideological and cultural maintenance, and to individual development (Niss, 1996). I contend that these foundational reasons should not be confined to the needs of school students if one follows the tenets of lifelong education, espoused by many governments, and assumes that adults are continuing to develop throughout their mature years. In any case, there are overlaps in age between Australian VET sector students with senior school and undergraduate students, so that there can be no justification for an abandonment of goals other than industrial ones (Stevenson, 1996, 1997).

Sue Willis (1996), developing the idea of cultural conflict identified, from a social justice perspective, four approaches to curriculum with consequent (re)solutions:

1. The curriculum is taken as more or less given. Students who are not adequately prepared are treated as *remedial,* or regarded as having *skill deficits,* and the solution is to provide assistance for that which is lacking.
2. The curriculum is also assumed as fixed, but pedagogical and assessment practices favour or relate to the experiences, interests, and cultural practices of some social groupings more than others. The proposed solution is to develop *non-discriminatory* practices so that the experiences of all students are recognised in a supportive learning environment with more valid and fair assessment practices.
3. The curriculum is viewed as a selection, neither given nor unchangeable, which reflects the values, priorities, and lifestyles of the more powerful members of the dominant culture, and which acts to produce relative advantage. The solution is to provide curricula which acknowledge, accommodate, value, and reflect the experience of the diversity of social groups, adopting an *inclusive* perspective.
4. A *socially critical* perspective considers the problem to lie with the way the curriculum positions, classifies, and selects students, in the interests of reproducing the status quo. The solution is to challenge the hegemony in a way that is recognised by all participants. This means helping students to understand and exploit the explicit uses of mathematics in their own interests and in the interests of social justice, as well as the problematic uses of mathematics curriculum.

Following Willis's analysis, the first perspective could describe TAFE vocational mathematics since the inception of the TAFE sector, at least, in its provision of remedial tuition and access programs. The second perspective could be related to the history of technical education in Australia which has traditionally favoured masculine interests, as have mathematics curricula—especially in view of their close connection to the trades and technologies. Encouraging the use of vocational applications probably renders an appearance of non-discrimination and hence gender neutrality since the curriculum is supposed to reflect the students' perceived vocational interests. However no other social interests are seriously addressed — as is the case in some other subjects such as basic computing (e.g., Australian Committee on Training Curriculum [ACTRAC], 1994) — and vocations themselves may be inherently gendered, racist, ageist, and so forth.

The third perspective could be related to the past as well as recent vocational curriculum selection which reflects the dominance of powerful industry representatives who sit on advisory bodies, and the consequent privileging of industrial values over all others. In terms of mathematics it means privileging the traditional school mathematics experienced by predominantly male industry spokespersons (Willis & Kenway, 1996). ("It was good for me, so . . ."). There has been a failure in Australia to problematise either the relevance to current industry practices or the unequal distribution of access to rewards in the form of mathematics-linked credentials. On the other hand, the proposed solution of inclusivity has long been espoused by the ACFE sector (see FitzSimons, 1997a, 2000d) and some TAFE preparatory courses with few or no externally imposed restrictions on content, assessment, and/or pedagogy. Notably, the latter, unregulated courses have all but disappeared in the current political and economic climate of accountability.

The fourth, socially critical, perspective appears antithetical to the thrust of the training reform agenda which, as illustrated in chapter 4, appears to desire a compliant, self-regulating workforce.

The question may be asked: "What are the goals and purposes of vocational mathematics instruction and whose are they?" In senior secondary school, where mathematics becomes an optional subject, the focus would appear to be on achieving a credential as a prerequisite to further study, sometimes employment, and as a general tool for other areas of study. In this environment the emphasis is on the discipline of mathematics itself, with applications usually included to provide some motivation. By contrast, mathematics in the vocational education sector, when identified as such, is usually compulsory; therefore it is essential for completion of the desired course of study and hence achievement of the credential. Its inclusion in a course of study is ostensibly on the grounds that it will be useful as a tool on the job if not in other subject areas (ACTRAC, 1993). However, Corinne Hahn's (2000) study of jewellery apprentices problematises this assumption. Similarly there appears to be a belief that learning mathematics (any mathematics) will enhance higher order thinking skills — this is not necessarily a valid assumption either. Certainly worker/students have strong opinions (often expressed in graphical language!) as to the usefulness or otherwise of the content and processes of vocational mathematics subjects in actual practice. Although the intended emphasis is on the utility of mathematical applications, it is not uncommon to find an ambiguity of purpose between mathematics as a means to an end and mathematics as an end in itself. Personal experience suggests that, contrary to popular belief, it is the latter which actually prevails in mathematics modules such as those indicated for applied science, business studies, and manufacturing operator courses, for example.

Chevallard's (1989) distinction between explicit and implicit mathematics (see chapter 1) highlights the dilemma which confronts the construction and selection of vocational mathematics curricula. The opinions of decision makers (curriculum developers and teachers) who have not given thought to this distinction are likely to reflect the popular view that less and less (explicit) mathematics is needed in any occupation (e.g., Noss, 1997). The continuation of modernist Fordist production and Taylorist workplace organisation ideologies results in fragmented, hierarchical mathematics curricula which tend to reinforce the tradition of giving workers at the lower skill levels a similar mathematical diet to children in lower levels of school, albeit dressed in supposedly adult or vocational examples — as illustrated in chapter 4. Adults are positioned as incompetent in an educational system based upon abstraction. Such curricula also fail to recognise the actual knowledge and skills they do (or might) possess which are often quite sophisticated, and frequently invisible (e.g., Farrell, 1996; Fasheh, 1990; O'Connor, 1994). In fact, as Elizabeth Buckingham (1997) observes, such workers are likely to be using and understanding different, broader, even more sophisticated mathematical and statistical ideas, simply because they are contextually significant (see also Cooley, 1985, quoted in Dowling, 1998), but may be unable to satisfy competency requirements on a decontextualised basic skills test without the use of a calculator.

Lack of agency was noteworthy among workers at lower qualification levels in Buckingham's (1997) study. In order to participate meaningfully in workplace decision-making, a sense of mathematical empowerment needs to be engendered (Wedege, 2000a, 2000b). However, it is questionable whether the previously accredited mathematics curriculum could make any contribution to the higher order thinking skills, to say nothing of day-to-day work practices. According to Jim Ridgway and Don Passey's (1995) study, engineering apprentices require great precision, different techniques from school, and much practical problem solving. They found that, contrary to expectations, the competencies learned from a broad-based education generalise to practical work whereas the acquisition of mathematical technique does not; technical perfection is not a 'foundation,' but rather is a component of mathematical education. In other words, basic skills do not underpin mathematical performance in general. They conclude that, rather than concentrating on basic skills, mathematics education should encourage the development of a broad range of skills and some successful application of technique; skills should also be deployed in a range of contexts. This emphasis on 'the big picture' (particularly in dealing with statistics) was underlined by an Australian engineer for the Ford Motor Company (Pettigrew, 1992). Similarly Paolo Boero (1989), NBEET (1995a), and NBEET/ESC (1996) argue for more holistic appreciation of mathematical aspects of workplace and broader social problems and issues but with an emphasis on the use of technology as a tool in statistical and spatial modelling.

The evidence from workplace research suggests that the formation of vocational mathematics curriculum — through a process of occupational task analysis (e.g., Blackmore, 1999; Johnstone, 1993), followed by selection of mathematical topics from the national framework formulated in CBT mode by so-called 'curriculum specialists' and garnished with supposedly contextual applications — is not viable, premised as it is on an unproblematic notion of transfer. In fact, the literature on changing workplaces and the new work order suggests that industry will not be well served by a reliance on epistemologies, curricula, and pedagogies grounded in eras of the past. As noted in chapter 2, Clive Kanes's (1997b) empirical research on how workplace mathematics is used in practice has a certain resonance with attempts at producing reflective knowledge in the classroom, situating mathematical learning within problematic social and environmental issues (e.g., Keitel, Kotzmann, & Skovsmose, 1993).

5.2.3. Transfer, Process, and Content

One fundamental issue linking content and process and the goals of curriculum with the goals of teaching is the notion of transfer. There is a large body of research, including that written from a sociocultural perspective (e.g. Lave, 1988; Lave & Wenger, 1991), which indicates that there is no evidence that what is taught in school (or vocational) mathematics classrooms will transfer *directly* to the workplace. Joanna Masingila (1993) asserts that the so-called contextualised applications of typical textbooks are of little use in aiding transfer because they ignore the complexities inherent in any workplace. However, to increase the complexity of textbook problems would also increase the complexity of the reading required and, as mentioned above, still not provide all of the affordances contributed to the formation and solution of problems posed in authentic settings. Jeff Evans (1999, 2000), following the poststructuralist work of Valerie Walkerdine, used discourse analysis to theorise the boundary between everyday knowledge and school knowledge. He was able to identify possible difficulties inadvertently caused by the use of contextualisation. Respondents called up incorrect or inappropriate responses if they felt positioned in practices other than academic mathematics, such as practical mathematics. Evans (1999) argues that "the quality and intensity of affective charges may often be a major influence in the success or failure of many attempts at transfer — an influence that has so far been largely ignored in the mathematics education literature" (p. 32). Robyn Zevenbergen (1996) drawing on the work of Evans, used the case study of a novice swimming pool builder to argue that it cannot be assumed that school mathematics will transfer unproblematically (see also Williams, 1993); in fact the novice's faulty attempts to do so resulted in costly mistakes. At the same time much of the ethnomathematical knowledge of the workplace experts was inaccessible because it was intuitive and unable to be articulated. In mathematics education, Jo Boaler (1993) and Masingila (1993) among others have made recommendations for the enhancement of transfer in mathematics education; Fred Beven (1994) and Stephen Billett (1996, 1998) have done so in the vocational education sphere.

The issue of process appears to have been largely ignored in the Australian VET sector. It could be expected that, being promoted in the rhetoric of the NVMCP (ACTRAC, 1993), process issues would be underpinned by an ongoing, research-based professional development programme, but this has not been the case. Problem solving strategies cannot be utilised effectively in the absence of domain-specific knowledge according to Alexander and Judy (1988); for vocational education generally, the teaching of process has been addressed as 'thinking skills' (e.g., Soden, 1993). In mathematics education there was a strong push about a decade ago for work on problem solving and metacognition (see, for example, Charles & Silver, 1989; Mason, Burton, & Stacey, 1985; Mason & Davis, 1991; Schoenfeld, 1992). However Ken Clements and Nerida Ellerton (1996) observe that the problem solving movement is now in decline because it had neither theorised the nature of problem solving itself nor its pedagogical development. Jeremy Kilpatrick (2000) adds that proposals for radical change to mathematics education have not always provided sufficient evidence to counter the inevitable criticism from conservative elements, as evidenced by the recent backlash against the NCTM Standards documents in the USA (e.g., Wu, 1997).

However, the vexed question of selection of content for adult students who have yet to decide on an occupation remains unanswered. Clearly there has to be a balance between content and process. Thus, mathematics education for vocational students ought to be broader than a set of skills and techniques. Ole Skovsmose (1994) distinguishes between three types of knowledge:

> (a) mathematical knowledge, which refers to the competencies we normally describe as mathematical skills. . . ; (b) technological knowledge, which refers to the ability to apply mathematics and formal methods in pursuing technological aims. . . ; and (c) reflective knowledge, which has to do with the evaluation and general discussion of what is identified as a technological aim, and the social and ethical consequences of pursuing that aim with selected tools. (pp. 101-102)

Following the work of Skovsmose, Tine Wedege (2000b) defines technological competence in the workplace under three broad categories: professional, social, and democratic. According to her, mathematical qualifications for a technological workplace must comprise knowledge, skills and applications that are relevant to both technical use and work organisation, together with their interaction. Niss (1983, cited in Skovsmose, 1994) asserts that competence is needed to understand the role of mathematics as well as to be able to perform applications. However, he claims that these instruments of understanding need not be mathematical in themselves, maintaining that an accumulation of mathematical knowledge does not necessarily provide the competences for evaluation and criticism.

Commentaries such as these suggest a wider role for mathematics education than has traditionally been the case, particularly in the VET sector. Vocational mathematics curricula in Australia appear to be based on notions of essentialism, exemplified in the CBT approach (see below), which are clearly inappropriate. Is it possible to work around this curriculum and operate more holistically to integrate workers' breadth and depth of prior experience across a broadened view of curriculum in a manner that enhances rather than hinders lifelong learning? According to Wedege (2000a, p. 133), the teaching of mathematics for the workplace "must reach across established subject demarcations, precisely because the reasons for choice of material and content are derived from outside, and not within the subject of mathematics."

Neither the grand narrative of the NVMCP framework nor an individual employer's determination are likely to provide an adequate mathematics curriculum. In order that students are able to gain some experience in transferring their knowledge as well as utilising in a practical sense their non-mathematical knowledge, a mathematically informed analysis of occupational needs is necessary. This should be supplemented by detailed knowledge of the occupation or broader vocation, with vocational and mathematics educators working in collaboration with each other and with people actually employed in such work. As discussed in chapter 2, Achtenhagen (1994a), Onstenk (2001b), and the TWIN project (1999) all recommend teaching through core vocational problems. In contrast to the Australian approach which focuses on the acquisition of a collection of isolated skills, the Danish general qualifications approach (Onstenk, 2001b; Wedege, 2000a, 2000b) centrally locates the subject who is to possess and develop these qualifications, accommodating their needs rather than *vice versa,* involving personality and identity in an integrated way. Paul Ernest's (1998c) idea of capability (outlined in chapter 2) provides a structural approach towards addressing the set of three goals identified by Niss (1996). An alternative framework which is focused on the development of the individual's identity as learner/worker is suggested by John Abraham and Neil Bibby (1988).

As noted in chapter 1, Abraham and Bibby (1988, p. 4) comment that ". . . *mathematics* cannot be completely understood without some understanding of the social institution of mathematics." They claim that an understanding of how mathematics structures our judgements and experiences is a necessary complement to an ethnomathematical perspective which is founded upon everyday experiences. They propose a diagrammatic representation of the role of 'conscientization' in a socially and culturally-oriented mathematics curriculum which could provide the framework for a reconceptualisation of vocational mathematics — where, from an industrial perspective, *ethnomathematics* is understood in particular as *workplace mathematics.* The breadth and depth of this approach, although focused on mathematics education, has strong resonance with Onstenk's (1999, 2001a, 2001b) model of broad occupational competence in its attention to social and cultural agendas rather than merely technical knowledges and skills. Abraham and Bibby's process of conscientization proposes a pathway of identification, engagement, critical reflection, critical judgement, and critical synthesis, manifested in the dual institutions of mathematics and the local culture. Adapting their model calls for: (a) locating oneself within the social institution of mathematics and within a particular culture (here, the workplace); (b) confrontation with the socially organised mathematics and the problem of understanding it, together with the collective generation of problems in the workplace requiring mathematical technique (i.e., ethnomathematics); (c) location of mathematical techniques in the social institution of mathematics and understanding why they are produced, together with consideration of the purposes of using different mathematical techniques by reference to values; and (d) the reaching of conclusions about how the purpose of the mathematical techniques affects their usage and social impact, together with the selection of some techniques over others and the production of workplace ethnomathematics. Taken as a whole, these result in the consideration of how the ethnomathematics produced might have been affected by both the techniques made available and the values adopted by the social institution of mathematics.

This model appears to provide a synthesis of requirements as outlined in chapter 2 for a reflective and critical mathematical occupational competence. However, Abraham and Bibby (1988) warn that any attempt at critical debate in mathematics education may be perceived as threatening to certain political interest groups who may try to undermine it. As noted above, this point is particularly salient to the Australian VET sector.

Alan Bishop's (1988) six pan-cultural mathematical activities (*viz.,* counting, locating, measuring, designing, playing, & explaining) may provide a broader framework for observation of mathematical activity in the workplace from which to formulate locally meaningful curricula. As recommended by writers such as Llandis Barratt-Pugh (1997) for vocational education and Stieg Mellin-Olsen (1987) for mathematics education, students should be actively involved in the design and construction of the learning process, situated within the broad social and political domains of their existence. This, however, is not to deny a role for the teacher.

In the promise of the economic, social and cultural capital it offers, mathematics education is generally accorded high status; it can be harnessed to serve a range of particular interests, locally and globally. An underlying theme of curriculum debate is that of knowledge interests. Whose interests have been served in the past, and whose interests are educators of adult workers, paid or unpaid, fully employed, under-employed or unemployed, intending to serve? The mathematics education of the person as current or prospective worker contributes to a larger complex of roles played as a member of the multiple layers of the society which they inhabit. The development of practical self-confidence in meaningful situations is an element of personal empowerment, inextricably linked with other social and cultural contextual factors, yet something characteristically lacking among the general public when confronted with an explicit mathematics problem (see chapter 1). In an increasingly technological world workers in a wide variety of industries will be confronted with explicit and implicit mathematical problems extending far beyond the basic skills of elementary arithmetic in breadth of content as well as in higher order skills of problem conceptualisation, interpretation, and so forth — as illustrated, for example, in Onstenk's (1998, 1999, 2001a, 2001b) model of broad occupational competence, discussed in chapter 2. One issue is whether workers will be able to access and develop their existing mathematical knowledge with confidence to creatively find solutions for the real problems they encounter, personally and professionally, in the workplace and elsewhere. Vocational mathematics curricula have been closely linked to certain areas of school mathematics and some under-graduate mathematics with insertion of (oftentimes spurious) vocational applications; yet these may be inappropriate for meeting the *actual* needs of workers and workplaces. However, the needs of the whole person should also be taken into account so that curricula are not unnecessarily restricted to the immediate needs of one occupation or even just the one worksite. The worker/student should be able to function socially and democratically in society at large (including the workplace) as well as have enough technological background to progress in their occupation, or to be able to change occupations. Further, this social and democratic competence should extend to allow for critique as well as adaptation. Is it possible for vocational mathematics curriculum design to transcend the narrowness of content focus in the tendency towards essentialism, given a burgeoning mathematics education research literature (e.g., chapter 2) to indicate its inappropriateness?

5.3. BERNSTEIN'S MODELS OF COMPETENCE REVISITED

One of the most powerful means of establishing stronger central control, steered at a distance, over teachers and students in the Australian VET sector has been the implementation of competency-based education and training. This has not been unproblematic yet it remains entrenched after a decade in Australia (and other English-speaking nations as well).

As discussed in chapter 3, Basil Bernstein addresses the concept of *competence* as part of his theorisation on pedagogising knowledge. In his analysis at the macro-, institutional level, competences are intrinsically creative and tacitly acquired in informal interactions. Socially constituted, but independent of any particular culture, Bernstein summarises the features of competence theories as having an inbuilt procedural democracy, creativity, and virtuous self-regulation. The concept of competence resonates with liberal, progressive, and even radical ideologies. The official rhetoric (e.g., Porter, 1993, quoted in chapter 3), in specifying outcomes and conditions, illustrates 'procedural democracy' in terms of openness, but only at a superficial level. As illustrated in chapter 4, there are silences not only about the knowledge workers actually possess; also about understanding and critique of power relations in the workplace.

Pedagogic communication may occur formally or informally, with or without request (e.g., via the mass media); but pedagogic acts are distinguished by information being specifically recontextualised in order to meet the needs of the requester.

In the remainder of this section I re-state distinctions made by Bernstein, first iterated in chapter 3. These are exemplified in the comparisons between traditional school mathematics (performance) and CBT (competence) pedagogic models.

By producing two contrasting general models, *competence* and *performance,* Bernstein (1996) shows how knowledge recontextualised as 'competence' constructs a specific pedagogic practice. In contrast to the informal competence model described above, the performance model "places emphasis upon a specific output of the acquirer, upon a particular text the acquirer is expected to construct, and upon the specialized skills necessary to the production of this specific output, text or product" (pp. 57-58). I suggest that the competence model has much in common with the institutional discourses of (CBT) vocational education, and the performance model with the institutional discourses of mathematics education. The subsequent section will address some implications of such an alignment at the institutional level.

Firstly, in the performance model but not the competence model, there is a specialisation of subjects, skills, and procedures; explicitness of rules; and a lack of control over (content) selection and grading. Time is differentiated insofar as the present tense is favoured in competence models, with weak and implicit sequencing and pacing, based upon the needs of the acquirer. Relative to competence models, performance models emphasise the future.

Secondly, competence models emphasise what the learner can do, although the criteria are likely to be implicit and diffuse. By contrast, the performance model emphasises what is absent in the learner's work, with criteria explicit and specific so that they learn to recognise and to perform legitimate tasks.

Thirdly, under the competence model, positional control is a low priority strategy. Control, then, is likely to focus upon the intentions and dispositions of the learner. The performance model adopts a mode of the instructional discourse "where deviance is highly visible" (p. 60); personalised modes of control are less favoured.

Fourthly, in the competence model judgement rests with the teacher's professionalism, not able to be made totally explicit. In the performance model, the learner's performance is objectified by grades. Grading gives rise to potential diagnosis and remediation, and distribution of blame. Although the future is made visible, it is constructed from a past invisible to the learner.

Bernstein's fifth category of pedagogic autonomy is particularly complex to interpret within the central concerns of this monograph: vocational education and 'progressive' education have many similarities but also differences. According to Bernstein, competence models require a large degree of autonomy. However, the autonomy of teachers regarding their pedagogical practice may be reduced due to the necessity of conforming with the required homogeneity of practice (as is the case with the hegemony of CBT). At the same time, any particular context and practice will require a degree of autonomy in order to meet the particular needs of the learner. According to Bernstein's theory, resources in the form of textbooks and teaching routines are less likely to be pre-packaged, although the trend in Australia's VET sector is towards self-paced learning supported by and embedded within a module production industry — print-based, audio, video, CD-ROM, on-line, and so forth. Perhaps autonomy lies in the acquirer's and facilitator's selection of available resources.

Finally, Bernstein proposes that competence models attract higher costs in terms of specialised teacher training and stricter student selection processes. This is definitely not the case for the Australian VET sector. However, his identification of the hidden costs of teacher time in planning, monitoring, networking, constructing resources, and providing feedback on the acquirer's performance, and so on, is most appropriate. In addition he recognises that these hidden costs are rarely explicitly recognised, and may lead to ineffective pedagogic practice caused by excessive demands on the practice and hence the fatigue of teachers. However, in the performance model, hidden costs are considerably reduced because of the explicit structures of transmission and progression.

This divergence of competence and performance models appears to offer a significant explanation for the rupture between the two institutional discourses — vocational education and mathematics — as played out in the day-to-day experiences of Australian VET mathematics teachers and learners whose institutional history is grounded in performance models but who must now operate under the dominant competence model with its restrictions on curriculum, teaching, and assessment.

5.4. COMPETENCY-BASED TRAINING

In Australia, as in many other English-speaking countries, one major outcome of vocational education policy formation in the 1990s has been the imposition of competency-based training (CBT). In recent years it has profoundly influenced curriculum and teaching in the VET sector — the everyday work of VET mathematics teachers in particular—and is likely to continue to do so. Not only has curriculum changed, but as a result teachers' work as a profession has also changed. Mike Brown (1994, cited in Lindsay, 1999) argues that CBT as a technology is a powerful means of deskilling and deprofessionalising teachers. In this section I will trace the development of CBT and differentiate it from the so-called *Key Competencies* and their counterparts in other industrialised countries. Teaching and learning in the VET sector continue to undergo transformation in response to political imperatives. The underlying CBT model seems to have withstood the best efforts of educational researchers to discredit it although there has been violent opposition by spokespersons from higher education to its introduction in their sector. Several critical perspectives are presented here.

5.4.1. Perspectives on CBT

Harris, Guthrie, Hobart, and Lundgren (1995) remind us that the concept of skill is a social construction, powerfully shaped by underlying social expectations as well as by social and political contestation. Distinctions between professional and occupational categories, often taken as natural, depend on historical and social factors, as well as technical complexity and economic scarcity, which help to determine the value accorded to workers. Following industrial award restructuring agreements, CBT has been mandatory in Australian vocational education since 1992, actively promoted by union leaders. The National Training Board [NTB] (1992) adopted a broad, holistic notion of *competence* including all aspects of work performance, but its definition of industrial *competencies* was presented as an attempt to narrowly specify knowledge and skills, together with their applications. The history of CBT has been linked variously to Taylorism, behaviourism, mastery learning, criterion-referenced testing, and has been the object of criticism for its atomistic tendencies as well as gaining support for its holistic qualities (Harris et al., 1995).

Peter Raggatt (1997) researched the politics of the development of CBT since 1985 in the UK, noting with some surprise its subsequent adoption by other English-speaking countries. He asserts that the term *competence* was never precisely defined so that it held appeal for a wide variety of constituents including government, employers, and progressive educators; policy makers originally understood it as a broad notion consistent with the contemporary concept of capability, including teamworking, systems thinking, and problem solving. The agency responsible for the development of National Vocational Qualifications (NVQs) was directly under ministerial control and faced difficulties of having to address a variety of conflicting agendas, not the least of which was the tension between the meeting the requirements of providing a more highly skilled workforce while at the same time operating under conditions of reduced public expenditure and rising youth unemployment. In the convoluted process of implementation the original notion of competence was reconstructed to be replaced by a "narrow, task-focused and increasingly technicist concept which marginalised knowledge and understanding" (Raggatt, 1997, p. 122). The model adopted by Australia resembles this reduced conceptualisation.

Karen Evans (1995) reviewed the British experience of CBT in relation to the NVQs. She found that, although the approaches reflected the values of industry rather than educators, there had actually been a very low level of takeup by industry. Employers found the system to be complex, and only 6% of firms with under 50 staff were using the modules; often these firms were unable to provide training in all of the relevant areas. The numerous disaggregated tasks had generated substantial bureaucratic work, and the language of CBT was found to be a barrier. Evans observed that commonality of language and standardisation of tasks and functions does not, in practice, achieve consistency of standards between providers. She also felt that, after nine years, responses to ongoing criticism framed in terms of better marketing and communication were not credible. She outlined four major criticisms.

1. In terms of competence, the behaviourist approaches based on a functional analysis — in contrast to generic competencies — are reductionist, very elaborate, and assume a reintegration by the learners. Such approaches could only apply at basic levels and would be impossible at more complex levels of jobs and roles.
2. In terms of the relationship between learning and performance, processes and outcomes are intimately linked. That is, there are links between an activity, its context, and the skill or concept to be learned. Learners are entitled to a certain quality of learning process, which is reflected in the outcomes.
3. In terms of assessment, the requirement of inferring underpinning knowledge from competent performance is an impediment to acceptance at the professional level. This underpinning knowledge is important for a future orientation to work, for developing the capacity for transfer, and above all for safety in crisis situations.

4. In terms of core skills (such as mathematics) she believed that, in spite of recommendations for holistic teaching, they are placed in an ambiguous position if they are not separately assessed.

Given that this model of training was prefaced on ideologically-driven preferences for an employer-led system, she noted with surprise the unity between employers and educators in their calls for broader approaches, citing a 1995 report by the Employment Policy Institute which stated that employers prefer a good general education to narrowly based vocational qualifications (see also Brown, 1998). Evans concluded that there had been no thorough evaluation of this CBT model — it was untried and untested, buried in counter-productive bureaucratic procedures, and that this attempt to control the training system by qualifications was implemented with inadequate piloting. Among her recommendations was the call for a more holistic approach, that is "integrating knowledge, understanding and skill, combining analysis with synthesis and recognising that there is a place for judgements about overall performance" (p. 10) (cf., Onstenk, 2001b). It remains to be seen whether much has been learnt in the Australian context since the publication of this report commissioned by Australian authorities.

In examining the construction of competence, John Stevenson (1995, October) notes that, as in other areas of education, policies assign differential values to different kinds of knowledges and represent only particular interests. In the Australian VET sector industrial values have been taken to be the defining criteria for competence, pre-empting the debate about what is desirable for society (the 'good'); the normative aspect of competence has been ignored. Stevenson problematises the nature of competence from a philosophical perspective as he claims it has causal and teleological (i.e., related to purposes) aspects stemming from the ethical matters of capacity and disposition to pursue a good, itself problematic. In the cognitive psychology literature a certain kind of expertise is valued implicitly, and includes activities such as "problem solving, far transfer, adaptability, innovation, creativity, metacognition, so-called abstract understanding" (Stevenson, 1995, October, p. 11). However, although cognitive psychology purports to be value-free, this position of adopting differential values for different kinds of cognitive representations (e.g., conceptual over procedural) has allowed it to be colonised by CBT for which it has offered legitimacy and respectability in CBT's move from its original behaviourist position. Stevenson concludes that CBT, representing a new set of particular values, has assigned a pre-emptive good to education and training. In Australia it has formed a strategic part of the implementation of neoliberal training reform through its stranglehold on curriculum and assessment practices.

Discussing CBT from a pedagogical perspective, Nancy Jackson (1993) claims that

> . . . there exists nearly two decades of scholarship, including theoretical critique and empirical research originating in philosophy, psychology, linguistics, education and sociology, which argues in various ways that the competency paradigm has not and

> probably will not 'improve learning' in most of the educational contexts where it has been applied. (p. 46)

However, in order to explain the enduring popularity of CBT, Jackson (1993, 1995) argues that it is necessary to see such curricula as a tool of administrative reform making teachers and administrators more accountable to the policy process. She insists that CBT reforms be seen as a critical shift in the social relations of the curriculum. The initial process of task analysis based on the perceived needs of the employer (e.g., Johnstone, 1993) has the effect of shifting the reference point of CBT away from traditional disciplines such as mathematics, privileging the workplace as the site of knowledge. (This point will be taken up again in chapter 6.) According to Jackson, in the textually mediated process of curriculum formation the living subjects of the process (individual employers, teachers, students) have been displaced by an objective system of documented curriculum planning and implementation (cf., Gjone, 1998, in relation to mathematics). For example, employers' input on goals and objectives is mediated by curriculum specialists; teachers' roles have shifted from planners of curriculum to implementers of decisions made elsewhere, and they are left feeling alienated and confused by the process. Further, she asserts that the capacity of the curriculum documents to authorise action depends, not on their accuracy or comprehensiveness in depicting the workplace, but on their condition as being organisationally warranted and having officially designated status.

Victor Soucek (1993) identified conceptual problems with the CBT approach in determining: (a) what constitutes knowledge, (b) the relationship between performance and deeper knowledge/understanding, and (c) who selects the skills to be tested and how standards are determined. Adopting the Habermasian categorisation of knowledge into technical, practical, and emancipatory, where he asserts that all three must be taken together to form a unified whole, Soucek (1993, p. 174) observes that "the practical and emancipatory areas of knowledge are ignored, and the normative, expressive, and affective learning domains are significantly undervalued" (see also Bagnall, 1997). He is also critical of the modularisation of the curriculum as tending to fragmentation of learning without providing structures which enable students to make necessary connections. He claims that CBT does not address the social and moral dimensions of the learning experience, such as allowing the learner to develop a sense of task ownership and emotional investment through participation in the setting of problems posed in a social context (cf., Mellin-Olsen, 1987; Skovsmose, 1994, for mathematics). In this way CBT constrains or denies the possibility of learners becoming aware of possible social consequences of alternative solutions.

From a philosophical perspective, Richard Bagnall (1994) asserts that CBT, as a modernist project, provides only one among many alternative ways of addressing vocational education needs of a postmodern society. He argues that the competency-based tendencies "towards orthodoxy, rationality, simplicity, centralisation, knowledge technicisation, pragmatism, learner dependence, reactiveness, commodification, privatisation, conformatism, internal differentiation, and instrumentalism" (p. 18) are in contrast to postmodernist tendencies "towards heterodoxy, expressiveness, complexity, reflexive contextualisation, knowledge diversity, critical understanding, student independence, responsiveness, openness, indeterminacy, participation, internal de-differentiation, and phenomenalism" (p. 18). He places the goals of CBT within a utilitarian social framework of maximising the return on human capital, pursued by means of educational efficiency and effectiveness. Personal experience of teaching women in a non-CBT environment (see FitzSimons, 1993a, 1993 March, 1994b) suggests that Bagnall's elaboration of the postmodernist tendencies has much in common with their preferred learning settings and is supported by feminist literature (see, for example, FitzSimons 1997). Indeed, it can be asserted that the modernist tendencies of CBT are not necessarily compatible with the needs of industry at large (Collins, 1997; Marsick, 1997; NBEET/ESC, 1996; Stasz, 1996).

The new Training Packages fail to incorporate generic competencies or do so in token fashion, according to Sue Foster (1998) — workplace competence needs to include contingency management, knowledge of the job role environment, and task management. Although it is conceded that some providers may customise curriculum, integrate mathematics and other modules, and move between the classroom and the shop floor (e.g., Sefton, Waterhouse, & Deakin, 1994; Sefton, Waterhouse, & Cooney, 1995), it appears that there are few models or incentives for others to do so. The official guide for numeracy trainers (ANTA, 2000) illustrates the perpetuation of the tokenistic approach, identified by Foster, to workplace numeracy.

5.4.2. Key Competencies and CBT

It may be useful to differentiate between the Australian Key Competencies and competency-based training. A series of reports focusing on young people and their employment was passed onto the Mayer committee to develop a set of generic *Key Competencies* (Mayer, 1992), described as being essential for effective participation work and in other social settings. They are as follows: (a) collecting, analysing and organising information, (b) communicating ideas and information, (c) planning and organising activities, (d) working with others and in teams, (e) using mathematical ideas and techniques, (f) solving problems, and (g) using technology. An eighth competency, (using) cultural understandings, was proposed but not officially endorsed; according to Mark Werner (1995) it was recognised as being embedded in the other seven. He also notes that none of the competencies specifically incorporates creativity. Although industry spokespersons strongly argued for the inclusion of attitudes and values, this idea was rejected as not amenable to credible assessment; it was considered that they would be reflected in the application of key competencies. Similar sets of *core* or *essential* or *foundation* competencies or skills have been adopted in the UK, the USA, and New Zealand. (See Werner, 1995, p. 38, for international comparisons; Wedege, 2000b, for European orientations; also Wedege, 2001, on competence as a construction.)

In the workplace, Cathy Stasz (1996, p. 11) observes that the use of these competencies in practice depends on a complex and variable array of "job demands, the purpose of the work, the tasks that comprise the job, the organization of the work, and other aspects of the work context." Somewhat surprisingly, Alan Brown and Ewart Keep (1999) report on a study which found information technology was the skill for which British employers claimed to have the least need; in any case overall demand for these key/core skills was only strong if they were specified at the lowest levels — reflecting the ethos of the prevailing workplace model which remains largely attached to a hierarchical Fordist model of operation, apart from a few leading-edge employers. In the UK, then, numeracy and information technology were not seen to be generic and so were included in only some NVQs. The issue of transfer remains problematic, and although there are expressed desires for the competencies to maximise transfer, it cannot be assumed. Rather, Werner (1995) claims, there is now a greater emphasis on seeking teaching methods which will enhance transfer. This is an issue worthy of consideration with respect to vocational mathematics education.

The key competencies have been criticised by many writers (e.g., Sedunary, 1993; Soucek, 1993) for subsuming (in Habermasian terms) lifeworld interests under system/administrative interests; even signalling the loss of collective capacity for critiquing these changes. There have been warnings about reducing the school curriculum to narrow technicist skills to the detriment of original, creative, independent thinking. As Stevenson (1993) points out it is harder to sustain the argument in the VET sector, but I have argued elsewhere (FitzSimons, 1996a) that creativity, and independent, original thinking are necessary, particularly in mathematics.

A study by Down, Fechner, and Lilly (1997) found that there is an implicit expectation in workplaces that the Key Competencies will be applied at all levels, in routine and non-routine tasks. The ability of employees to use and apply them is often described in terms such as commonsense, experience, and nous (cf., Coben's, 2000a, findings on mathematics and commonsense). It follows that they are expected to develop naturally, and are unlikely to be addressed formally in workplace training programs; they are rarely codified explicitly in workplace instructions, such as routine procedures or standard operating procedures (SOPs). The assertions by Down et al. that (a) the Key Competencies are grounded within the context in which they are applied and cannot be abstracted from their context, and (b) their transfer across differing contexts is neither automatic nor assured, have major implications for vocational mathematics curricula.

The generic key competencies, taken as a whole, have a certain resonance with international mathematics standards documents (e.g., Australian Education Council [AEC], 1990; Business and Technician Education Council [BTEC], 1995; Cohen, 1995 (for AMATYC, the American Mathematical Association of Two-Year Colleges); National Council of Teachers of Mathematics [NCTM], 1989, 2000). It could be argued that all of the Key Competencies are embedded in mathematics understood in its broadest sense. By contrast, the CBT curricula developed in Australia derive from a strong behaviourist tradition and are heavily prescriptive at every stage from concept to classroom. As illustrated in chapter 4, mathematics curricula at various levels (e.g., ACTRAC, 1994) appear to treat the issues of abstraction and transfer as relatively unproblematic; contextualisation is at best often artificial and at worst highly contrived.

The vociferous critique of CBT — which nevertheless has found support among some teachers and trainers of students operating at lower skill classifications — has not been overlooked by the national research strategists who mention the need to assess CBT "with a view to developing strategies to address [its] perceived problems" (NCVER, 1997, p. 9). Although CBT has tended to alienate VET teachers, dampening interest and enthusiasm (Jackson, 1995), Dianne Mulcahy (1996) argues that a more autonomous model of competency training tends to emerge when practitioners reappropriate the formal CBT resources while maintaining and incorporating their own professional knowledge. However her research shows that such reappropriation proceeds informally, unofficially, illegitimately, without threatening the "controlling" mode of curriculum organisation. Allie Clemans (1997), FitzSimons (1998a, 2001a), and Mulcahy (1998) illustrate how teachers can and do operate in the interstices.

Raggatt (1998) suggests that the competence-based approach has strong attractions for the state. Specifying contracts in terms of outputs rather than inputs enables new contractors to more readily enter the field, also reducing the collective power of traditional producer groups. Monitoring performance is easier and cheaper. Funding can become more finely focused, targeted on 'need-to-know' skills. The extent of professional knowledge is reduced, cutting costs and shifting control of expertise from professional bodies to managers. These arguments illustrate one realisation of theorisation of neoliberal technologies of management (to be discussed further in chapter 6) and help to explain the resilience of CBT in the face of enduring educational and industrial criticisms.

In summary, the processes of teaching and learning in the Australian VET sector have been severely constrained by the imposition of a modernist CBT model whose enduring popularity appears to be attributable to its structural formation, ensuring accountability in a era where what can be *shown* to have taken place is of prime importance. It is a technology of management, designed to achieve control over teachers and students alike, underpinned by a technical-rational model of human action. Accredited curricula, notably mathematics which appears on the surface to manifest the required characteristics, have become atomised, reduced to the lowest common denominator of what can be specified, and tested accordingly. Although curricula are *not* endorsed in the new Training Packages, teachers and trainers are referred to previously developed CBT curriculum materials (e.g., ANTA, 1998a). Although CBT was supposed in theory to support the development in students of a set of generic competencies claimed to be essential for participation in the workplace and adult life generally, the connections between the nationally accredited mathematics curricula and the range of key competencies are far from apparent, as was shown in chapter 4. A major issue arises from the implicit assumption of transferability of mathematical (and other) skills and techniques promoted under CBT. In the case of mathematics, the situation appears to have been rarely problematised — Billett (1996) is one exception (apart from my own work, e.g., FitzSimons, 1996a, 1996b, 1997b). On the other hand, research indicates that the competencies themselves are heavily context-bound, and their transfer is neither automatic nor assured. The scant public critique from teachers or from industry of the practices of CBT in relation to the Key Competencies is testament to their pervasive controlling influence in an era of management technologies, where teachers have been led to believe that "this is what industry wants."

CBT is but one, albeit pervasive, technology of management associated with neoliberal policies. An important aspect is the control and de-professionalisation of teachers who are to be rendered replaceable — by workplace trainers or by technologies of education — under the guise of offering flexibility to their VET employers and clients, whether industrial enterprises or individual students. The term *flexibility* has positive social connotations such as adaptability to meet the needs of another person or group of people. However, the concept also has negative connotations, socially and economically, for groups of workers when it requires them to accept reduced autonomy and/or quality of working conditions, even to be replaced.

5.5. FLEXIBLE LEARNING: AN INSTRUCTIONAL PERSPECTIVE

Along with responsiveness, the term *flexibility* has been widely promoted in the provision of vocational education. Alan Brown and Ewart Keep (1999) analysed the various uses of the term in education, from local micro-level to the macro-level provision of national and international systems, together with their frameworks of access and progression. They assert that a system could be judged on the extent to which it allows differentiation in the creation of individual pathways through education and training (e.g., OTFE, 1999). From an individual's perspective it should equip them for flexible careers involving frequent job changes, it should take into account their personal biographies, and allow "self-determined choices irrespective of any more 'instrumental' requirement" (p. 95). Within the system are considerations of openness of entry in terms of access to different types of employment, as well as access to qualifications through Recognition of Prior Learning (RPL). Occupational flexibility could be encouraged by broader vocational areas of study, as would access to higher education. Curricular flexibility may be increased through modular-based systems provided the individual is given scope to choose at least some elements. All of these connotations are reflected in recent glossy Australian publications (e.g., ANTA, 1999, n.d.-a).

I now draw upon research associated with flexible learning as predominantly *self-paced instruction,* where flexibility is predominantly concerned with time and/or location, and implies minimal direct interaction between teachers and students. The sites of learning could be TAFE institutes, homes, community settings, institutions such as prisons and hospitals, or workplaces. In recent years there have been significant steps towards the realisation of the intention of harnessing the potential of global technologies (e.g., ANTA, 1998b; State Training Board of

Victoria [STB], 1998). A second major interpretation of the term flexible delivery is as a description of *the work of TAFE teachers* or other private providers working on-site in industry (usually), at times and locations to suit the clients' needs, delivering a recognised, usually packaged but sometimes negotiated, programme generally to groups of workers. This will be discussed below.

According to Josie Misko's (1994) review of flexible delivery, the rhetoric suggests that TAFE institutes are to modify their structures to "deliver quality learning" (p. 3), and that vocational education will be 'democratised' under flexible delivery. There is a pedagogical assumption that learning will improve if it is tailored to student preferences. One aim states that flexible delivery will "help students develop the technological, organisational and interpersonal skills to become effective members of a flexible and adaptable workforce" (p. 4). There is no compelling evidence given in the report for any of these assertions and assumptions. However, the review does suggest the need for research into costs, structures, and the impact on teaching and learning. It recognises the shift in onus of responsibility (but not costs) to students, and the difficulties which may be caused for people who are not motivated, organised, or who have literacy problems and language difficulties. Access to technologies and technological literacy appear not to have been mentioned although this issue was subsequently addressed by the National Board of Employment, Education and Training/Employment and Skills Formation Council [NBEET/ESFC] (1995).

As with all educational work, flexible delivery is underpinned by a pedagogical framework — even if this not always apparent to the designers themselves. Brown and Keep's (1998) review highlights the need for appropriate selection of media to best support the individual at each stage of his/her learning, in a process which is "discursive, adaptive, interactive and reflective" (p. 51). They also acknowledge that the social dimension of learning is often not recognised in a technology-led approach. But, the questions arise: How often are these factors given consideration in the rush by institutions keen to promote on-line delivery and themselves as leaders in technology? How often do project reports distort or selectively choose evidence in an attempt to justify receipt of special funding for 'innovative' practice? Brown and Keep make the further important point that the notion of skill has undergone a radical change from purely technical task completion to more complex, socially-oriented skills of the key competency kind: communication, working in teams, and so on. Individualised tuition via technology alone has limitations here, although these can be overcome to some extent through interactive means such as teleconferences or videoconferences provided that there are the intellectual and financial resources to support them.

Mathematics, in particular, is susceptible to on-line promotion because of its apparent ease of development. However, this line of thought betrays a lack of depth, or even an awareness, of the importance of pedagogical content knowledge (e.g., NCTM, 2000) in the process; also ignorance of the extreme difficulties experienced by students at 'remote' locations trying to learn mathematics in isolation from the teacher and other students. Personal experience over many years as an off-campus tutor of mathematics subjects suggests an extremely high non-completion rate by students using print-based materials. Short timelines for new on-line projects means that courses are developed in great haste so that there is no time for adequate research into what is already known about teaching and learning mathematics, let alone with technology (e.g., Lagrange, 2000), as energies are devoted to technical features such as screen appearance, action 'buttons' and to administration. For Australian vocational education students skill development tends to remain at the lower levels of Bloom's (1956) cognitive taxonomy, accompanied by spurious contextual examples. Higher order thinking skills and most of the range of key competencies embedded in mathematics are ignored in the pursuit of skills and techniques which are easy to write, produce on-screen, and to assess.

So far in this chapter I have identified and addressed some issues relevant to technologies of power from a broad instructional perspective. The imposition of CBT has brought about massive changes to the practices of teaching and learning over the last decade, and it appears that conceptualisations of flexible learning as the technologising of vocational education have the potential to transform institutionalised teaching and learning in even more significant ways. However, the educational research base in support of these changes in general is meagre, ambiguous, or non-existent. In the particular case of mathematics there is a considerable body of research available on general and specific workplace considerations (e.g., Bessot & Ridgway (Eds.), 2000) the characteristics and needs of adult learners (e.g., FitzSimons & Godden, 2000), and mathematics curriculum, assessment and teaching issues for proximal and distance education that could be utilised for the benefit of all stakeholders. Why is it that these burgeoning areas of research in relation to mathematics education appear to be all but ignored in the Australian VET sector? Is there a nexus between attitudes to mathematics education (and other) research and the conditions of teachers' work?

5.6. THE CONDITIONS OF TEACHERS' WORK

In this section I will address the identity formation of teachers in the Australian vocational education and training sector over the last quarter century, related to their professionalisation in the context of emerging technologies of management.

5.6.1. Teachers' Work in the Australian VET Sector

Forces on teachers are manifold, and the impact of globalisation of economies beyond the determination of individual nations (Harvey, 1989; Shah & Maglen, 1998) can influence education systems, particularly vocational education and training which is implicated both as a cost to the state and as an economic and social investment. The world of work in developed countries is changing rapidly. Peter Kell (1997) notes the compression of time and space, described as 'fast capitalism' (see also Gee, 1994). Referring to the work of Gorz, Kell asserts that the workforce is now being banded into three distinct groups which mirror growing social and economic inequalities: (a) core workers, professional and technical elites, well qualified and well paid; (b) peripheral workers, a 'disposable workforce,' low-skilled, casualised, part-time and poorly paid; and (c) people permanently excluded from the legitimate labour market, but who need to be occupied by attending job preparation courses, and who risk being exploited through being paid "training wages." In Australia, the TAFE workforce itself is increasingly being structured on a core/periphery model: workers' competencies are structured around the central tasks of the organisation, with increasing responsibilities devolved to all staff for personal career management and professional development. TAFE and other VET teachers are increasingly expected to be flexible in their approach to work as they develop their capacity to become knowledge workers (Office of Post-Compulsory Education Training and Employment [OPCETE], 2000).

Seddon, Angus, and Brown (1997) claim that education and training reform has been informed by two converging discourses: economic rationalism and new institutionalism. In the last two decades one focus of political attention has been on "the organisational infrastructure that makes teaching and learning possible: the funding arrangements, industrial relations, the rules of access and choice, policy frameworks governing curriculum and assessment, and governance arrangements" (Seddon et al., p. 112). They note that reformist governments wishing to redesign institutions recognised that they could shape behaviour by manipulating contextual settings.

Thus, teachers' work has been intensified and reshaped. In an attempt to balance increasing costs with diminishing recurrent funding, institutional measures have been designed effectively to reduce classroom delivery costs. As Kell, Balatti, Hill, and Muspratt (1997) observe, for the most part teachers feel that financial, rather than pedagogical considerations have prompted the significant changes to teaching. Composite classes and self-paced learning modules are complementary elements of flexible delivery, accompanied by an increased use of contract, part-time, and sessional (casual) teachers, and these have been viewed by staff "as a significant impediment to a long term and systematic response to client needs" (Kell et al., 1997, p. 11). Kevin Peoples (1995, p. 31) concludes that: "highly trained and professional classroom teachers are no longer seen as providing TAFE with a comparative advantage in the market place." In Australia, as in the UK, questions have been raised about the ethics of policies and practices of vocational education institutes, especially in relation to the discrepancies between glossy advertisements and the everyday realities of teaching and learning (Bailey, 1999; Blunden, 1999).

Changing work practices have tended to polarise staff, resulting in tension and hostility between adherents of old and new models (see Funnell, 1993). As will be discussed in chapter 6, relations between 'neomanagers' and 'public service' orientated teachers have also been polarised (Bailey, 1999; Chappell, 1998). Stephen Ball (1992, quoted in Kell, 1993) suggests that marketisation of education confuses social relationships with exchange relationships, emphasising individualistic notions of choice, resulting in the commodification of education. However, this steering at a distance by the state, utilising paradigms of efficiency and accountability as controlling technologies, has had serious implications for social relationships which arguably have been, until recent years at least, an important motivating force for the majority of TAFE teachers. Over the last two decades TAFE teachers in Australia have lost status, self-respect and autonomy. Could it be said that they have been progressively deprofessionalised under the imposition of neoliberal technologies of management?

5.6.2. Professionalism and VET Teachers

The Australian Senate Standing Committee on Employment, Education and Training References Committee (1998) inquiry into the status of the teaching profession asserts that characteristics of the concept of professionalism include:

- a strong motivation or calling
- the possession of a specialised body of knowledge and skills acquired during a long period of education and training
- control of standards, admission, career paths and disciplinary issues
- autonomy in organising and carrying out their work
- the need for ongoing exercise of professional judgement
- members accept and apply a professional code of practice, (p. 23)

In the Australian VET sector, for example, the entry requirement of long educational preparation and the control of registration and standards have disappeared. The autonomy in work practice has been curtailed, as has the *recognition* of need for exercise of professional judgement. It is difficult to comment on the motivation to take up vocational teaching and training, although Seddon and Brown (1997) ascribe the commitment among trade teachers to repaying and replenishing their industries. What might be the justification for adult and vocational mathematics teachers?

Magali Larson (1990, cited in Seddon, 1999) argues that professionalism establishes a structural link between scarce resources of knowledge and expertise and scarce resources of status and reward. Two important factors are that there is ongoing recognition and authorisation of knowledges by the state, and that there are adequate rewards. Not only have control of entry through educational qualification and registration been removed, but the status of teachers is uncertain in terms of (a) functional occupational differentiation (e.g., from other trainers), (b) public recognition and status (e.g., the tendency towards peripheral rather than core positioning in the workforce), (c) lack of autonomy and workplace control (cf., other human services, such as doctors, lawyers; also professional mathematicians (Martin, 1988/1997)), and (d) the tendency for sections of the community to hold them (and their worker/students) simultaneously responsible for creating and for providing the solution to problems of economic malaise. Addressing the problem of declining status of teachers in general, the Senate Committee (1998) observes that "in some professions status is enhanced by specialised knowledge of its practitioners. . . . everybody has been to school and therefore supposes they understand what teaching is all about" (p. 26). This is precisely the case for mathematics teaching, especially in the Australian VET sector, and this may well contribute to the failure of decision makers in the sector to problematise it in any way.

One issue implied but not mentioned specifically by the Senate Committee (1998) is that of ongoing professional development — it is inconceivable that any other profession, or its management, would fail to expect and to support continual updating by all staff in the literature and practical implications of the latest research. Yet, as mentioned above, this is the case in the Australian VET sector. Kell et al. (1997) found that there was a need for the provision of training and developmental opportunities in activities outside the traditional roles of teachers, such as marketing and negotiation. (The issue of professional development specifically for mathematics teachers seems not to have been raised at all in the report.)

> Staff were generally critical of the number and nature of professional development opportunities offered as well as the procedures for accessing them. Many staff expressed a sense of frustration about the availability of professional development and had, in many cases, undertaken professional development independently in an effort to meet their own developmental needs. (Kell et al., 1997, p. 13)

This lack of continuing, appropriate professional development is all the more unbelievable when it is considered that the business of the VET sector is to encourage the professional development of others (e.g., ANTA, 2000).

The common tendency to make simplistic assumptions about the nature of teaching suggests a return to what Andy Hargreaves (1997) terms 'the pre-professional age,' dating for about one hundred years prior to the 1960s, where knowledge of content matter alone was deemed sufficient for teaching. Following Bourdieu (1991), teachers' symbolic capital in terms of authority to speak has been eroded by state intervention. Conditions of work for teachers are constantly being eroded as the forces towards de-professionalisation intensify; they are tending to become replaceable factors in the production of vocational education and training (Girdwood & Reich, 1997).

The future for teachers as professionals in the Australian VET sector does not look promising. Changes to work practices as a result of the globalisation of economies as well as the adoption of neoliberal policies together with new institutionalism have seen the intensification and reshaping of teachers' work. There are expectations of an increased range of tasks outside of traditional teaching, restrictions on dimensions of classroom activity in terms of flexible delivery and composite classes, and changes to teachers' employment which see the transition for many from core to peripheral workers. Paige Porter (1997) comments on the irony of a reduced public commitment to education at the very time when, according to Thurow (1996, cited in Porter), the development of human skills are more critical than natural resources or capital to a nation's economic competitiveness and prosperity. The impact of successive corporate restructures in TAFE institutes and intensification of teachers' work, together with an apparent lack of empathetic understanding of the nature of teaching has, not surprisingly, had detrimental effects on teachers' morale (Funnell, 1993).

5.6.3. The Work of Mathematics Teachers in the Australian VET Sector

The trends towards casualisation of the workforce and removal of educational qualification requirements, for example, suggest that there is also likely to be less demand for qualified *mathematics* teachers — as is already the case in many trade areas. This is in part a consequence of the trend away from discipline knowledge in favour of occupational skills (McIntyre & Solomon, 1998). It is also partly due to the fact that mathematics in the workplace is barely visible ‘to the naked eye’ — those called upon to identify education and training requirements tend to perpetuate the ‘basic skills’ regime rather than acknowledging the breadth and depth of its application. And of course, as Mary Klein (1999a) argues, everybody knows from many years of apprenticeship served in the school system how mathematics should be taught!

The shift away from disciplinary structures is already evident in the demise of mathematics departments in TAFE institutes. In a quarter of a century the work of TAFE mathematics teachers has been reconstructed. Previously, they were securely employed, helping students complete trade or technician qualifications, or second-chance courses. Relatively autonomous, albeit subject to curriculum and assessment constraints, teachers were proud of their chosen profession and felt valued by their institution and by many of the students whom they assisted in gaining a career. Vocational mathematics education was firmly institutionalised until the last decade or so. Now it is fragmented, without any career path for discipline-oriented mathematics teachers. Although there may be a case for someone with a strong vocational background to teach the mathematics for that particular trade or vocation, a common practice has been to relocate specialist mathematics teachers individually within vocational areas, destroying any feeling of professional community — at a time when networking across colleges was becoming virtually impossible due, among other things, to increased workloads.

Just as curriculum development recontextualises mathematics text for broad educational purposes, mathematics teachers recontextualise curricular text for specific pedagogical purposes. In other words, teachers form a crucial link between the curriculum and the students. One question which arises is the impact of the epistemologies of mathematics held by vocational educators. Another is that of their content knowledge — pedagogical and disciplinary. Absolutist epistemologies and limited choices of pedagogical approaches are likely to prevail when entry standards are non-existent and professional development is minimal (see below).

Contradictions and tensions are played out between mathematics education as a field and its historical provision in the Australian VET sector. Reflecting the sector’s technical school and senior technical college origins, vocational mathematics teachers were, and still are, respected for supervising quiet classes, passing on the year’s teaching notes to the next person, being attentive to individual students (especially in self-paced learning mode), and handing in results on time. The traditional transmission paradigm was and remains paramount in most vocational classes, if not necessarily in further education classes. The technologies of management in the organisation and control of teachers’ work, manifested through the imposition of CBT and measures of so-called ‘quality assurance’, may have brought about structural changes in classroom management and delivery, but have made minimal impact on the dominant transmission paradigm in mathematics. Ironically, they have curtailed opportunities for creativity by mathematics teachers and students alike — contrary to industry demands for a creative workforce.

Since the 1980s, school mathematics education has been influenced by international movements towards a problem solving and modelling agenda, incorporating the use of technology as a means as well as an end of instruction. These agendas and strategies were soon to follow in the university sector, in the USA at least (e.g., Schoenfeld (Ed.) 1990; Steen (Ed.) 1992), and in the Netherlands for vocational mathematics (TWIN Consortium, 1997, 1998a, 1998b). Although it is acknowledged that the curricular content, assessment structures, and resources available to teachers will constrain their work to a greater or lesser extent, it could be argued that each teacher retains a certain agency in their epistemological interpretation and consequent pedagogical practices. So, why have these revolutionary changes in mathematics education, internationally, made so little visible impact upon Australian vocational education? Non-traditional pedagogies appear to have been little valued, either locally at the institute level or more globally at the statewide or nationwide systemic level. The isolation of vocational mathematics from contemporary workplace practice and related pedagogies is particularly surprising in view of the dialogical relationship of mathematics with technology, especially in a sector so overtly focused on industrial needs.

As discussed previously, the CBT era has seen shifts in control over curriculum and assessment, thereby making teachers more accountable to central bureaucracies while holding them individually responsible for the implementation of policies they had no part in formulating. However, this may be yet one more technology of management contributing to the deprofessionalisation of teachers, (re)forming their identities away from traditional educational discourses. The mechanics and outcomes of CBT are examples of what Habermas (1974) terms a 'technical-rational' model of human action in relation to curriculum and teaching. Related to the failure to problematise work done in the act of teaching, whether face-to-face or by distance education, is the dearth of professional development for discipline-related teaching — a situation exacerbated by the vesting of responsibility with individual colleges, and ultimately with individual teachers.

5.6.3. Professional Development

The apparent deprofessionalisation of teachers in the Australian VET sector is clearly related to the quality of professional development. In particular, the devolution of responsibility to individual institutes has had serious ramifications, especially for discipline-based, generic subjects such as mathematics which appear remote from their 'core business.' The resulting dearth of professional development in mathematics education is a contributing factor to the lack of impetus to change the inherently conservative pedagogical practices in vocational mathematics. As noted above, this situation is somewhat paradoxical in an industry that is itself concerned with education, and latterly lifelong learning. What about the lifelong learning requirements of teacher employees? In the case of mathematics education, at least, VET providers publicly espouse, yet appear to ignore operationally, the principles of learning organisations outlined by Marsick (1997) and Watkins (1998).

Richard Edwards (1997) argues that the encouragement of reflection (in its various forms — adaptive, interpretative, critical, rational, aesthetic) by workers at all levels is central to the tenets of professional development (e.g., Schön, 1983). This is particularly the case for professionals, for whom Edwards claims reflection-in-action is held to displace technical rationality, as a response to its epistemological limits. But, he warns, this expectation may well be used as a technology of self-management through which work may be intensified and regulated. By situating reflective practice in the socio-economic and cultural changes associated with reflexive modernisation, Edwards concludes that it is not only essential to professional practice but at the same time is "a part and outcome of the particular division of labour within which flexibility is a key component" (p. 50). In other words there is an element of exploitation at work in the assumption of reflective practice by teachers. (See Lerman, 1998, for a critical perspective in relation to mathematics education.)

In the Australian VET sector, action learning and action research by practitioners are supported by national professional development funding, albeit limited to areas which support and reinforce government policy. However, a concern arises as to the ultimate purpose of this action research/learning. Adopting a Habermasian approach, Robin McTaggart (1991) identifies three major idealisations of action research: technical, practical, and emancipatory. The first is restricted to improving technique, and appears to assume a deficit model of the teacher. Practical action research is self-directed, but assumes an unproblematised view of the constraints. Emancipatory action research extends beyond interpretations of meanings (social, political, and economic) for participants to gain understanding of and to improve social and educational conditions. In ANTA-funded projects at no time is the theory or practice of CBT, for example, ever under serious challenge. Collections of practitioner-authored papers (e.g., Clayton & House (Eds.), 1997) reveal an underlying theme of ameliorating CBT assessment; neither the curriculum nor the pedagogy are ever under question, except peripherally. From a mathematics education perspective, Ken Clements and Nerida Ellerton (1996) warn of the serious misuse of action research in the justification of politically motivated agendas.

Another project conducted under the auspices of ANTA was to develop a professional competence profile that could be used to inform the initial and continuing education programmes for TAFE teachers (Chappell & Melville, 1995). Several propositions recognise: (a) the complex nature of professional knowledge, (b) that knowledge creation is a characteristic of professional practice, and (c) that any description of professional practice must include its emotional features as well as its ethics, implicit values and professional dilemmas. Importantly, Chappell and Melville note:

> Adequate competency descriptions cannot be developed using an expert systems model of professional practice. Behaviours cannot be analysed and broken down into a myriad of components without losing the contingent nature of professional practice. Rules

> cannot be developed to codify and objectively assess correct professional practices in all contexts. (p. 7)

Yet, filling 12 densely packed, small-font pages, the format and behaviourist language used in the profiles is strongly reminiscent of the learning outcomes and assessment criteria used in CBT modules — and probably for good political reasons! Nevertheless, they are comprehensive and may be compared with the USA National Board for Professional Teaching Standards (NBPTS) [http://www.nbpts.org/nbpts/].

5.6.4. Vocational Mathematics Education and Professional Development

Although there can be no deterministic relationship between the quality of teaching and the qualifications held by any teacher, it may be assumed that any individual exposed to educational research through professional development, informal research, and/or formal tertiary study will have a wider, more considered range of choices in a pedagogical situation than otherwise.

As mentioned above, one outcome of recent policy decisions in Australia is that the responsibility for the professional development of vocational teachers has been transferred from the systemic to the individual provider level. This devolution means that within an institute there is very little likelihood of teachers of mathematics subjects (a) being offered professional development appropriate to their individual needs, (b) being aware of the existence of any such professional development, and (c) being encouraged (or even allowed) to attend. For teachers employed by other, private, providers the chances are more remote. As noted above, mathematics teachers are virtually isolated within VET institutions or other teaching locations. Professional development offered and/or funded by an institution tends to be either generic (e.g., first-aid, computer applications/on-line skills, managerial techniques), or industry-specific. Mathematics education fits with neither and in any case is not seen to be problematic. There is little incentive for mathematics teachers to pursue further educational studies as costs of time and money are high, and promotion opportunities unlikely. The limited provision for industrial release is equally unlikely to be targeted specifically to mathematics education. The paradox remains: on one hand the term 'world's best practice' and images of Total Quality Management (TQM) abound in TAFE institutes, on the other it appears that these have little or no impact on ameliorating actual classroom practice, especially in mathematics.

Although internationally there are documents making recommendations for the initial and ongoing professional development teachers of school mathematics (e.g., Aichele & Coxford (Eds.), 1994; NCTM, 1991; Section 4 in Bishop et al., 1996), there are few guidelines for teachers in the vocational sector. Changing teachers' practice involves more than rhetoric, or one-day seminars, no matter how well intentioned. An exemplary model of standards for USA teachers of students in two-year colleges was given by AMATYC (Cohen (Ed.), 1995). These were designed with a particular purpose — that of general mathematics education prior to Calculus courses — but may serve as a model for other curriculum and teaching projects for adult students. Their genesis may be traced back to several reports over the last decade, including recommendations for school mathematics by the NCTM (1989, 1991, 1995) pre-dating the NCTM (2000) standards. The AMATYC standards are comprehensive and based on a combination of research-based theory and pragmatics of experience, as may be seen from the list of acknowledged contributors. However, unlike an Australian numeracy package (Johnston & Tout, 1995), they appear to assume the presence of a qualified mathematics instructor rather than a workplace trainer (or literacy teacher).

In summary, it would appear that the Australian VET sector has a very high proportion of mathematics teachers with minimal knowledge of recent findings of research in mathematics education. Further, there is little incentive in terms of promotion through recognition of post-graduate study in mathematics education. As with curriculum, the issue seems not to be problematised, especially where responsibility for mathematics is devolved to industry training boards whose prime interest and expertise is in their particular occupations — certainly not in mathematics. This lack of interest in the quality of mathematics teaching is perplexing in view of the fact that almost the entire student cohort is virtually self-selected for being less successful as learners of mathematics.

5.7. CONCLUSION

This brief review of the recontextualising field for vocational mathematics education suggests a need to reconceptualise the assumptions upon which it rests. For example, the goals for all stakeholders need to be made explicit, predicated upon open discussion and negotiation. In this way it may be possible to overcome the apparent dichotomy between vocational and general education in the interests of all. There is no support in the research for the simplistic view that observable workplace competences should take sole priority in the determination of curricular content or assessment — as is currently the case in Australia. Michael Young (1999), an eminent researcher on matters of curriculum, asserts the importance of maintaining theoretical underpinning knowledge as the source for reflection and innovation, while acknowledging the limitations of the legitimate peripheral participation model associated with situated cognition. Importantly he recommends the development by the individual of learning relationships in their spheres of involvement. Popkewitz (1997) and others have highlighted the association between curriculum and power relations, and clearly the workplace, in practice as well as in production of curricula which pertain to it, is by no means exempt from these relations of power. Power relations have also been well documented in the case of mathematics and mathematics education (see chapter 1).

In the Australian VET sector, conditions of teachers' work have been altered as a result of the introduction of neoliberal technologies of management, focusing on cost-cutting (or economic rationalism) — discussed further in chapter 6. Institutional changes in the organisation of teachers' work have radically altered what may be done — or be seen to be done — in the teaching/learning situation, as well as reconstructing what it means to be a professional mathematics teacher. The introduction of CBT in the early 1990s represented a complexity of change for teachers of mathematics subjects, imposing atomised curricula and, in theory at least, individualised learning. Since then, new Training Packages have superseded previous nationally accredited courses, subsuming curricula in favour of industry standards, reducing contact hours (i.e., content) and requiring teachers to revise and reinterpret courses — greatly increasing workloads in some areas. Personal experience indicates that curriculum documents and support material available to teachers may not always, if at all, contain useful reference material (see chapter 4).

The technical-rational model of CBT curriculum was introduced contemporaneously with the de-regulation of entry requirements for teaching and when centralised professional development for mathematics education, if it ever existed, had all but ceased (except for the further education sector). Over the last two decades, the hegemony of CBT together with the deteriorating conditions of mathematics (and other) teachers' work in Australian adult and vocational education, has left many mathematics teachers wondering: What counts as mathematics teaching in adult and vocational education? Who cares? Vocational mathematics teaching has become deprofessionalised.

As noted in chapter 3, technology has a pervasive, but not deterministic, impact socially and culturally across time and space. Within the institution of mathematics education it may be the subject and object of study (i.e., learning how to use technology, about it, even to critique its uses, and so forth) or it may be used as a tool for finding solutions to classroom or recontextualised workplace problems. As a domain within the institution of mathematics it has been applied in the macro-level political and economic structuring of society, locally and globally. However, it is the application of technology to the management of particular social institutions, specifically the institution of vocational education and training, which will be the focus of the next chapter. In order to make the transition from a capitalist economy to the new work order of the 'fast-capitalist' world, Gee (1994) suggests that the concepts of 'customers' and 'knowledge' are critical, transformative agents. According to Drucker (1993), knowledge has replaced capital, labour, and natural resources as the basic economic resource; productivity and innovation are seen as the application of knowledge to work. Knowledge workers, as the new élite, own both the means and the tools of production. Evolving, ever more sophisticated strategies of management have, of necessity, accompanied these technological developments. Since the mid-1980s, policy determination processes in the Australian VET sector together with implementation processes at the local level have utilised managerial discursive strategies and techniques, *technologies of management,* based upon that data which is quantifiable to achieve pre-determined, narrowly defined, uncontestable, technicist goals. The question arises: In the case of mathematics education in the Australian vocational education and training sector, could it be that technology is being harnessed by those in positions of power to turn back against the discipline of mathematics?

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CHAPTER 6

TECHNOLOGIES OF POWER: KNOWLEDGE PRODUCTION AND DISTRIBUTION

The De-Institutionalisation of Education

6.1. INTRODUCTION

This chapter focuses on the broader institutional issues associated with knowledge production and distribution. Although the context is largely Australian, the consequences of neoliberalist political decisions are by no means unique to Australia. The discipline of mathematics, as described in chapter 1, is closely tied to the academic institution. On the other hand, as we have seen, vocational knowledge is closely tied to the workplace. What, then, might be the consequences for vocational (and other) mathematics and mathematics education if knowledge production and distribution were to be de-institutionalised? What are the political influences on adult and vocational education in Australia that make this situation conceivable at all?

6.2. TECHNOLOGIES OF POWER: POLITICAL INFLUENCES

6.2.1. Technologies of Power

Chapter 1 introduced discussion of technology in relation to mathematics — in particular, Skovsmose's (1994) interpretation of technology as a basic, although not necessarily deterministic, condition for social development reflecting the social and economic features of a society. He distinguishes four illustrative types: generic, energy, social, and information technologies. According to Skovsmose the applications of formal mathematical methods have come to colonise all other areas of life, and other types of technologies become dependent on if not absorbed by information technology.

From a democratic theory perspective, Willem Vanderburg defends the work of Jacques Ellul (cited in Bishop, 1988, and Skovsmose, 1994, with reference to humans being entrapped in a technological society), acknowledging his criticisms of technology — but not as deterministic and excessively pessimistic; rather as invigorating debate. Vanderburg (1988, p. 6) quotes Ellul's definition of technique as "the totality of methods rationally arrived at and having absolute efficiency (for a given stage of development) in every field of human activity;" this concept goes beyond machines or specific procedures for obtaining an end. Vanderburg then outlines a four-stage process — akin to mathematical modelling strategies — that cultures undertake, based upon the assumption that quality of life will be improved by rendering the means of existence more efficient. Information technologies, designed to meet the challenges of increasing amounts of data, have greatly accelerated patterns of development. However, he observes that technological studies are not generally undertaken holistically, and externalities with serious negative effects for society and the environment may result. An input/output model of efficiency, adopted without regard for the sociocultural matrix, produces a variety of tensions. Thus, "striving for a micro-level rationality produces nonrationality on the level of the whole" (p. 9). Technological applications also separate "knowing from doing as well as the knowers from the doers" (p. 9), according to Vanderburg, working against self-regulated activities and causing insecurities such that people need 'expert advice' on practically everything. These concepts of technical rationality will be demonstrated as being applicable to policy and practice in the vocational education sector — not least upon image formation — impacting upon worker/students (current and potential), teachers and trainers, and the broader society.

6.2.2. Policy Formation

Policies carry possibilities and constraints and can have unintended effects (Bowe, Ball, & Gold, 1992; Marginson, 1997). The end product of vocational mathematics curriculum and teaching is likely to be many stages removed from the original political decision-making process and in all probability never under conscious consideration; nevertheless the effects of policy have both subtle and tangible effects. Policy formation (in the Australian context, at least) is claimed by Ken Wiltshire (1993) to have the following characteristics of: (a) limitations of time resulting in truncated potential for in-depth analysis; (b) incremental change; (c) the tendency to adopt a piecemeal approach; (d) the preference by Cabinets for pragmatic, sharp recommendations; (e) preference for a small number of focused recommendations from advisers who are non-elected and performing an essentially political function; and (f) the addressing of policy options in resource terms rather than values, where considerations are invariably short term and related to the current budget. There are external constraints to policy making in education through internationalisation or globalisation. A plethora of international conventions, many in education and labour, impact on vocational education.

From the mid-1980s federal and state governments came increasingly under the influence of what was known in Australia as *economic rationalism* (Pusey, 1991), as governments of left and right adopted neoliberal philosophies. As Peter Kell (1994) observes, the system of administration shifted from a legal-rational framework to a market-oriented training organisation, with bureaucracies headed by career public servants for whom economic considerations were and still are paramount. Marginson (1997) identifies four features of 'ministerialisation' of education: (a) the dismantling or restructuring of the responsible programme department for education,

(b) the appointment of generic managers with no history in education, (c) fiscal restraint or real financial cuts weakening the resistance to restructuring and encouraging alternative fund-raising, and (d) reorganisation of the system itself. In the 1980s the rise of Ministries conjoining Employment, Education and Training, Youth Affairs — or various permutations of these — of these, signalled a more deliberately instrumental role for education.

Clearly the ministerialisation of portfolios such as education suggests a new trajectory. Far from the bygone days of 'frank and fearless advice,' public service bureaucrats are now expected to support the ideological pursuits of the government of the day — short-term contracts tied to high salary packages at the upper echelons have been widely used in Australia as a means of achieving organisational change in and through the public service. The organisational changes brought about by the shifting ideology of government towards neoliberalism will be discussed further below under the section *Flexible Learning and the De-institutionalisation of Education.*

Policy making in the Australian VET sector now resides largely the domain of the federal government and its bureaucracy, with major implications for budgets and curricula. However, the origins of the current VET sector are still strongly associated in the public mind with its predecessor, the TAFE sector, institutionalised following the Kangan committee report (ACOTAFE, 1974). Summarising the legacy of the Kangan reforms, Kell (1994) highlighted the transformation of technical education to a unified, nationally (and state) funded education sector within a broad educational framework. At the same tune as it underwent a cultural change to become more broadly based in terms of participation across class, gender, race, and age lines, the changing nature of the international economy together with the introduction of micro-technology in the workplace changed its orientation from a narrow focus on training to a more comprehensive educational role. Over the years business and industry have come to play an increasingly influential role, as they attempt to deflect attention from their own poor performance, using TAFE as a scapegoat for economic decay, and evading their responsibilities for the funding of training, according to Kell. This shift was encouraged by the adoption of technologies of corporate management by successive Australian governments, of both neoliberal and neosocialist persuasions.

6.3. TECHNOLOGIES OF CORPORATE MANAGEMENT

Since the 1980s governments in many countries have introduced technologies of corporate management to render educational systems and institutions more accountable under the guise of devolution of authority and responsibility. In Australia, neoliberal philosophies of management have mirrored overseas developments in the UK (Raggatt, 1997) and the USA (Apple, 1993), for example. The notion of hegemony, discussed in chapter 1, helps to explain how conservative projects of the New Right displaced the Keynesian welfare-settlement: the public-private divide was used to demarcate the 'public sector,' subject to formal political processes, from the 'private,' subject to negative freedom, and protected from direct intervention (Marginson, 1997).

One outcome of the technologies of corporate management has been to shift the blame for the economic, cultural, and social ills arising from the policies and actions of dominant groups to education and other public agencies. At the same time market forces and consumer choice serve to atrophy public debate about educational policies (Apple, 1993). In Australia, as elsewhere, a range of agendas had already been transplanted from industry to the education sector, particularly the commitment to developing a more deregulated labour market (Kell, 1993); these have since been reshaped under more stringent neoliberal philosophies. Governments in many English-speaking countries, including the UK (Brown & Keep, 1999), Canada (Lipsig-Mummé, 1996), and Australia (Marginson, 1997) appear to have been shifting away from central planning toward market- and employer-led reform in vocational education and training — although Gleeson (1994) wondered why post-compulsory reform in the UK should pursue this course, given that country's historical failure of voluntarism.

The training reform discourse has been predicated on the perception disseminated by policy makers that Australia's economic problems have been caused by lack of appropriate skills in the workforce, rather than any failure on the part of business and industry managers to adjust to changing economic circumstances (Kell, 1993). The situation is paralleled in the USA, where the conditions of work and employment even "undermine skill development, productivity, and competitiveness" (Stasz, 1996, p. 14), and in the UK (Deissinger, 1994); see also Beach (1999, 2000). The argument that education and training should be directed towards equipping workers with skills more relevant to the needs of the workplace and the requirements of industry assumes a direct causal linkage between education, skills formation, productivity and an improved international trading position, according to Kell (1992), and perpetuates what he describes as a transparent and simplistic view of economic forces where the emphasis is firmly on translating educational attainment to 'progress' and 'growth.' An attempt is being made to link instrumental purposes and outcomes with a broader liberal generalist perspective, thereby reducing the value of education (in boti school and VET sectors) to economic utility (Kell, 1992; Sachs, 1991; Sedunary, 1993). On the other hand many writers, including Gleeson (1994), have observed that simply increasing the educational levels of adults, especially young people, will not of itself solve the problem of unemployment.

Vocational education reforms have been accomplished through a range of practices: discursive, social, and institutional. Terri Seddon (1992/1993) observed that the training reform agenda sought not only to modernise education and training in the national interest, but at the same time to overcome opposition to its reformist program. One way of achieving this has been through the discourse of policy documents which attempt to take readers to a new position of "unquestioned acceptance of increasing the role of education to serve the needs of industry . . .

often to the extent that educational outcomes and corporatist philosophy become one and the same" (Sachs, 1991, p. 127). In other words, language is being used as a technology to produce new social realities (McIntyre & Solomon, 1999).

In the shift from social welfare to economic rationalities and their attendant technologies (Girdwood & Reich, 1997), neoliberal ideologies seem to have provided the solution to the disjuncture between economic goals and the situations in which nations such as Australia have found themselves (Dwyer, 1995). According to Simon Marginson (1997, p. 13) "education is implicated in economic policy discourse; in strategies for population management; in the preparation of labour for work, and its retraining; and programmes for unemployment." The management of education itself is shaped by economic concepts and its material resources defined in marketing or manufacturing terms — as illustrated graphically in a VET newsletter which indicated that: students and/or industries are to be known as *clients,* teachers as *trainers,* curriculum *packages* are *delivered* not taught; diverse *products* come from a diversity of *suppliers* to meet diverse *demand* in a diversity of *locations,* in a *training market* (Harmsworth, 1996). "TAPE institutes are *service delivery organisations,* their workforces are their major *input* (costs and assets) and learning, *facilitated* by TAPE staff, is their primary *output"* (italics added) (OPCETE, 2000, P. 14).

Over the last decade the dominance of neoliberal forms of government has necessitated the reform of post-compulsory education. John Girdwood and Ann Reich (1997), analysing neoliberal technologies of management, observe that reform of the public service in general has been achieved by discrediting any enterprise of the social economy associated with social welfare shaped by a *public service ethos.* In Australia the *customer service enterprise* was created as supposedly being more flexible; public service protections were dismantled and its expertise was reformed and relocated within commercial markets, regulated by consumer choice. Public service, economically and socially progressive, was made to be a thing of the past, countered by the dominance of customer service mentality; resistance met character assassination. "'Human resources' emerge as a problem and solution for the neomanagerialist governance of the enterprise" (Girdwood & Reich, 1997, p. 4). They continue that humans as capital resources have been made substitutable in management and production processes between themselves and other forms of capital (e.g., technologies of education). To make human capital accountable and auditable, social forms have been devalued in favour of enterprising, commercialised forms. Accumulation of competency as a measure of value and competitiveness in labour markets is now desired, and performance appraised in relation to the objectives of 'corporate plans'. Thus individuals are to take responsibility for failures and achievements in enterprises and economies, according to Girdwood and Reich.

Reviewing the reforms to the vocational education system, Girdwood and Reich (1997) argue that one neoliberal strategy then, as now, has been to discredit all forms associated with the *political technology* of the public education system — of the kind envisaged by Myer Kangan (ACOTAFE, 1994). New and reshaped vocational education techniques have been inserted as technologies of government, with managerial and seductive qualities. Whereas the purpose of education under the public service system was assumed to be for the good of liberal democratic society, under the customer service model it is assumed to be for the individual in a competitive society, as a personal investment. Although the public service system of vocational education was based on a factory-model of the school in its managerial regimes of administration and classroom organisation, its scope extended beyond the school to include sites of vocational learning as experienced in the enterprise, the household, and the neighbourhood. These forms of organisation and management have been actively resisted by the customer service model in favour of business forms, with a shift in favour of sites external to the institution — notably the workplace. Not only is the workplace to be the seat of knowledge production (see also McIntyre & Solomon, 1998, 1999) but it is idealised as the site of learning while the institution is discredited. Non-classroom technologies are valorised, such as online delivery (see ANTA, 1998b) or learning from one's workplace colleagues (see ANTA, 1998c). Certification of skilled persons under the public service model was achieved through the political authority of the public vocational system, through external industry-based forms of examination and assessment, and manifested in portable documents (albeit varying from state to state). Under the customer service model, assessment from national industry competency standards can be negotiated by the individual (and their employer); recognition is given to prior learning (RPL), whether institution-based or on-the-job, and curriculum is no longer mandated (ANTA, 1997). Neoliberal rationales used to discredit social and institutional practices of the public service regime as "lacking expert authority and managerial practicality" (Girdwood & Reich, 1997, p. 5) have been used to justify the establishment of new centres of regulation to oversee the development of new norms and standards of vocational competency. Thus, political authority under the customer service system has been distanced from government. Teachers, who were invested with the political authority under the public service system have been divested of this authority. In fact, the conduct of teachers (and hence students) has been reshaped as a consequence of the reforms. Teachers are now positioned as having to sell themselves and their products (e.g., courses, programmes), shaping customer choices. Bill Bailey (1998) identifies a range of ethical issues associated with staff having to attract enrolments in the competitive post-compulsory educational market in the UK; as does Ralph Blunden (1999) in Australia.

Girdwood and Reich (1997) further argue that a counter issue to the neoliberal problematisation of the public service regime is that of formulating solutions. This is reminiscent of Skovsmose's observations concerning technological solutions, outlined in chapter 1, where the originating questions may be unknown, or even non-existent. Providers in the vocational education market are now in open competition for funds formerly reserved for public vocational education. Girdwood and Reich claim that money saved as a result of the political invention of the desire for tax relief is to be used along with other personal sources for purchasing education. In terms of management, derision has been cast upon the centralised budgeting, purchasing, planning, recruitment, industrial relations, and staff development and training of the public vocational education system. These have been replaced by concerns for profitability and financial survival: knowledge of the consumer is valued (ANTA, 2000, n.d.-b), as are management accounting technologies, risk-taking, and competitiveness. In terms of production, the highly regulated and socially planned structures of the past have been replaced by (supposedly) responsive, competitively priced, vocational education goods and services set within broad outcome, performance and quality standards and targets. A range of production sites and diverse teaching methods attempt to match the commercial desires of the customer. A focus on inputs and the processes of vocational learning and teaching has been replaced by one on outcomes and outputs. Teachers are to "develop and deliver pleasurable modularised flexible training available at multiple sites, in multiple modes" (Girdwood & Reich, 1997, p. 10) — see, for example, ANTA (1998c). They are to be self-employed and contracted; their futures aligned with the customer's will to pay for the consumption of a product. "The criteria for production becomes the 'self-fulfilment' of customers' needs, even if these are seen by the teacher with a public service mentality as 'educationally ineffective'" (Girdwood & Reich, 1997, p. 10). In terms of consumption, customers must be mobilised to undertake this new kind of marketised vocational education freed from prescription (ANTA, 1997, n.d.-a), and persuaded to pay the full costs or gain sponsorship. The key attraction is the perceived cost/benefit relationship, according to Girdwood and Reich.

Coupled with the shift of accountability to the local level, increasingly the role of the state is to formulate policy for predetermined, easily quantifiable, self-fulfilling outcomes, regardless of what they actually mean in terms of educational practice, according to Peter Dwyer (1995). He notes that there are progressive strands in the policy documents (see also Sedunary, 1996), and warns of the danger that isolated evidence of progressive practice at the local level may be taken as evidence that the new policies have educational outcomes which are broadly achievable (see chapter 5). Following Foucault's imagery of the 'domination of truth,' Dwyer asserts that those who define education as a 'product' have power over what counts as 'marketable' knowledge, and as a result professionals have been structurally displaced. The discourse of vocational education has become commodified as a technology of power.

One outcome of government policies and their persuasive discourses is that non-industrial stakeholders have been marginalised. Teachers have been systematically excluded from policy formation, and reduced to the role of implementers (Stevenson, 1993). Students, nearly all of whom are entitled to vote, and who collectively make the largest financial contribution to their own education, while enrolling for a wide variety of reasons, according to Damon Anderson (1997a), have also been largely excluded. Policy advice on the provision of vocational education and training is sought exclusively from the privileged (e.g., ANTA, 1997). The human capital paradigm, which has replaced that of social and personal development over the last two decades, has clearly shifted the focus of VET policy away from the needs of students to the concerns of industry, although such shifts appear to be cyclic (Stevenson, 1995a; White, 1995). In the contestation of knowledge as the goal of vocational education and training, educational values appear to have been subsumed by industrial values.

One notable feature of policy discourse, over the last decade at least, is that it has been framed by non-educators, for purposes attuned to the needs of the economy. Yet, at the same time as policy makers have colonised the discourse of education with the language and practices of business, they have appropriated educational discourse to achieve economic and social goals. The following will give three brief historical examples of how economic goals have dominated the cultural politics of vocational education in Australia.

6.3.1. Industrial Award Restructuring

A common theme of the 1980s was industry criticism of the lack of responsiveness of TAFE to meet its needs, but this was partly due to the rigidities of the labour market in which TAFE operated, as well as of the training system itself (Sweet, 1993). In the 1988 National Wage case, as part of the so-called National Training Reform Agenda, the unions sought to link pay increases with a commitment to restructure their industrial awards. The Structural Efficiency Principle linked salary increases with the acquisition of higher levels of skills. Its basic objectives were to establish skill-related career paths giving employees a financial incentive to participate in skill formation, and to encourage multi-skilling through reduction in the number of classifications in skill levels. It raised a number of issues related to the ways of defining and classifying the skills needed in the workplace, their arrangement in levels for wage purposes, their assessment, and how they were to be taught and learned. Education and training were to be used as the basis of mobility through higher skill levels.

Thus, the nexus was made between education and industrial award restructuring and which saw federal and state ministers agree to the national implementation of a competency based training system by 1993. The development and ratification of national competency standards, developed for occupations and classifications linked to industrial awards, was the linchpin of the proposed system. Two other principles endorsed by state and federal governments were: (a) the need to change from a time-serving apprenticeship system to a competency-based approach to education and training, where qualification is based on achieving specified standards of skill; and (b) recognition of the need for diversification, expansion and improvement of the training infrastructure through greater emphasis on industry-based formal training provision (Goozee, 1993). These continue to have great impact on the vocational education and training sector.

6.3.2. Organisational Change: An Open Training Market

As noted above, part of the neoliberal strategy of enterprise reform has been to reshape the institutions of VET. This has generally been achieved by the commissioning of reports with limited terms of reference and strategically chosen members and chairperson, or by tender with the possible implication that findings tend to be aligned with the prevalent ideology of the government in power.

Since 1990 a series of policy decisions has led to the ambiguous and sometimes contradictory outcomes of deregulation of the sector at a local level while strict control is maintained at the central, national level (Dwyer, 1995; Kell, 1994). One recommendation was the introduction of an open training market: TAFE was to adopt a more commercial role to increase the proportion of its activities on a full cost recovery basis. This was followed by an agreement which allowed for the introduction of nationally consistent methods for the recognition of training; it encompassed the registration of training institutions including non-TAFE providers, the accreditation of courses and programs, and the certification of individuals who were entitled to recognition of prior learning (RFL). The TAFE system experienced a shift from having sole responsibility for publicly funded vocational education and training, to being one of many participants in a training market. The sectoral acronym TAFE was replaced by VET (Vocational Education and Training) to reflect the broader constituency. Direct funding of industry and private providers was seen as one way of achieving the goal of developing a client-focused culture, and legislation to encourage the growth of a training market has been supplemented by diversion of public funding away from traditional institutions to support private providers. These providers include for-profit colleges in areas such as business, tourism and hospitality; industry training centres; and in-house training by enterprises, some of whom are part of wealthy multinational companies. The creation of an open training market enhanced the powers of industry while it contributed to the marginalisation of professional educators. Mathematics education per se could not be expected to assume a high priority in such an open market.

The results of policy decisions, as Bowe et al. (1992) predicted, have not always been as intended for a variety of reasons. Institutions work to serve their own interests of survival; education is not and can not be regarded as being in the situation of a perfect market (for example, in consideration of the differing needs of rural and urban centres); and employers are not always able to elaborate their own training needs (Billett, Cooper, Hayes, & Parker, 1997; Fisher, 1993). Beyond deregulation there has been little analysis of the effects of markets in the redistribution of skills and resources in the interests of producers, customers, or the nation (Gleeson, 1994; Stevenson, 1993). As Marginson (1997) observed, none of the reports advocating the introduction of a training market had ever assessed its costs and benefits. Anderson (1997b) also questioned whether the transformation of the supply side of VET, which has seen the transfer of scarce educational resources to marketing and tendering activities, has been the most effective and strategic, or improved the quantity and quality of vocational education and training. These uncertainties were echoed by the National Centre for Vocational Education Research [NCVER] (1997, p. 7) which stated: "too little is known about the real benefits and costs of a more market-oriented approach." Researched or not, the concept of an open training market, introduced under a federal Labor government, was to form the basis of further radical institutional changes to the VET sector under the subsequent neoliberal regime, where the relationship of VET with industry and enterprises continued to shift and to be renegotiated in conformity with market liberal philosophies of education.

6.3.3. The National Training Framework

The National Training Framework (NTF) introduced a system of *Training Packages* aimed at reducing the curricular restrictions of existing courses by focusing on outcomes. This deregulation has serious implications for teaching and learning, according to Anderson (1997b):

> The NTF effectively removes responsibility for curriculum content, delivery and assessment from the control of professional educators; displaces course content and delivery with assessment as the primary focus of teaching and learning in VET; and delegates the powers of course accreditation and credentialling to employers and recognised training providers, most of whom are likely to be private for-profit providers, (p. 147).

Responsibility for these lies primarily with national Industry Training Advisory Bodies (ITABs), whose members may have only an industrial relations background with limited actual industrial experience; teachers have never been formally recognised as members of these boards (Hawke & Cornford, 1998). Assessment systems, focused on the recognition of competencies against endorsed competency standards, are developed by industry. Thus it is possible for a qualification to be awarded without any formal or structured training activities having been undertaken (ANTA, 1998c). There is also a very low probability that anyone with a sound knowledge of mathematics, let alone mathematics education, would be involved in high-level decision-making processes of conception and implementation.

The introduction of *User Choice* shifts the locus of responsibility for courses from the providers to the clients (employers and/or students); clearly the negotiations between employer and employee are undertaken in a situation of unequal power relations. As noted above, the policy has clearly been introduced to allow public funds to flow to individual training providers to encourage a direct and market relationship between providers and clients. However, there are still many unresolved issues. Anderson (1997b) claims that the NTF is clearly designed to enhance the ability of employers and private providers to harness the training market for their particular interests rather than the students.' As with other policy decisions the actual effects cannot be fully determined in advance. When an economic utility view of VET prevails, equity issues become problematic under a human capital paradigm of efficiency, increased productivity and competition (Powles & Anderson, 1996; Taylor & Henry, 1994; Willis & Kenway, 1996). Public providers incur additional costs in supporting student counselling and educational support services (including mathematics access), not generally provided by private or industrial providers, for students with special needs and disabilities.

At the institutional level the literature illustrates the position of TAFE, then VET, (re)emerging as a sector whose prime focus is on the needs of industry at the expense of its other major stakeholder, namely students. Due to a complex array and interconnection of social, economic and political agendas, stakeholders are being channelled in certain directions to pursue often ambiguous or contradictory agendas. For example, the trend in TAFE institutes for autonomy and self-management has resulted in an overwhelming concern at all levels for financial accountability and entrepreneurship. Paradoxically this results in poorer quality teaching resources (material and immaterial) in the effort to cope with declining levels of government funding.

In summary, under continuing deregulation of the VET sector, the National Training Framework has replaced curriculum content and delivery with assessment against industry competency standards as its primary focus of teaching and learning. The concept of User Choice has been promoted, supposedly to enhance responsiveness and flexibility. However, as Anderson (1997b) claims, it represents a shift in the locus of decision-making away from providers, and absolves the state of direct responsibility. What are the implications for institutions of knowledge production and distribution? I return to the work of Basil Bernstein (1996) for analysis of the classification of knowledge in relation to these technologies of power.

6.4. A WEAKENING CLASSIFICATION OF KNOWLEDGE

The brief historical accounts provided above lead to a weakening classification of knowledge (Bernstein, 1996), where the boundaries demarcating disciplinary power are becoming blurred. Text from the ANTA (n.d.-a) glossy brochure, *A bridge to the future. Australia's national strategy for vocational education and training 1998-2003* [also available: www.anta.gov.au/publication.asp?qsID=32] shows a weakening of the external boundaries through:

(a) the erosion of the vocational educational institution's (i.e., TAFE's) sole powers to award credentials on the basis of curriculum, teaching, and examination:

> [Training Packages will] enable the awarding of qualifications through the assessment of skills and knowledge rather than on the basis of whether a person has completed a particular training course, (p. 6)
>
> People will have more opportunities to have the skills they develop on the job recognised towards a national qualification because the qualifications in training packages will be awarded if people are assessed as competent against industry competency standards, (p. 10)

(b) the erosion of the vocational educational institution's sole powers to determine course content:

> [Training Packages will] encourage the development and delivery of training programs which suit individual needs, (p. 6)
>
> [Under New Apprenticeships] employers and their apprentices or trainees will be able to put together a structured training program which meets their particular needs. They will also be able to choose the training provider to deliver that program. (p. 6)

(c) the erosion of the TAFE institutes' predominant right to deliver vocational teaching programs funded by government:

> [Programs offered by registered training organisations (RTOs) will become increasingly relevant, recognised and valued through the] establishment of partnerships between institutions and industry, encouraging greater responsiveness to industry needs. (p. 8)
>
> [Private and industry training providers registered as RTOs, numbering over 3000 in 1997,] now have access to contestable funding. (p. 8)
>
> [RTOs include a large number of adult and community education providers offering] less formal [learning] environments. (p. 10)
>
> State, Territory and Commonwealth governments and schools have agreed to increase the quality and quantity of nationally recognised vocational education and training as an integral part of senior secondary school studies. (p. 10)
>
> An apprenticeship or traineeship can be combined with attendance at school. (p. 10)

(d) the erosion of the educational institution's predominant right to deliver vocational teaching programs at fixed locations and times:

> New forms of educational and communications technology will generate increasing demands for flexible, convenient and accessible training. For example, more and more Australians are expected to demand 'just in time', 'just for you' vocational education and training through the internet. (p. 9)
>
> There will be a major investment in the development of products to support online delivery. (p. 9)

These last two quotations, in particular, highlight the encroachment of the discourse of the marketplace into education. In addition, there appears to be no adequate research base to justify this re-allocation of scarce resources on educational grounds, let alone economic grounds. The rhetoric indicating weakening of external classifications is summarised in three projected outcomes:

> Individuals and enterprises will have maximum choice and flexibility in learning pathways and in the use of vocational education and training products and services, including User choice in New Apprenticeships [Objective 1, Outcome 2] (p. 12)
>
> All qualifications and statements of attainment issued by registered training organisations will be recognised by other registered training organisations throughout Australia. [Objective 2, Outcome 1] (p. 14)
>
> All qualifications in Training Packages will provide clear links to each other, to other qualifications in other industries, *and to university courses.* [Objective 2, Outcome 4] (p. 14, italics added)

Consistent with Bernstein's theorisations of weakening classification, the sites of power over knowledge production and reproduction can be clearly seen to have shifted away from the institution of vocational education in Australia. At the same time under the aegis of lifelong learning, through the attempted linkage between Training Packages and university courses in the rhetoric (e.g., OTFE, 1999), there is an attempt to transgress the historical academic/vocational divide; perhaps as an assault on the relatively impermeable boundaries of higher education. There is a notable silence from the national body, ANTA, on the pedagogical implications of individuals moving from a deregulated system of curicular content constrained by the restrictions of CBT to the more strongly classified academic discourses of higher education. The issue has, in fact, been raised at the state level by OTFE (1999), although the case of mathematics continues to be treated unproblematically.

Within the boundaries of the local vocational institute there can also be strong or weak classification. Strong classification implies that the staff are tied to their disciplinary departments with internal cohesion and possibilities for promotion. This is no longer the case in the Australian VET sector, where there are now few recognised mathematics departments. In terms of Bernstein's (1996) *horizontal discourse* — typified by everyday, oral, or commonsense knowledge and which I suggest could well apply to much workplace knowledge, including aspects of teaching in the VET sector — the isolation of members (such as mathematics teachers in this case) fails to provide an effective social base for the development of a reservoir of group strategies or a repertoire of individual strategies. Circulation and exchange of professional knowledge depends upon the structuring of social relations which are inhibited by stratifications (of power and control), engendering defensive or even challenging behaviours, according to Bernstein. In Australia, organisational change has contributed (wittingly or unwittingly) to the decline of *singular* (specialised) knowledge discourses such as mathematics which, if it survives at all, must be accommodated by and accommodate to *regional* discourses (i.e., recontextualised singular discourses at the interface between the disciplines and the technologies they make possible), in an increasingly technologised vocational education system. That is, mathematics (and/or statistics) as an object of study in its own right, is becoming less visible due to reductions in curricular content and to its deliberate subsuming under other subject titles — even the title 'numeracy' is often reduced to low level number skills — especially when it is integrated with other vocational and literacy teaching (e.g., ANTA, 2000b). The word 'mathematics' has virtually disappeared from the ANTA lexicon. At the same time organisational change in the VET sector has undermined the professionalism of teachers of generic subjects such as mathematics through their physical and intellectual isolation from any professional peer group.

Within the institution, according to Bernstein's (1996) theorisation, weak classification also facilitates greater centralisation, weaker solidarities, and more competitive relations between staff. This is consistent with the experiences of many vocational teachers working under neoliberalist ideologies, where departments, and programmes within departments, are continually competing for scarce resources in terms of student enrolments and central funding monies. Many are organised along the grand narratives of (pseudo-) business management, where staff are presented with continually updated organisational matrices for their edification. Such overwhelming concerns with structure and financial survival leave little room for educational debate and development.

Bernstein (1996) also turns his attention to the classification of the *distribution* of knowledge. He notes that hierarchical discourses (such as mathematics) are likely, although not logically necessary, to produce an empirical progression "from concrete local knowledge, to the mastery of simple operations, to more abstract general principles" (p. 25) (cf., Walkerdine, 1994). This last sentence would aptly describe the large majority of mathematics education trajectories of individuals in industrialised countries over the period of so-called universal secondary education. Bernstein continues that this distribution of forms of knowledge results in those who fail along the way being positioned, and restricted to simple operations (as illustrated in chapter 4) where knowledge is impermeable. The few who do succeed in accessing general principles become aware of the possibility of the unthinkable, the disorder and incoherence in the mystery of the discipline; whereas the majority have been socialised into the pedagogic code and cannot visualise alternative realities. Needless to say, students enrolled in vocational courses are almost without exception drawn from those who are less successful students of (school) mathematics. Here, Bernstein's theorisation supports the claims made by Klein, Popkewitz and others (see chapter 1) about the positioning of school students in relation to mathematics education, and empirically supported by teachers of adults returning to study mathematics (FitzSimons & Godden, 2000). This leaves open the issue of who determines the goals for vocational education and training.

6.5. GOALS OF VOCATIONAL EDUCATION AND TRAINING

Jasmin McConatha and Frauke Schnell (1995) argue that values are not innate, immutable given qualities as has often been perceived, but are endogenous properties, shaped by cultural factors. Although values are transmitted from individual to individual, group to group, and generation to generation, educators remain one of the primary agents of values transmission. They assert that the study of values is consequently central to understanding the current philosophical debate regarding educational policy. At the societal level, Campbell, McMeniman and Baikaloff's goal value system for a desirable future Australia placed social valuing and ecological responsibilities at the local, national, and global levels ahead of the fifth-ranked 'robust economy' (Stevenson, 1996). However, within the workplace Stevenson claims that economic goals are the only ones regarded as legitimate, with a stark absence of knowledge valued for its concern with social and ecological goals. This is reflected in attitudes of employers with respect to task/organisation, community of practice, quality standards and so on (e.g., NBEET/ESC 1996; Stasz 1996; Stevenson 1997). These goals demand dispositions suited to the needs of employers and the economic good of the nation as a whole (Butler 1998c) — including lifelong learning.

According to Joanna Le Métais (1997, p. 5) basic values (where the primary focus is on the individual) include: "democracy, participative governance, differentiated provision, professional autonomy or discretion." These may be supported by, or in tension or conflict with operational values (where the focus is on the system or society) where a balance is sought "between universal and residual provision, between the public cost and meeting individual needs, between effectiveness and economy and so forth" (p. 5). Le Métais (1997) further observes that

> there may be a dissonance between the aims of education expressed by legislation or reforms, and those pursued by students, teachers, parents, education administrators and others. It may be difficult for a single educational structure to reflect the diversity of values and aims. . . . As a result, criticisms may be levelled at the system for failing to: instil basic values; teach basic skills; develop higher order thinking and problem solving skills; develop creativity, flexibility and cooperative working; prepare young people for today's jobs; prepare them for tomorrow's unemployment and lifelong learning and so forth. These criticisms reflect different expectations or different value positions, (p. 6)

Vocational education, in Australia at least, has a long history of such criticisms from government (e.g., Koutsoukis, 2000) and industry leaders. In spite of this it has survived because of its perceived ability to continue to meet the needs of its key clients (Anderson, 1998). On the other hand, Stevenson (1997) claims that the industrial relevance of vocational curricula — based on industry standards — supplants personal and societal needs; misreading current and future industrial as well as general social needs. Yet, it is also now recognised that there will not be continuous paid work for all, full-time, part-time, or casual, and that the limited (e.g., gendered) nature of the construct of skill fails to recognise the multifarious kinds of unpaid work performed daily (Butler 1998a). As noted by the OECD (1971), the criteria for judging the effectiveness of education cannot be judged in isolation from its goals. A shift may be identified in the UNESCO (1999) Seoul congress report, from current orthodoxies towards the development of a new human-centred paradigm, where economic goals are integrated with cultural and environmental considerations. In order to overcome problems of social marginalisation and labour market segmentation it recommended that vocational education and training become an effective tool to achieve social cohesion, integration and self-esteem.

The question arises as to the balance to be drawn between the range of narrow occupational and broader industrial and educational considerations. Are countries such as Australia following down the UK path of employers diminishing the breadth of training due to fears of having their employees poached by competitors (Deissinger, 1994)? But their situations vary — especially in cases where a variety of multinational companies operate. For example, those from the European countries of Germany and Scandinavia have an outlook on production and training very different from the UK (Brown & Keep, 1998). One area in which Australia is following the UK and European trend is along the path of lifelong learning.

6.6. LIFELONG LEARNING

The concept of lifelong learning had a profound influence on the tenor of the Kangan Report (ACOTAFE, 1974). In fact the rhetoric of lifelong learning has been adopted by governments of many countries around the world over the last quarter century.

Although the notion of lifelong learning was posited by Dewey (1916), together with the importance of experiential learning, the concept was given prominence by the UNESCO-commissioned report (Faure et al., 1972) which emphasised the dual ideas of lifelong education and a learning society. Whatever the previous educational uptake and intellectual abilities of the person, the rapidly changing economic and social circumstances of our society require that education be seen as a lifelong endeavour, removed from particularities of time and location. It recognised the need for optimisation of professional mobility as well as the development of personal interests in education of the self, in order to develop and maintain a sense of personal agency in areas such as reason, creativity, democratic competence, and a spirit of social responsibility. According to Faure et al. (p. 163) the learning society "can be conceived as a process of close interweaving between education and the social, political and economic fabric, which covers the family unit and economic life;" with a sense of responsibility replacing that of obligation.

At approximately the same time the OECD (1971) was focusing on what it termed *recurrent education,* suggesting the reorganisation of the traditional patterns of education and work to accommodate "the aspirations of the individual" as well as "the emerging requirements of modern society" (p. 17). It called for reform of the basic presuppositions of education as the monopoly of the young, arguing for the centrality of continuing education as part of normal programmes, but warning against its possible marginalisation through the perception that its focus was to provide solutions to problems that schools could not or would not solve. Individuals, as 'person[s]-in-community' (p. 137) were to be granted a claim on education to accommodate their lifestyle needs, and this would act as "a counterweight to the dominantly selective function" (pp. 17-18) of educational systems. This de-emphasis on the selection function of education was viewed from the double perspective of the state benefiting economically from certain minimum levels of schooling among the population as a qualification for social membership, and in return affording its members further opportunities to acquire scientific and artistic culture "not necessarily linked to selection for occupation" (p. 18).

The impetus given to the concept of lifelong learning in the 1970s by reports of bodies such as UNESCO (Faure et al., 1972), was revitalised in the 1990s. The more recent UNESCO report *Learning: The Treasure Within* (Delors, 1996) made the following statement which appears to maintain a holistic approach to personal, social, and economic development:

> There is a need to rethink and broaden the notion of lifelong education. Not only must it adapt to changes in the nature of work, but it must also constitute a continuous process of forming whole human beings — their knowledge and aptitudes, as well as the critical faculty and the ability to act. It should enable people to develop awareness of themselves and their environment and encourage them to play their social role in work and in the community. (p. 21)

Notwithstanding the tenor of the 1996 UNESCO report, it has been argued that the concept of lifelong learning has undergone fundamental changes in discourse since the late 1980s. Within the last decade a vision framed within new politico-economic imperatives has placed importance on highly developed human capital, science and technology — thereby increasing the importance of work-related education and, in some cases, reducing the concept of lifelong learning to a narrow interpretation of equipping the workforce with necessary skills and competencies.

From a socio-political perspective, Kjell Rubenson (1995) claims that the original conception of lifelong learning/education, encompassing formal, informal and non-formal settings, would have moved towards a classless society through the reduction of educational gaps. He asserts that this second-generation lifelong learning "neglects to critically examine the underlying assumptions regarding work such as the link between education and work (see also Butler, 2001; Stevenson, 1998), and the combined effects of family and school that hinder lifelong learning across class and ethnic lines" (p. 15). Using Bourdieu's (1991) concept of *habitus* to provide a perspective on this phenomenon, he notes that socialisation within family, school, and working life provides a positive disposition towards adult education for some groups only. Larsson et al. (1986, cited in Rubenson, 1995), found that for non-skilled workers with little formal education there is a restricted view of adult education: It is only when participation results in better and higher paying work that it becomes meaningful.

As reflected in the UNESCO (1999) document, the Commission of the European Communities (EU, 2000) is promoting active citizenship and employability as being equally important and interrelated aims. It encourages participation in social and political life, arguing that there is a noticeable shift towards more integrated policies that combine social and cultural objectives with those of economic rationalism.

From a socio-economic perspective Marginson (1997) observes that, in contrast to the 1971 OECD publication, by the mid 1980s the OECD policy documents attributed to education a human capital function of contributing both as a socialisation and a screening mechanism. He continues that the OECD, if not all member governments, realised that simplistic assumptions about the nexus between education and productivity were tempered by the effects of market forces as well as the individual's capacities. To assist with the screening function, standardisation of credentials as a mechanism of control were proposed. The OECD argued that the economic contribution of education was better understood as a private return to individuals or firms rather than a social investment, but recommended that this data not be used for public financing of education lest it encourage its expansion! In essence the OECD was advocating the use of market and semi-market competition for education. Not only has education been linked to productivity, it is also implicated in the production of a self-managing subject. This may be achieved partly through inculcation the aspirations of citizenship and partly through encouraging people to invest in themselves through education (ANTA, 2000, n.d.-b; Butler, 1998c; Marginson, 1997).

Following the periodic surges of interest in lifelong learning over the last three decades, there appears to be an over-riding belief among policy makers, at least, in the positive linkages between VET and economic performance in the UK (Brown & Keep, 1999), and in Australia as these nations seek to establish, maintain and enhance economic advantage through the development of a more highly skilled labour force. This is paralleled by expressed beliefs among policy makers, if not all employers, about linkages between mathematics education and the economy (e.g., Department for Education and Employment [DfEE], 1998a, 1998b, 1999; DETYA, 2000; Kemp, 1998a, 1998b, 2000; NBEET, 1995b; NBEET/ESC, 1996). Interestingly, in the UK the work of Sigmund Prais, a New Right economist, has been particularly influential, both in VET policy formation internationally (Brown & Keep, 1999; Maglen & Hopkins, 1998) and also with respect to school mathematics (Ernest, 1991; Gjone, 1998) — inserting a managerialist model into education, narrowing its scope to that which can be easily measured and evaluated, simultaneously controlling both curricular content and teacher behaviour. Deleuze (cited in Butler, 2001), describes this as the embedded modulation of the corporation and education systems.

Elaine Butler (1998c, p. 69) warns, however, that "readings of lifelong learning texts illustrate both their persuasiveness and the contradictory positions available within their discourses." She claims that depictions of mutuality, shared loyalty and trust between employer and worker are illusory. According to Butler (2001), the concept of lifelong learning is taken as a univocal construction of global logic, with little or no acknowledgement of the contestability of notions such as the concept of work, which is rarely problematised, or the issues of power on which official texts remain silent (whose metaphors are used and for what purposes?). In the Australian adult and vocational education sector, which she claims is characterised by massive institutional re-norming and whose national reforms appear as a "mass of contradictions," there is an attempt to re-market itself to overcome the problem of citizens who value qualifications but not necessarily learning. And, as Butler (1998c), Lesley Farrell (2000), Nancy Jackson (1995), and others have commented, within the textual representations of discourses such as curriculum documents, learners/workers are often absent.

The observations of the preceding paragraphs were clearly manifested in the rhetoric of ANTA (2000a — now defunct) website document on lifelong learning which builds on the rhetoric of the Delors (1996) report to UNESCO, linking social and economic change with the need for lifelong learning. Social marketing, as in health awareness campaigns for example, is to be the vehicle used to instil a desire, even a passion, for skill acquisition and engagement in lifelong learning within the Australian community. However, the paradox remains that there is little evidence of any heed being paid to the educational or social messages of lifelong learning at the vocational mathematics classroom level. The explanation may lie more deeply within contemporary lifelong learning ideologies.

Richard Bagnall (2000) identifies three interrelated progressive sentiments, which he claims transcend epistemology, emerging in the ideological commitments of philosophical traditions informing contemporary lifelong learning advocacy. Within each, however, lies the potential for the ideal to be "subverted, distorted or contracted into programmatic forms that fail to capture — entirely or in part — the liberatory thrust of the sentiment" (p. 24).

According to Bagnall (2000), the first, *individual progressive sentiment,* is committed to individual growth and development, seeking liberation from ignorance or dependence, and is reflected in the work of authors such as Dewey, Knowles and Mezirow. Although individual in focus it tends to frame a perception of public benefit arising from increased functional independence and cultural awareness, with a tendency towards advocacy of state support. The educational institution is seen to be important and distinct from other social institutions, and teachers are expected to have specialist expertise. The second, *democratic progressive sentiment,* is committed to social justice, equity, and social development through participative democratic involvement, informing social action and its reflective and discursive evaluation; it is reflected in the work of authors such as Freire, Illich, and Aronowitz and Giroux. It is considered first and foremost a public good, calling for relatively high levels of state support. Teachers need to be relatively well educated and skilled, with a commitment to cultural reform, and educational organisations require a degree of institutional autonomy. The third, *adaptive progressive sentiment,* seeks liberation from deprivation, poverty and dependence through adaptive learning, based on the impact of accelerating cultural change, and calling for the development of metacognitive skills to allow learners to manage their own actions. Individuals or organisations are seen as the primary beneficiaries, with public benefit a secondary consequence; the role of the state is limited to the support of marginalised groups and regulation through setting standards and frameworks for recognition and transfer of adaptive learning. Costs are shifted to those perceived to be direct beneficiaries, and teachers are expected to have relevant recent task experience and to be open to change. There is a strong element of enculturation into ever-changing realities of lived experience. However, Bagnall claims that the progressive, ethical, liberatory nature of each sentiment is marginalised or excluded from the discourse.

Under the influence of what Bagnall (2000) describes as *economic determinism,* contemporary educational change is driven by considerations of cost and economic benefit, and preoccupied with educational accountability. There are implications for outcomes, accreditation, generic vocational skills, as well as a de-differentiation of education from other cultural domains (discussed below) together with the commodification of both education and personal identities.

Education funded by the state is focused increasingly on the needs of the global economy. Thus, the individual progressive sentiment has been reduced to a focus on basic and minimal skills, arguably deskilling and disempowering for students, and teachers idealised for their conformity to prevailing orthodoxies. In contrast to the second, democratic progressive sentiment, Bagnall (2000) asserts that contemporary lifelong learning discourse is strongly counter-critical in its vocationalisation and contextualisation of learning, the claims for democratisation through RPL and so forth are patently false, and that the sentiment is in fact vigorously marginalised. The third, adaptive progressive sentiment appears to be more appropriate to the contemporary lifelong learning discourse in its individualisation and the creation of "a mind-set of ephemerality, changeability and fragmentation" (p. 30). However, Bagnall notes that its liberatory emphasis is only for the culturally privileged; for the remainder the discourse is directed to fitting them to the cultural realities and ideologies informing those realities. Bagnall goes so far as to criticise UNESCO's support for lifelong learning at congresses in Hamburg (UNESCO, 1997), on adult education and in Seoul, (UNESCO, 1999), on technical and vocational education, for making serious errors of judgement in accepting the superficial but misrepresentational gloss of these ideologies.

In summary, there has been a shift in the orientation of lifelong learning discourses from social to economic goals, although both still feature in the rhetoric. They are being operationalised as a more subtle yet nevertheless persuasive strategy in Australia. Not only have the discourses of lifelong learning been appropriated by economically-oriented governments, but the promotion of lifelong learning has in turn appropriated discourses of marketing and its associated psychologies in the formation of (potential) workers' identities. Flexible learning is promoted by ANTA (2000a, n.d.-a, n.d.-b) as an important strategy of encouraging learning (supposedly) when, where, and how the learner wants it. However, at a deeper level it is yet another instantiation of neoliberal technologies of management or what Butler (2001), drawing on Haraway, calls 'knowledge-making technologies' to highlight both knowledge-making practices and Foucauldian discursive 'truth games.' Nicoll and Chappell (1998) identify the shift to new discourses — in particular the shift from *education* to *learning,* giving rise to the possibility for a discourse on lifelong learning as enabling the breakdown of previous boundaries of the VET sector. In this way lifelong learning becomes (re)positioned as a strategic tool of the economy.

6.7. NEW FORMS OF KNOWLEDGE PRODUCTION

Michael Gibbons et al. (1994) argue that the adequacy of traditional knowledge-producing institutions is being called into question. They assert that a transformation is taking place in the mode of knowledge production, heuristically contrasting what they call *Mode 1* traditional knowledge with *Mode 2* knowledge. Highlighting the problematic usage of language in Western cultures — where the terms science and knowledge are often used interchangeably or in combination — the Mode 1 form of knowledge is intended to summarise the cognitive and social norms of the Newtonian empirical ideal of science which must be adhered to in production, legitimation, and diffusion of knowledge of this kind.

In Mode 2, knowledge is produced in the context of application, addressing a much broader range of considerations than the norms of scientific research or commercial considerations. Because knowledge production becomes diffused throughout society, they speak of *socially distributed knowledge.* This form of knowledge production is above all embodied in people and their socially organised forms of interaction. Hence they see the tacit components of knowledge as taking precedence over codified components; those elements of knowledge learned on the job may be more important in some situations than textual, migratory knowledge.

Gibbons et al. (1994) describe Mode 2 knowledge production as transdisciplinary, because it moves beyond any single discipline, and they identify four significant features of transdisciplinarity:

1. it develops an evolving framework to guide problem solving, generated and sustained in the context of application;
2. it develops its own distinct theoretical structures, research methods and modes of practice;
3. the diffusion of results is accomplished initially in the process of production; and
4. its problem solving capability is dynamic.

Importantly, they claim that Mode 2 supplements Mode 1 knowledge production, rather than supplants it. Elsewhere (Fitz/Simons, 2000c), I have argued that a disciplinary base in mathematics must be sustained in post-compulsory education in order for transdisciplinarity to function effectively in the workplace.

The heterogeneity and organisational diversity of Mode 2 knowledge production is marked by: (a) an increase in the number of potential sites of knowledge creation, (b) the linking of these sites through functioning communication networks, and (c) new societal contexts arising from the simultaneous differentiation of fields and areas of study into finer and finer specialties. Gibbons et al. (1994) assert that whole process is permeated by social accountability and that participants are more reflexive because research issues extend beyond scientific and technical problems, reflecting on the values implied. Unlike the Mode 1 form of quality control, which they see as being defined "largely in terms of the criteria which reflect the intellectual interests and preoccupations of the discipline and its gatekeepers" (p. 8), other social, economic, or political interests may be included in Mode 2.

Following from the above, one of the implications of Mode 2 knowledge production is the trend towards the de-institutionalisation of academic knowledge with the expansion in the potential supply of knowledge producers, paralleled by a demand for specialist knowledge in the development of new technologies, possibly through collaborative arrangements. This has serious implications for universities and vocational institutes, as discussed above. Another closely related issue is that of quality control within the educational institution; this issue, dependent upon the institutional space, is particularly pertinent to vocational education in Australia where quality accreditation issues are assuming increasing importance, impacting upon the daily work of teachers.

Gibbons et al. (1994) observe that as institutions become more permeable, the socially distributed knowledge production will encompass a wider social spectrum of individuals and groups, tending towards the form of a global web. Thus, Mode 2 knowledge production creates both a demand for and supply of innovative information technologies.

Socially distributed knowledge production, predicated upon participation, has implications for the prevailing division of labour and the sense of community. The involvement of a wider social spectrum appears to have serious consequences for adult and vocational education, underlining the importance of preparing graduates at all qualification levels to participate in workplace and other social and civic problem solving and decision-making processes. For this to happen, they need to be able to communicate in the broadest sense — drawing upon mathematical knowledge and insights. The shift to transdisciplinarity and heterogeneity of the academy and the workplace should be expected to inform vocational mathematics curriculum and teaching in terms of content, process, and values, both explicit and implicit — however, this would constitute a radical change to the current situation, in Australia at least.

In an era of globalisation, Gibbons et al. (1994) conclude that governments themselves will be challenged. As national institutions need to be decentred, to be made more permeable, it is imperative that they interact collaboratively with other national and supranational bodies. This is already happening with institutions such as UNESCO and the OECD, but there is scope for more collaborative interaction at the post-compulsory education level in vocational education, especially as it pertains to mathematics.

6.8. FLEXIBLE LEARNING AND THE DE-INSTITUTIONALISATION OF EDUCATION

Flexible learning in its various forms has a long history, fulfilling a range of *bona fide* needs on behalf of particular groups of students (e.g., Foks, 1988). Here, it implies the modularisation and customisation of courses, and delivery outside of the regular institutional sites and times — possibly face-to-face but increasingly through print and electronic media; almost always self-paced. However, from a political perspective, Katherine Nicoll (1997) suggests that flexible learning provides a technical solution to the political problem of “a perceived failure of the education and training systems to respond to an increasing pace of social change” (p. 104). She notes that there is a tendency to promote it unproblematically as a new technology for delivery, increasing access and choice; it is positioned dominantly as a ‘better’ form rather than as something which may change content, outcomes, even identities of students and teachers. In other words, the consequences have been given little attention.

In what John McIntyre and Nikki Solomon (1998) see as a trend towards *de-institutionalisation,* the old boundaries between theory/practice, disciplines, learner/worker, working/learning have become blurred, and therefore contested. However, new and different kinds of boundaries are providing the framing. They draw on the 1996 work of Bernstein for a broad meaning of curriculum in relation to sites of contestation, including:

> (a) curriculum knowledge categories, particularly what kind of work counts as 'curriculum' and what does not, and how this is to be known (b) pedagogical relationships, or the nature of the transactions which mediate workplace-based learning (c) assessment, or the problem of representing and validating evidence of learning, and (d) location, the question of the site of educational exchanges. (p. 144)

In my experience, underlying feelings of unease among TAFE teachers — even if rarely articulated — could be located at each of these four sites of contestation. Each is becoming fragmented under technologies of power in relation to knowledge production and distribution in Australian adult and vocational education. Bruce Lindsay (1999) elaborates on the fragmentation in the first three process:

> [the] recruitment and the development of content (in the form of markets and client groups on the one hand, and research, curriculum, programs, etc on the other, especially with "industry" input and regulation)
>
> [the] transmission, and interpretation and performance of content (notably of the codes and information that are integral to it, such as "competencies" and professional techniques and attitudes)
>
> [the] assessment, monitoring and evaluation of learning (i.e. of appropriation of content, through grading and credentialism; but also of the workforce through performance indicators, quality assurance, etc). (p. 2)

And, as indicated above, the sites of educational exchanges are certainly becoming fragmented in time and space with flexible delivery.

McIntyre and Solomon (1998) suggest that the state has actively been seeking to reshape institutional forms of vocational education (in both university and VET) away from what they term the *socio-democratic settlement* in education through the mechanism of work-based learning. In essence, they claim, this amounts to externally mounted challenges to traditional discipline-based knowledge production — these call into question the institutional power of the universities by means of a politics of curriculum, attacking the accepted order or codification of academic knowledge. Curriculum in workplace-based learning is almost completely defined by work activities. While there is contestation between the workplace and the academy, as mentioned above, another layer of complexity is added with the worker/learner confronting their own issues of identity and subjectivity, as well as taking responsibility for their own learning. Marginson (1997), McIntyre and Solomon (1998), and others assert that the workplace-based learning is a particular commodification of knowledge; the concept of flexible learning is one manifestation of this process.

The theorisations of Gibbons et al.'s (1994) 'new modes' of knowledge production (discussed above) help to explain the shift from *culturally concentrated* to *socially distributed knowledge*; they also raise important issues for vocational mathematics education. The emergence of a new mode of knowledge production, Mode 2, characterised by transdisciplinarity and heterogeneity, heterarchy and transience, is contrasted with the academically constrained problems of Mode 1, those of Mode 2 are set in the context of application and are more socially accountable and reflexive. These ideas give support to the importance of the ability to solve problems through selecting relevant data and having the skills to organise them appropriately, even imaginatively (e.g., NBEET/ESC, 1996). It would appear that the mathematics used in the workplace is aligned with Mode 2, emanating as it does from a broad range of considerations, whereas the culturally concentrated mathematics of the academy is aligned with Mode 1. What is, then, the role of the discipline of mathematics for vocational students in the new order of learning and work? This question is particularly important as Mode 2 knowledge production transcends social and traditional hierarchical levels; communication may, of necessity, take place across the traditional workplace demarcations.

Even though the culturally concentrated knowledge of the academy is challenged by the instrumentality of workplace-based learning, according to McIntyre and Solomon (1998) workplace-based learning still requires disciplinary knowledge in order to constitute itself. Workers need to be competent in disciplines such as mathematics in order to communicate effectively in times of crisis or creativity. This is not to suggest that they need high academic levels of abstract theory; rather that they need to have developed higher order thinking skills around the breadth of mathematics that they actually confront in order to participate as workers and as citizens in any 'democracy.' Such skills might include being cognisant of the 'bigger pictures' such as symmetry, randomness, chaos theory, recursion, infinity (Ernest, 1998c) — see also Steen and Forman (1995) and Steen (Ed.) (2001) — and of the broad principles of economic and social modelling which underpin many decisions which affect their daily lives. As Peter Drucker (1993) observes, the qualitative aspect of knowledge — its productivity — is more important than the quantity.

Lindsay (1999), drawing on Nicoll (1997), suggests that the concept of socially distributed knowledge is at the heart of flexible learning. In the neoliberal strategy of conflation of learning and work the implementation of flexible learning is reduced to a technical problem (see also Girdwood & Reich, 1997; Raggatt, 1998). At the same time credentials "act to decodify, for capital and on the labor market, the skills, capabilities, work discipline, and professional attitudes of an individual or mass of people" (p. 7). In other words, the structures of flexible learning and its associated credentials are being harnessed ostensibly for the good of the nation and individuals as members of society, but it would appear that they are actually serving as a means of control over worker/students and their teachers. Lindsay observes three coherent tendencies of flexible learning consistent with the technologies of management discussed above, which are summarised here:

1. It increases the space of mediation between students and the teacher, especially by technological means, but also through forms of packaged and modularised curriculum. This implies a deskilling of teachers, and arguably students; ultimately the replaceability of teachers.
2. It shifts responsibilities and obligations for learning, support and the organisation of the learning process onto students themselves. Technological solutions such as

chat groups and email lists are part of these schemes, but they also provide a solution to on-campus overcrowding.

3. It increasingly integrates learning into the flows and organisation of work.

As noted by Lindsay, the flexible learning agenda is also associated with privatisation and contracting out of support services, including library services, and the rationing of face-to-face access for students.

McIntyre and Solomon (1998) elaborate this concept of socially distributed knowledge as it applies to flexible delivery in the form of *workplace-based learning*. According to an unpaginated ANTA flexible delivery brochure, (1998c), it "describes a whole range of approaches that would provide the vocational education and training that employers and learners want, when they want it, at a convenient location and using a variety of approaches and resources." Curriculum in workplace-based learning is almost completely defined by work activities (e.g., Beach, 1999). In the academy, McIntyre and Solomon argue, this is "a site of considerable tension and contestation . . . because practice-based and co-operative education fundamentally challenges the boundedness of disciplinary knowledge" (p. 143). But, in my own experience, such tensions tend not to surface in vocational institutions.

McIntyre and Solomon (1999) see workplace-based learning as a manifestation of technologies of power used in conjunction with technologies of the self to construct workers' identities as docile, self-managing subjects, appreciative of the opportunities for self-improvement through lifelong learning. Boundary crossings signalled by flexible learning, lifelong learning, and so forth, provide a mechanism for the de-institutionalisation of education, the conflation of learning and work, and ultimately the redundancy of qualified teachers as skilled professionals through the fragmentation of systemic functions — as culturally constructed knowledge becomes socially distributed knowledge. Thus, as McIntyre and Solomon (1998, p. 147) note, this fragmentation and standardisation of power and control are more diffuse, and so "less visible or transparent, and thus less easily described, represented or managed by all concerned, including academics, workplace supervisors and learners themselves."

Thus far, I have focused on the political aspects of technologies of power as they have catalysed organisational change in the Australian VET sector, from the Kangan era to the present, including the promotion of lifelong learning, together with strategies of flexible delivery. For teachers such as myself, the last quarter-century has been one of rapid change and confusion as to our professional identities, embedded in dissonant conceptions of what is, and what no longer is, valued. One major impact of the technologisation of vocational education and training is the intensified separation of 'knowers' from 'doers' (Vanderburg, 1988); those who remain in the classroom have become firmly established as the doers in need of constant surveillance, while their managers at all levels appear from below as the knowers in a system predicated on technologies of power.

Educational research is one form of knowledge production and, as elsewhere, one with (sometimes) unequal access to funding, even limited distribution. The question arises: Is research in VET yet one more technology of power?

6.9. RESEARCH IN VOCATIONAL EDUCATION AND TRAINING

Clive Chappell (1996) asserts there is a research vacuum in the Australian VET sector, and it is my contention that this is especially the case for vocational mathematics where curriculum and teaching have been under-theorised. A climate of restricted possibilities for critique of policy discourse together with control of curriculum determination being ceded to employers and spokespersons from industry has contributed to the near total absence of public (popular and academic) debate about the mathematics taught in the sector. This is in marked contrast to the lively debates that seem to accompany prospective and actual changes to school mathematics curricula, and even the faintest possibility of government interference in the higher education sector's teaching effort.

Could it be that the introduction of the National Training Framework, where the very concept of curriculum has been downgraded to a non-endorsed component, as has professional development, represents a deliberate attempt to avoid debate on issues of social reproduction? Could it be, as Fitzclarence and Kemmis (1989) suggest, to undermine the possibilities of critical thought in both teachers and students? Under current technologies of power it appears, to use Skovsmose's (in press) words, as though the essential educational questions have been eliminated.

6.9.1. International Perspectives

The German Research Council has adopted a broad definition of vocational education and training research as that which examines the "conditions, processes and consequences of the acquisition of professional qualifications and of personal and social attitudes and positions which appear significant for the execution of professionally organized work processes" (Achtenhagen, 1994b, p. 19).

In common with the UK (Brown & Keep, 1998) and Germany (Achtenhagen, 1994a), the Australian research effort in relation to vocational education is fragmented in terms of its disciplinary base and of its location in a multiplicity of institutional settings, public and private. Apart from the range of designated VET research centres, there are national and international generic and discipline-based educational and other associations, conferences, and journals to which researchers and practitioners may subscribe. One consequence of this fragmentation is the marginalisation of VET researchers in discipline-based fields of education. However, there are signs of change at recent ICME and PME meetings, for example.

Alan Brown and Ewart Keep (1998) identify several policy issues in the UK which appear to have increasing resonance elsewhere in their effects on VET research: (a) the substantial role played by the economic imperative, even in the face of the lifelong learning rhetoric of pursuing social goals; (b) the institutional framework of continuous change, with over 15 years of structural reform; (c) the reliance on voluntarism by industry in their training effort; (d) the weakened role for social partners such as trade unions; (e) qualifications-led change; and (f) the reliance on market mechanisms for achieving VET reform. As in Australia, research has been undertaken to evaluate the effects of policy changes but this has been problematic because of the pace of innovation which has seen a shift in focus, or indeed the implementation of new initiatives before the evaluation or piloting has been completed. Brown and Keep also point out that policy makers tend to be nervous of academic criticisms and questioning (cf., Ellerton & Clements, 1994), opting for competitive tendering and often selecting commercial consultants who are more likely to pursue the government line. Ultimately, they say, UK policy in VET has been predominantly informed by neoclassical economic theory rather than educational theory — with limited, if any, systematic capacity for assimilation of research results into decision-making. Resonant with Vanderburg's (1988) description of technical rationality which ignores externalities, Achtenhagen (1994a) explains that politicians (and bureaucrats) who solve policy problems with hasty decisions tend only to consider the main effects of policies and give insufficient attention to the possible and probable side-effects which are very often counter-productive to the intended main-effect. They think mainly in institutional and organisational categories and

> try to gain their ends - which very often are inadequately defined - by changes of institutions and of tracks through the educational system. They are not used to thinking in person-related, content-related, goal-related and process-related categories or - globally - in pedagogical dimensions. (p. 207)

As a result there are major disjunctions between policy-makers and practitioners and research communities — across many countries, it seems. Yet ultimately these policy decisions are intended to achieve social and economic reforms through technological management strategies of manipulation of the institutions of teaching and learning. A dilemma arises: how are teaching and learning processes to be informed of and, in turn, to inform these policy decisions?

Vocational education research in Europe tends to adopt a more comprehensive approach to questions of teaching and learning. For example, Onstenk's (2001b) contributed chapter for the European Centre for the Development of Vocational Training [CEDEFOP] identifies several issues which could be problematised in relation to uncritical adoption of policies and practices. These issues include:

1. The differentiation of core skills and general qualifications, including the skills lists of Australia, the UK and the USA — as distinct from key competences and key qualifications models found in Denmark, France, Germany and the Netherlands, which lead to the concept of broad occupational competence (see also Wedege, 2000b, 2001).
2. The various curriculum designs which might follow from chosen competence models in (1); for example, the GNVQs in the UK, criticised for failing to produce "broadly skilled polyvalent workers" or to address broader visions of citizenship and personal development. These may be compared with the Danish General Qualifications Project which centrally locates the student/worker, placing their needs ahead of those of the current labour market, accommodating the training framework to the learner rather than *vice versa*.

3. The differentiation between self-steered and self-directed learning educational methods in initial vocational education, and the impact of these on teachers' work — requiring constructivist, cognitive psychology in the first case, or coaching and encouragement of reflection in the second.
4. The possibilities of developing broad occupational competence through problem-based learning, focusing on core occupational problems, in a reflexive, collaborative learning environment which support the development of "creative and flexible approaches to problems" and "contextualised, critical learning," with preference for "subject integrative and thematic problems and projects."
5. Differentiation between formal on-the-job training and informal on-the-job learning (Onstenk, 1999).

As discussed in chapter 2, there are centres in Denmark and the Netherlands, for example, focusing on vocational mathematics education as a field worthy of research.

As Maurice Kogan and Albert Tuijnman (1995) point out, educational research and development must comply with two conflicting sets of conditions. It must be rigorous and recognisable within the scientific community. At the same time it must be reflexive, responding to "the needs of useful knowledge from an extraordinarily complex and important sector of human activity" (p. 73), that is, the practitioner community. Time and resource allocation are imperative. They argue that there is also a strong case for publicly funded research to include representatives from all stakeholders on steering committees. "Indeed, the more complex, multi-variable and uncertain the patterns, the more likely are practitioners, policy-makers and the public to need information and insights into what education is doing and what it achieves" (p. 81). They argue that educational values and policies are and should be contestable, as should agendas and the interpretation of research findings; evaluation should not be limited by the needs and objectives of consumers. They conclude with a plea for an adequate time scale, possibly involving scholarship rather than project-based research. The total agenda for educational research and development ought to be "broad, deep and eclectic" (p. 87) — that is, reflexive. Is this message being heeded in the case of vocational mathematics education?

6.9.2. Research as a Technology of Power?

John McIntyre (1998) pursues the issue of reflexivity of VET research, arguing that funding programmes which press for 'useful' research with 'policy impact' are but one aspect of the *performativity* of new bureaucratic styles in an interventionist state which adapts research to policy management. He asserts that researchers are co-opted to policy work in which the conditions are set for direction, management, and dissemination. Thus, there needs to be a shared understanding between researchers and bureaucrats as research is sought to answer policy imperatives, thereby implicating research in policy processes. McIntyre urges researchers to problematise the nature of VET research culture, to explain why education and training should be a domain for policy intervention, and to critically analyse their engagements with state-sponsored research — in other words, to see "how policy processes are constructing research" (p. 215). McIntyre concludes by urging the VET research culture to take a socially critical approach of inquiry into the conditions of its own research production.

The issues raised by McIntyre are compelling — not only for vocational education research, but also for mathematics education research. McIntyre's paper provides an insight into why this kind of scholarly interest in the teaching and learning of mathematics from practitioner and research perspectives appears to be marginalised in VET research. It helps to explain the predominance of macro-level policy-related research published in journals and conference proceedings over meso- and micro-level issues of teaching and learning. Even where the latter receive attention, this is mostly generically oriented — interest in discipline-focused issues is minimal.

Inquiring into the conditions of knowledge and research production, Bill Green and Alison Lee (1999) address the issue of disciplinarity from an education research perspective. They see the study of education as being "about the ways in which knowledge is socially constructed, authorised, and organised, and hence [involving] a distinctive attitude towards knowledge as well as its enabling technologies" (p. 210). According to them, education as a discipline is a 20th century phenomenon, located in universities that were expressly set up for professional studies such as theology, law and medicine. As an aside, they note that teacher training was never accorded the same status in Australia as other professions in the traditional universities due to the lesser status of teaching which was associated with public service and apprenticeship training. Green and Lee continue that discipline knowledge, implying differentiation and specialisation, and privileging research over teaching, evolved in the late 18th and early 19th centuries as universities reconceptualised and reorganised their roles. Education, they say, has found itself marginalised through its emphasis on process over (disciplinary) content, and by its traditional association with the meta-disciplines of philosophy and psychology which they claim are no longer held in such high esteem. They also assert that the multidisciplinary character of education is problematic in that, in meta-organisational terms, its normative positioning oriented towards the traditional Ph.D. "effectively albeit implicitly marginalises pedagogy and practice alike" (p. 217); yet education has symbiotic links to practice and to institutions and policies. Bob Lingard and Jill Blackmore (1997) observe that there is a tension between the 'multidisciplinary' orientation of educational research and its own contextualisation within changing material and discursive circumstances, such as workplace-based learning and online access to information and education, including contemporary challenges to disciplinarity. Green and Lee see these tensions as marking a significant contradiction in the education research culture's self-understanding. (Green and Lee's analysis may also provide some insights into the passionate debates over mathematics education as a research field, as may be found in

Sierpinska & Kilpatrick, 1998, for example.) One example of this challenge to the disciplinarity of educational research, particularly as it applies to VET research, can be found in the OTFE's (1995) research strategy where the definition of research is as follows:

> In this strategy the term research is used in its broadest sense and encompasses the full range of conceptual and empirical investigations undertaken to expand knowledge of vocational education and training. They can be both pure and applied in nature. Defined in this way, research activities are relevant to all stakeholders in the State Training System. (p. 4)

Although the prospect of recognition of an increased breadth of knowledge production from outside of the academy is to be welcomed, the issue arises as to the status of each of the knowledge claims; holders of specialised research expertise and credentialled skills face the prospect of being accorded ambiguous status in relation to other knowledge producers. For example, Ralph Blunden (1999) suggests that policies and practices are often determined by appeals to numerical strength rather than the merits of the policies and practices themselves.

Several issues for further research arise in relation to vocational mathematics education. What are the boundaries for this research? What are the interfaces with mathematics education research in other sectors and with adult education research? What is the relationship between culturally concentrated academic mathematics and socially distributed workplace knowledge? And what are the implications of this for vocational education across the board? More broadly, who are constructed as knowers in and by the VET sector? What are the objects of knowledge that define these subjects' (i.e., teachers and students) institutional existence as authorised knowers? Finally, how can these be problematised and challenged at a political level?

6.10. CONCLUSION

In this chapter I have sought to broaden the frame of reference for technologies of power from the micro-level of teaching and learning situations (chapter 4), and major elements of the recontextualising field (i.e., curriculum and teachers' work) at the meso-level (chapter 5), to macro perspectives on politically oriented, if not determined, issues of knowledge production and distribution. Discussion has been focused on technologies of power through political and corporate influences which have been manifested in discourses of lifelong learning, user choice, and flexible delivery, for example. Ultimately, these are contributing to the de-institutionalisation of post-compulsory education and training. Ironically, TAFE institutes have been complicit in implementing policies which might bring about their own eventual demise. Even research funding in the Australian VET sector could be considered a technology of power as it is largely structured to reinforce policy of the government of the day, eschewing critical commentary. Researchers have to choose their words carefully when applying for funding, and writing up reports; those which challenge official policy or suggest the possibility of radical social change may be left ‘on the shelf’ (e.g., Buckingham’s 1997 report — according to a public servant who wishes to remain anonymous). However, although vocational mathematics and other practitioners are likely to feel relatively powerless in the face of continual policy shifts and structural changes, the VET research community — which by no means excludes practitioners — is exhorted to adopt a critical and reflexive stance, not only towards the sector at large, but towards the conditions of its own knowledge production and distribution.

In chapter 7 I revisit the discussion raised in earlier chapters concerning the production and use of public image as yet another technology of management, both in vocational education and in mathematics education.

CHAPTER 7

CONCLUSION

What Counts as Mathematics in Adult and Vocational Education?

7.1. INTRODUCTION

This chapter will raise for discussion unresolved policy, research, and practical issues which relate dialectically to the range of technologies encountered over the terrain of this monograph, but whose outcomes are ultimately effected through technologies of power — albeit not unproblematically. The concept of *aporism* was first introduced in chapter 1 as a means of expressing uncertainty and perplexity about the formatting role played by mathematics and its social implications. Ole Skovsmose (1998a, 2000) invoked the concept in an attempt to clarify the paradox of the double role played by mathematics — as an extension of human rationality and as a powerful force acting, for better and for worse, on society.

Plato's understanding of *aporia* is related to the fundamental irreducibility and undecidability of an idea or concept. It is described or presented as an impassable passage or an epistemological dead-end; an absence of a way through a problem. However, the impossibility itself of finding a way or passage becomes the motivation for doing so, and potentially points to the solution. In Aristotle and later philosophy aporia is described as a puzzle arising from the difficulty of reconciling two or more accepted or plausible beliefs (I am indebted to Evan Kritikakos and Constantinos Tzanakis for these insights.) Nicholas Burbules (2000) defines aporia as lacking a path or passage but conceptualises it as a movement towards an unknown destination, distinguishing it from progress towards a fixed answer; metaphorically as seeking a path where no trail yet exists rather than a road connecting knowns. Faizal Rizvi (1997), in response to Burbules, adds that people experience doubt and uncertainty in ways that are culturally and historically specific, and that aporia "should not be seen as a state to be overcome in search of epistemic certainty but as an opportunity to ask new questions, to view things differently and to create new maps in order to improve the quality of our intellectual work" (p. 3). This is my hope for this concluding chapter. So, what might be a way forward, a new trail, for adult and vocational mathematics education, in Australia at least, to re-view and perhaps resolve some of the apparent contradictions and paradoxes?

I firstly revisit the issue of public image raised in chapter 1, arguing that this is but one of a range of technologies of management and must be taken seriously by the international mathematics education community. Suggestions are made for vocational mathematics teaching and curriculum, professional development, and research which might contribute to an enhanced public image of both mathematics and vocational education. The concept of broad occupational competence introduced in chapter 2 is revisited, linking it more closely with the institution of mathematics and pedagogical issues of teaching through core problems. I then close with a broad-ranging summary of the issues and some final thoughts.

7.2. PUBLIC IMAGE AND TECHNOLOGIES OF MANAGEMENT

Public opinion, it appears, is being constructed more and more through its correlate, public image. In a dialectical relationship, public opinion is a crucial factor in the formulation of VET policy. At the same time public image is being used as a tool of policy promulgation intended to influence identity formation, as technologies of the self, by targeted, segmented groups of citizens.

From a political perspective, Willem Vanderburg (1988) recognises that technology and techniques are not only employed as means to accomplish human ends but that they also mediate relations — hence the importance of image. He claims that the media help induce public opinions that are fundamentally different from private opinions arrived at by experience or by reading and reflection. Although both technically and culturally mediated relationships exist in contemporary society, he claims the former predominate. He continues that if these forces were perceived by the public as determining they would cause a sense of alienation, but this is avoided when both technique and the nation-state are 'metaconsciously sacralised.' Public opinion mediates between specific events and the deep structures of a culture. Political myths and rituals largely determine what members of a society can accept as politically realistic. According to Vanderburg, "it is not unusual for policies to remain popular even though they fail to bring about any results. Their role is in part to reinforce the images of a society which serve to perpetuate its way of life and power relations" (p. 22) — to maintain control even when they do not serve the best interests of the community. Following the work of Jacques Ellul, Vanderburg notes that human minds have become spontaneously oriented in a technical direction so that autonomous politics, decisions free from technical necessity, and values independent of technique, have all but disappeared. Clearly technique is not a neutral tool.

Following the work of J. K. Galbraith, Vanderburg (1988) observes that it can no longer be assumed that consumers make autonomous choices with respect to large producers; producers no longer respond to demand but create it through advertising (see also Gee, 1994). Under the influence of mass sociological currents, portrayed lifestyles become norms and are the primary means of social integration in a society, based on a technical way of life where knowing is separated from doing, the knowers from the doers. Ultimately, he claims, individuals come to rely on a range of human technologies so that to raise productivity, for example, would require motivation of workers through technical means such as those afforded by psychology.

Public opinion, according to Vanderburg (1988), not being based upon experience and personal knowledge of the individual, is therefore non-rational. The rise of this phenomenon is coupled with the inability of citizens to participate meaningfully in society due to the externalisation of control and its concentration in large institutions. Governments explain new problems and justify proposed solutions in terms of perceived public expectations, and any resistance is countered by public relations techniques to transform the government's decision into 'the will of the people.' Citizens who are incapable of understanding the many complex issues dealt with in the political process, yet unwilling to admit their inability to form genuine opinions about these processes, are ready to accept explanations offered by propaganda accompanied by preconceived positions and value judgements, claims Vanderburg. Thus, technique has reduced political sovereignty and now creates imperatives to which political life responds. "The sacralisation process makes it extremely difficult for a majority of society to see key phenomena for what they really are" (p. 29). Ellul (1982, cited in Vanderburg, 1988) argues that new techniques and technical possibilities tend to reinforce the existing system, but that this is not inevitable and a transition to a culture based upon human values and standards is possible using these techniques.

It would appear that policy formation in the Australian VET sector is driven by technologies of management that orchestrate and then act upon public opinion — a public opinion reflecting predominantly the interests of industry and big business, although small and medium-sized enterprises are attracting increasing attention possibly because of their large number. As noted in chapter 3, the work of Habermas suggests that decisionistic theses are employed to make 'value-free' decisions complemented by non-cognitive ethics, and this positivism is then underpinned by mythology — in this case of portrayed public image. This mythology then enables the macro-level decisions such as an Open Training Market and User Choice to be promoted as 'being responsive to clients' (e.g., ANTA, 1998c, n.d.-a) without drawing attention to the silences and gaps regarding the needs of those who are disenfranchised, such as members of the student population and the VET teaching profession. In fact the public image being promoted in ANTA documents suggests the non-necessity of having formal teaching arrangements, recognised industry-wide curriculum, qualified teachers or even teachers at all. It also enables publicly-funded research formulations to ignore the practical issues associated with discipline-based teaching, learning, and professional development, as well as social justice — although I assert that the last cannot be separated from the others. These are 'covered' under the generic headings of flexible delivery and benchmarking (Montague & Evans, 1996) associated with 'the new VET professional' (NCVER, 2000) in technically-oriented research — taken in both senses, as adoption of new technologies and as a research paradigm — to support uncritically current government policy positions.

Australian government policy-makers have diverted funding away from the public system of vocational education, yet need to attract fee-paying students who will add to the human resource base of the nation generally and to individual businesses and enterprises. The solution again lies in the utilisation of public image to reform the identity of segmented groups of citizens as lifelong learners, convinced that they should 'invest in themselves' (e.g., ANTA, 2000a, n.d.-b). How do these public images of the Australian VET sector impact upon the discipline of mathematics within it? What might theorisations of public image mean for mathematics and mathematics education in general? To address these issues I return to Restivo whose work on the sociology of mathematics was first introduced in chapter 1.

7.3. THE IMAGE OF VOCATIONAL MATHEMATICS AS LOCATED WITHIN THE PUBLIC IMAGE OF MATHEMATICS EDUCATION

Sal Restivo (1999, p. 1) addresses the mythology which "reinforces ideas of purity and genius, and even madness" about mathematics and mathematicians. He notes that publications which promote the authority of mathematics, masking understanding of human endeavours, ensure that issues of power, race, class, and gender are excluded. He claims that programs designed to advance public understanding of mathematics are generally only about its technical content. Vested interests wish people to be able to do that mathematics necessary to achieve external objectives of governments and immediate employers. In other words "they want people to participate in the social and moral order of educated publics" (p. 6), but without recognition of differential benefits accruing to individuals within any society. Restivo continues that there is also the hope of generating an understanding and appreciation of mathematics and mathematicians, but in this project the voices of social sciences and the humanities are silenced. Thus, public understanding of mathematics through this image construction of a human face comes to be about demonstrating its limits, the apparent ease of learning such traditionally esoteric subjects, and "the all too human qualities of its practitioners" (p. 6).

Although Restivo (1999) was attacking a narrowly conceived critical review of a recently published text by Reuben Hersh, some of these points may be pertinent to the discussion of public image of mathematics and the effects that flow on to stakeholders in vocational education, in Australia and elsewhere. Certainly there are vested interests who would like workers to be able to do just-enough mathematics just-in-time to suit parochial needs. It may be that the mathematics curriculum for pharmaceutical manufacturing operators, analysed in chapter 4, is an example of such an intention, albeit misconceived. Even requiring workers to submit themselves to this kind of post-compulsory education (i.e., tedious and largely irrelevant to any particular work role or life more generally) may be an exercise designed in itself to accomplish the ends of achieving a particular social and moral order. The rhetoric of the recent publicity release of the Australian Minister for Education, Training and Youth Affairs on numeracy standards (Kemp, 2000) underlines its rationale of promoting mathematics education to meet governmental objectives: "Australia needs capability in mathematics in order for the economy to grow and to be competitive on a global scale" (p. 1). In stating that "opportunity and numeracy go hand in hand" (p. 1), there is no indication to stakeholders of the differential rewards of unequal distribution of mathematical knowledge along gender, race, and class lines — from a government which is also heavily promoting private investment in the compulsory education sector through funding diversions to the private education system. Among the cohort of school leavers entering post-compulsory education, Australian VET students are likely to come from disadvantaged socio-economic backgrounds (e.g., Ainley & Long, 1998; McIntyre, 2000; see also Gorard, Rees, Fevre, & Furlong, 1998 for the UK).

At the TAFE institute departmental level, in the name of flexibility of staffing, it is possible for any teacher who is agreeable to teaching mathematics subjects to do so. This is irrespective of whether they have any post-school mathematical qualifications or even any educational qualifications at all, let alone mathematics teaching methods. What are the images of mathematics and mathematics education being portrayed here? It may be supposed that teachers' philosophical views of mathematics are likely to be absolutist (FitzSimons, 2000b), and that mathematics education is regarded as simply a matter of presenting algorithmic material clearly and concisely, followed by a sequence of worked examples and exercises to match, with assessment to replicate the format of the exercises. This approach to mathematics teaching and learning will do nothing to ameliorate the public image of mathematics held by vocational students who, in turn, are likely to perpetuate this image in their roles as workers and as relatives of children in their formative years. It militates against the rhetoric of lifelong learning in terms of approaches to learning and the desired outcome of producing creative problem solvers — both in the case of the students themselves and of those whom they influence, consciously or otherwise. Although Stephen Lerman (1999) suggests a possible beneficial influence on the public image of mathematics portrayed in recent times through the visual electronic media — consistent with the formation of public opinion discussed above —, long experience of sitting in classrooms (or nowadays at a computer) makes ingrained images, beliefs and attitudes difficult to shift.

Clearly, the international mathematics education community needs to be concerned with its public image for the sake of the discipline of mathematics and of the students themselves at all educational levels. This means that concern must be shown for learners of all abilities and for educational institutions and settings of all kinds. Personal experience of teaching adults (e.g., FitzSimons, 1993, March) suggests that there has been in the past an uneven spread of positive attention from mathematics teachers — generally least for learners perceived as 'less able.'

In comparison with research concerning adult learners, a disproportionate amount of attention from the mathematics education research community appears to be devoted to the needs of school children and their teachers, current and prospective. Youth and adult education are not mutually exclusive. Areas such as technology, special needs, and sociocultural issues, as well as the teaching of particular curricular topics may well be expanded to include adult perspectives. It must be acknowledged that attempts have been underway to broaden the focus in organisations such as the International Commission on Mathematics Instruction [ICMI] with their inclusion of a working group for action on adult lifelong education in mathematics (WGA-6) and a topic study group on vocational mathematics education (TSG-8) at the ICME-9 congress in Japan, 2000 — building on previous ICME meetings back to 1988 (see, for example, Strässer, 1994; FitzSimons (Ed.), 1997; FitzSimons, O'Donoghue, & Coben (Eds.), in press). It is also pleasing to note that groups affilitated to ICMI, such as the International Study Group for the Psychology of Mathematics Education (PME) and the International Study Group for the Relations Between the History and Pedagogy of Mathematics (HPM) are also incorporating adult and vocational interests (e.g., Fauvel & van Maanen, 2000; Straesser & Williams, 2001).

While there is a burgeoning research interest in adult and vocational education, the fact is that most participants at mathematics education conferences are school teachers or academics; production of publications is generally the realm of university-based researchers — relative to student numbers, there are very few people whose main occupation is adult and vocational mathematics teaching who are encouraged or even permitted by their own institutions to participate in international meetings such as these (or even regional or national conferences).

Goodwill from the international research community is necessary but not sufficient. Somehow it is necessary to locate the people responsible for teaching the millions of adult and vocational learners throughout the world, but this will never be an easy task. Rarely do they belong to recognised mathematics teacher associations, let alone know of them. Isolation is a major factor, even in an industrialised nation such as Australia, where mathematics teachers and other teachers of mathematics subjects may be located in large trade or vocational departments, in institutes around capital cities, provincial cities and towns, or in distant rural areas. With the exception of groups such as ALM (Adults Learning Mathematics) in the UK, AMATYC (The American Mathematical Association of Two-Year Colleges) in the USA and the BMN (Bridging Mathematics Network) in Australia, most other professional teaching associations appear focused on the needs of school children. It could be suggested by Ministerial advisors that industry or individual teachers themselves should take responsibility but clearly this is no solution at all. Access to websites is a beginning, but lacks a feeling of community in the real sense, and can be very time-consuming and perhaps of indirect relevance. Virtual conferences may provide a first step if it were possible to notify (and enthuse) mathematics teachers scattered in myriads of departments across the countryside and the funding could be found. This would overcome many of the problems of funding for travel and accommodation as well as of widely divergent teaching hours and weeks of operation in the sector. An amelioration of the professional development situation would need to be accompanied by a move towards the development of research-based curricular materials such as those found in The Netherlands with the TWIN Project and in Denmark with the Fagmat Project (Wedege, 1998b).

As mentioned above, one of the major factors affecting each vocational student's image of mathematics is the long period spent in compulsory education. The fact that so many school leavers, particularly those entering the vocational education sector, hold negative images of mathematics and their own abilities with respect to mathematics (justified or otherwise) and are fairly or unfairly criticised publicly for their lack of basic and higher order thinking skills, suggests that all is not well with the school system. As a thought experiment I propose that, just as attendance at a vocational institute is not compulsory and the sector must rely on its public image to attract and maintain student numbers, mathematics education be made non-compulsory for school students of all ages (and teachers' salaries dependent upon attendances). What might be the impact on curriculum and teaching, and ultimately the public image of mathematics carried by this new generation of school leavers? What might it mean for vocational mathematics education? Certainly student attitudes and expectations would be different. What might it mean for lifelong learning? It may even happen that big business and industry, seeing a potential black hole for mathematics education, decide to contribute substantial amounts of funding to mathematics education! This of course would raise ethical issues if the funding were to be tagged to selected students or to particular vested-interest programmes.

If the international mathematics education community were to address seriously public image as a technology of management, it could not afford to remain in the passive mode of description and analysis. Rather, following the work of Restivo (1999) it must theorise the technologies of public image with reference to its own identity. But, as identified by Peter Galbraith (1998) with respect to assessment, the community needs to develop an agreed ontology and, as evidenced by the ICMI study on research in mathematics education (Sierpinska & Kilpatrick (Eds.), 1998), it needs an identity that will encompass the plurality of research perspectives without falling into the modernist trap of the 'grand narrative.' Further, that identity needs to encompass, as does the ICMI study on history in mathematics education (Fauvel & van Maanen (Eds.), 2000), the International Handbook on Mathematics Education (Bishop, et al. (Eds.), 1996), also the subsequent edition (Bishop et al. (Eds.), in preparation), the needs of educators of adult and vocational students as well as higher education students. Failure to develop a cogent and theorised identity could result in political decision-makers defining mathematics (or numeracy) education on behalf of mathematics educators (e.g., Kemp, 2000) through the technology of 'objective standards' (see Coben, 2001, for a UK perspective).

According to Richard Bagnall (2000), educators need to avoid a reinscription of ideological certainty and foundationalism, yet need to discard the corrosive cynicism of profound disillusionment. He suggests that educators who are now being marginalised need to:

> devise and use ways of becoming more effective in moulding public opinion and discourse . . . [to] capitalize on the contemporary de-differentiation of education and other cultural entities and institutions . . . crafting a critical and constructive opposition to the non-progressive nature of contemporary lifelong learning discourse. (p. 33)

FitzSimons (2000d) identifies ways that adult and vocational mathematics educators might apply the principles of culturally-focused pedagogies, originally designed to overcome racism, to technologies of power associated with mathematics and mathematics education.

However, from a mathematics education research perspective, Jeremy Kilpatrick (2000) warns of the dangers of researchers failing to 'take the public with them,' of adopting research paradigms eschewing positivism, supposing that not only is absolute truth about teaching and learning unattainable but further that the pursuit of such truth is not viable. He claims that in rendering themselves incapable of providing reliable evidence with justifications in support of their theoretically-formulated models and making knowledge claims open to public debate, their ideologies will be unsustainable. In other words he is arguing for an extension of the scientific research paradigm to include interpretive research, yielding practical knowledge. This is a particularly salient point for industrially-oriented vocational sectors where traditional approaches to mathematics education prevail, and where there would arguably be high levels of cynicism towards innovation in mathematics education (should this be under consideration at all!). Thus, quantitative data, which contextually situates both the researcher and the researched, may be a necessary component of progressive educational research programmes; technical and practical interests cannot be neglected in the pursuit of critical interests. As discussed in chapter 2, and further elaborated below, general vocational education research and vocational mathematics education research is taking place in the Netherlands as a collaboration between educators and their social partners — including industry, teachers, and publishing houses. The stakeholder public is, in Kilpatrick's words, being 'carried with them.'

From a structural perspective, there are possibilities for vocational mathematics education in the Australian context, but which may have broader international implications.

7.4. VOCATIONAL MATHEMATICS, NUMERACY, AND WORKPLACE COMPETENCE

Given the apparent colonisation of the discourse of mathematics by 'workplace numeracy' in much official rhetoric, and its contested nature, I propose to review the concept of numeracy, while recognising that it has not been universally adopted. I will then revisit Jeroen Onstenk's concept of broad occupational competence, introduced in chapter 2, and refocus the discussion more closely on vocational mathematics. I link the institution of mathematics to the Australian Key Competencies (Mayer, 1992) and explore the possibilities of Onstenk's 'core problem' approach to vocational education, advocating collaboration between researchers from the fields of vocational education and mathematics education.

Recent studies, such as the ALL project (Manly & Tout, 2001), suggest that numeracy links mathematical knowledge, however acquired (formally, non-formally, informally) with communicative competence in the form of functional and information processing demands, be they in work, learning, home, community, or other social situations. It is necessarily contextualised, depending on the nature of the task within a given situation, and the type and nature of mathematical and other information (potentially) available. However, a definition such as this can only be taken as universal in its most general sense. Rather, actual practice, as in mathematics, will depend on background factors such as socio-historic, socio-cultural and local community of practice norms, together with the individual's dispositions influenced by their ontogenetic development. Thus there is an inevitable interplay of cognitive, meta-cognitive, and affective factors, which are not deterministic — rather they play out differently on each occasion. As discussed in chapter 1, there are critical dimensions to numeracy not generally acknowledged when courses or surveys are designed to accommodate the interests of the global economy, although individual interests are inevitably mentioned also.

Numeracy encompasses far more than familiarity with basic number facts and the four processes. As discussed previously, each culture (and here I include the culture of the workplace) engages in six universal activities: counting, locating, measuring, designing, explaining, and playing (or creative, rule-bound supposition) (Bishop, 1988). Bishop's concept has been adopted in further education numeracy courses which assume a broader interpretation (e.g., ACFE, 1996). But not only content and immediate context come into consideration. Important also is how learners are encouraged to use their developing knowledge of numeracy for emancipatory purposes as well as economic and social.

As discussed in chapter 2, a range of numeracies exist within the workplace, some recognisable within the discipline of mathematics, and some as valid ethnomathematical constructs. Reviewing Onstenk's (1998, 1999, 2001a) framework for broad occupational competence, in the workplace a range of interlinking competencies is considered necessary. These include: (a) *technical* competency, necessary to address production problems, (b) *methodical* and (c) *organisational* competencies needed to deal with planning and solving of routine and non-routine problems arising in production. Other competencies elaborated by Onstenk include: (d) *strategic,* (e) *social-co-operative,* and (f) *social-normative* ones, as well as a *learning* competence. These refer, among other things, to the local community of practice, where there are formal and informal rules governing work-related activities; the workplace is characterised by specific and sometimes competing cultural norms and practices.

In order to formulate this concept of broad occupational competence, Onstenk (2001b) drew upon two main strands of development addressing the need for a broader concept of skill. The first includes the basic, generic, core skills approach popular in Anglophile countries, such as the UK, the USA, and Australia with its Mayer (1992) Key Competencies. Other countries such as Denmark, Germany, and the Netherlands, have included generic qualifications as general labour market skills, but not in such a pre-eminent position. Their second, major focus, is on the development of an underpinning knowledge base, with increased emphasis upon logical, analytical and critical thinking.

Although Onstenk (1999, 2001a, 2001b) and other vocational researchers tend to reduce the Mayer (1992) key competency of 'using mathematical ideas and techniques' to an essentialist collection of arithmetic and measurement skills to be unproblematically transferred from school education, and no longer in need of development, I wish to open up this discussion. Following the analysis of the institution of mathematics in chapter 1, I propose that this competency is imbricated within each of the other officially endorsed competencies — *viz.* (a) collecting, analysing and organising information, (b) communicating ideas and information, (c) planning and organising activities, (d) working with others and in teams, (e) solving problems, and (f) using technology, together with the 'extra-official' cultural understandings competency. I assert that this entire set of competencies, viewed from a mathematical orientation, may be mapped onto Onstenk's (1999, 2001a) model of broad occupational competence discussed above (see Figure 2.1). In other words, the adoption of a broad, research-based interpretation of the term 'mathematics' — or even an acknowledgement of the pan-cultural nature of Bishop's (1988) six 'universal' mathematical activities — would see mathematics as a central underpinning and integrative study for living and working in a technologised world (e.g., FitzSimons, 1999b), instead of being placed in the ambiguous position it apparently now occupies within the Australian VET sector (FitzSimons, 1999a). In addition, such a mapping would enable the producers of vocational mathematics texts (curricular and pedagogical) to broaden their gaze beyond the persistent narrow focus on production problems associated with technical competency to encompass the full range of competencies falling within Onstenk's conception of broad occupational competence.

According to Onstenk (200la, 2001b), problems in work practice do not occur separately but in specific and various combinations. Concrete situations can often make contradictory demands on the worker, presenting problems and dilemmas which are of central importance to occupational performance, and for which they are required to find an efficient and effective solution. Describing these as sets of *core problems,* Onstenk asserts that learning through these — both in the direct acquisition of occupational competence and expertise, as well as in the concomitant development of learning, metacognitive and problem solving skills — will contribute to the development of transfer skills. Core problems may vary in complexity, strategic action, and social dimensions. As a didactic strategy, the complexity of core problems would be expected to vary as the level of the learning process. This approach is exemplified in a Netherlands vocational project initially for Building Engineers, supported by social partners, that blocks work into five to eight week cycles, accompanied by a series of booklets and CD-ROMs covering assignments, problems, and learning materials — all with the intention of integrating the executive skills (as in the Mayer competencies) with technical knowledge and skills (Onstenk, 2001b). However, van der Kooij (2001) notes that transfer in relation to mathematics in the workplace does not usually require the generalisation to abstraction as is the case where mastery of the discipline of mathematics is the endpoint. Rather, transfer is required to solve similar problems in different contexts. In terms of Bernstein's (1996) theorisation, the need to acquire the horizontal discourse overrides the need to acquire the vertical discourse. Onstenk (2001a) concludes that an important objective of vocational training should be the ability to handle the (almost) unpredictable and indefinable aspects which are characteristic of the work process.

I now wish to extend the link between the human resource or management aspects of technologies of production and the physical or material aspects, noting the dialogical relationship between mathematics and technology as a central, organising theme. Skovsmose (1994) noted that the application of formal mathematical methods has come to colonise all other areas of life, and other types of technologies have become dependent on if not absorbed by information technology. Thus, it would appear that vocational mathematics teaching requires a multi-dimensional approach to enable students to learn for, through, and about technology. That is, in keeping with Onstenk's (1999, 2001a) model, workers may be required to learn *for* technology, to expertly operate any or all of the four technology types (generic, energy, social, and information) identified by Skovsmose, in a practical sense — although it would not normally be sensible to teach explicitly the mathematics of the first. Teaching mathematics/statistics *through* technology, as obvious as it might seem to educators from other industrialised nations, is not necessarily a serious consideration in the Australian VET sector. It might imply the use of scientific or graphic calculators or other information technologies in concept and process formation and reinforcement; it might imply the use of information technologies as a vector for transmission; in neither case has there been any pedagogically-oriented research (cf., van der Kooij, 2001). Teaching *about* technology, as construed in the critical sense, is related to what Skovsmose called *the technology of mathematics* — which provides answers and only rarely articulates the questions from which they originated — and should be a consideration in this technological era. Each of these needs to be accommodated within a restructured vocational mathematics curriculum and teaching programme based on a solid foundation of research.

Onstenk (2001b) acknowledges that students (and teachers also) should be made aware of possible contradictions and choices in the restructuring of curriculum from the logic of disciplinary knowledge to the logic of occupational practice. He outlines five dilemmas inherent in this form of didactic innovation: (a) the relative emphasis to be placed upon the acquisition of learning skills versus an emphasis on content, (b) whether the role of the teacher is to be as expert or coach, (c) the choice between selection of breadth or depth of content, (d) the juxtaposition of thematic versus logical and analytically structured content, and (e) whether the student is to be defined as a learner and developing citizen or as a novice practitioner. He concludes that there is no one best solution; rather these dilemmas need always to be taken into account. I believe that each of these dilemmas needs to be firstly perceived and secondly addressed by decision-makers in all vocational sectors. Facing these squarely from an intellectual basis could offer the possibility of a 'curriculum of the future' (Young, 1999) which would present a transformative approach, offering learners a sense of agency in their ability to act upon the world, to create new knowledge as well as recreate existing knowledge, and to appreciate the interdependency of institutional knowledge and workplace knowledge.

The Netherlands appears to provide a credible model of innovation in institutionalised vocational mathematics education through the TWIN project, based at the Freudenthal Research Institute, Utrecht, with mathematics educators (researcher and practitioners) working in collaboration with a publisher, on engineering mathematics; also with a prospect of enhancement through an emerging linkage with vocational researchers such as Jeroen Onstenk from CINOP (den Bosch), a vocational research institute. Onstenk's notion of broad occupational competence provides a powerful way of conceptualising the possibilities of vocational mathematics education (and perhaps even school mathematics) beyond a narrow technical approach. It offers a theorised linkage between general educational competencies and practical realities (in this case, industrial) through its focus on core occupational problems. From a mathematics education perspective, another example of a curricular model which incorporates the discipline of mathematics with the construct of occupational competence (substituting workplace mathematics for ethnomathematics) is that of Abraham and Bibby (1988) — discussed in chapter 1. Focused at a more individual level, I believe that it is nevertheless complementary to Onstenk's structural model of broad occupational competence. Taken as a whole, a vocational mathematics curriculum of the future could meet the legitimate needs of *all* stakeholders — including higher productivity and satisfaction in the workplace and more fulfilling democratic participation by worker/citizens, predicated upon a critical approach to the discipline of mathematics and to the technologies it engenders and maintains. But this requires a collaborative approach between industry, mathematics educators, and vocational students.

7.5. FINAL WORDS

In the *Prelude* I positioned myself as a vocational mathematics teacher of approximately 20 years experience. Since beginning work in what has become known as the Australian VET sector I have been passionate about improving the quality of mathematics educational experiences for adult and vocational students — not only in the immediacy of my own classroom (however defined), but in the potential that a high quality mathematics education might have for all adult and vocational education students.

Of course, institutions are about more than buildings — important as they have been in the formation of public image of adult and vocational education in Australia and the UK, at least. In order to explore what counts as mathematics in adult and vocational education, I have used the construct of institution to explore perspectives on the fields of mathematics education and of adult and vocational education, and on the discipline of mathematics itself. Although social institutions are established to (re)produce shared meanings among members (Bauersfeld, 1980), they are nevertheless dependent upon constitution of meaning and may be resisted or contested by some participants. Throughout this monograph, I have considered a selection of historical antecedents and present-day practices of organisation in these most complex institutions which shape, through their regulatory norms, patterns of social conduct and value in relation to adult and vocational education — albeit with consequences which are often unexpected or contradictory.

The discipline of mathematics, argued by Restivo (1993) to be composed of constitutively social objects, yet entirely abstract unlike other sciences (Kahane, 1998), has a richness and complexity which leave it vulnerable to ignorance, criticism, and abuse, particularly in times of rapid social and economic change when stability and certainty are desired (e.g., Kline, 1980; Spengler, 1926). This has, not surprisingly, had an effect on the field of mathematics education — especially in vocational education systems, particularly in countries such as Australia where they are industry-driven. Thus, it is possible that those in influential positions (e.g., industry training board members, bureaucrats, vocational institute managers), who may have only a residual knowledge of mathematics and mathematics education derived from their long-distant school days, inform such deliberations as may be considered at all concerning vocational mathematics. In this case, it is likely that ideological meanings rather than structural meanings (Noss, 1994a, 1994c) hold sway. Somewhat paradoxically, mathematics (or the popular, but contested, construct of numeracy) is simultaneously held to be important, integrated into many vocational education courses, but rarely if ever problematised in terms of curriculum or pedagogy.

Part of the richness and complexity of mathematics lies in its historical and pervasive links with technology which, in this monograph, have come to assume the role of a unifying theme. The most obvious nexus is with the prime focus of the institution of vocational education itself, namely industry in the manufacturing, service, and symbolic-analytic sectors. Vocational education markets itself as preparing students to *work with* technology and *for* technology. As a direct result of the marketisation of education, vocational institutes (and universities) are now in open competition with one another, resulting in expensive marketing campaigns which project, globally and locally, glossy public images of high-technology learning environments, and supposedly relevant courses (Maaß, & Schlöglmann, 1999). Such marketisation is generally to the detriment of educational values (Finkelstein & Grubb, 2000). Vocational education also markets itself as *learning with* and *through* technology. Following from these it might be expected that vocational mathematics education would play a pivotal role, supporting and enhancing generic, energy, social, and information technologies — to use Skovsmose's (1994) categorisations. With further consideration it might inform an appreciation, even critique, of the structuring roles played by technology in our society; perhaps progressing along the way towards Skovsmose's epistemic concept of mathemacy which unites mathematical, model-, and context-oriented reflections *about* technology. There is evidence to suggest that the role of mathematics education in the Australian VET sector is anything but pivotal (FitzSimons, 2000b). In fact its survival in the sector is under threat with the demise of mathematics departments, the ever-diminishing hours formally allocated to curricular instruction — and the dissipation of what remains among vocational or literacy teaching, the chronic lack of discipline-related professional development, and the near-total lack of interest and ignorance towards the findings of international research in mathematics education, even when of direct relevance.

There are complex interrelationships between education and society in general, and industry in particular. However, in Australia it appears that what counts as vocational mathematical knowledge is a narrowly defined range of topics generally recognisable as school mathematics, garnished with so-called practical applications, with assessment largely focused on tests of facts and skills or short-answer questions. That is, there is an emphasis on that which is easily identified, delivered (increasingly, online) and assessed. With the integration of numeracy and literacy into workplace vocational courses, research indicates that mathematics education could disappear altogether (e.g., Falk & Millar, 2001, Sanguinetti & Hartley, 2000). This is in view of the situated nature of workplace tasks, the possible lack of mathematical and/or pedagogical content knowledge held by instructors, and the lack of serious research into the consequences of such integration for mathematics education. Where teachers are isolated, and networks are limited or non-existent, and with no formal means of renewal in the profession, consequences for vocational mathematics education can be serious.

From the student perspective there appears engendered, through their own compliance with the mechanisms of control, an inbuilt conservative tendency towards the mathematics education they have received in the past (for good or for bad), reflected in their expectations of the didactical contract (Brousseau, 1997). In my own experience of classroom teaching it is a challenge to simulate in any small way, apart from than onsite in industry, a community of practice other than that of the mathematics classroom itself (see, for example, Adler, 1996; Lerman, 2001). Given the inappropriateness of available curricular and teaching materials, such as those demonstrated in chapter 4, it can only be surmised as to whose interests are being served. What will count as mathematics for students in adult and vocational education? With what impact on their many societal roles (as workers, parents, etc.)?

A deeper question, and one that I remain unable to answer satisfactorily, is whose interests are being served by the sectoral isolation of Australian vocational mathematics teachers. Subject associations and research groups (generally university-based) make sincere attempts to offer possibilities for co-operation and collaboration, but none appears to be able to appreciate, firstly, the sheer complexity of the sector and, secondly, the pervasive political forces which, through technologies of power, have set this sector on what might be described as an 'anti-educational' trajectory in the pursuit of other political and social agendas. Mathematics teachers do care, but feel absolutely powerless to ameliorate the situation in any way (FitzSimons, 2000b). When both teaching and professional development have indeed become means of reifying neoliberal government policies, I wonder whether there is indeed a conscious attempt to undermine the possibilities of critical thought in both teachers and students (Fitzclarence & Kemmis, 1989); or, in Skovsmose's (in press) words, to eliminate essential educational questions.

The concept of technologies of power was introduced in chapter 3 through the work of Feenberg (1995), who asserts the importance of technology as one of the major sources of power, overshadowing political democracy. For him it is but one, non-deterministic, culturally constrained, social variable which enables functional rationality, isolating objects from their original contexts in an apparently neutral way. As a technology of power, curricula — in adult and vocational education, just as in school education — can become a means of social regulation. Vocational education has simultaneously been ascribed as the cause and the solution to economic problems of Australian governments over the last three decades at least. Yet, mathematics (and other) vocational curriculum and teaching has been under-theorised and under-researched as technologies of management override educational concerns, underlined by a lack of public debate over the goals of the sector. The enduring model of an atomised mathematics curriculum framework in the sector is testament to a technicist approach, even though curriculum itself has now been relegated to 'non-endorsed' status, with other fundamental questions such as transfer and assessment, understood in all its complexity (e.g., Galbraith, 1995a, 1995b), being accorded perfunctory attention in documentation. Alternative visions are possible, and have been realised through materials and professional development arising from pedagogically-oriented studies researching actual workplace sites in similarly positioned countries (economically speaking), such as the Netherlands and Denmark.

The search for an understanding of the nature and impact of technologies of power led me to draw upon several well-known theorists (e.g., Weber, Habermas, & Foucault) whose works have each made a significant contribution to education, although not always intentionally so. Max Weber's analysis of rationalisation and bureaucratic specialisation, calculability and accountability may be invoked to lend support to analysis of the shifts in management structure of the Australian VET sector over the last two decades. Weber's concept of technical rationality was developed by Habermas, whose interest extended to the condition of possibility of natural science and the conflation in modern societies of practical and technical power. This is at the heart of the work, and presents an insight into his decisionistic thesis, whereby value judgements are eliminated and goals can be treated as value-free decisions. Social commitment is gained by mythology which complements the positivist science — in this case, management science. The work of Habermas, then, has contributed to an understanding of how goals which were so contrary to professional beliefs widely held internationally, together with democratic values, came to be asserted and then imposed on this sector, with very little resistance from practitioners. The work of Foucault, especially on the production of 'truth' has been championed by educators who wish to resurrect marginalised knowledges (in this case, workers' knowledges). It also extends to the immanence of power, with respect to disciplinary power and surveillance. His identification of technologies of power and technologies of the self contribute towards an explanation for the normalising effects that policies and practices can have on managers, teachers, administrative staff, and worker/students.

Ultimately the work of Basil Bernstein — elaborated in chapter 3 — emerged as providing the most coherent and consistent framework for the wide-ranging terrain covered by this monograph. His concepts of symbolic control, pedagogy and identity, across institutional levels, recontextualising fields and texts, provided theoretical support for the analysis of texts as found in the discourses of lifelong learning, curriculum frameworks, and policy documents. In these I have just touched the surface and I believe that a more fruitful analysis might be developed through collaboration by mathematics education researchers with experts in discourse analysis.

Mathematics plays a key role, both as subject matter for study and as a means of quantification of 'output' in education systems where only that which can be measured is deemed, under technical rationality, to be important. At the conclusion of chapter 5, I posited that technology might be being harnessed to turn back against the discipline of mathematics — in the Australian VET sector if not elsewhere. In recent decades at least, there appears to be a consistent trend towards using vocational education as a political tool, even an arm of policy. Thus technologies, particularly social and information, have been utilised by those in power to achieve their not unproblematic ends.

In chapter 4 I presented examples of recontextualising texts in order to demonstrate at the micro-level the immediate realities faced by vocational mathematics students and their teachers; each group confronting the technologies of power which serve to construct their respective identities as 'doers' rather than 'knowers' (Vanderburg, 1988) — perhaps even their forms of consciousness of as producers and users of mathematical knowledge, and their personal desires (Bernstein & Solomon, 1997). This, of course, is not to deny agency to these groups; rather to highlight the practical politics of participation in the Australian VET sector.

The theorisations in chapters 5 and 6 concerning technologies of power in the Australian VET sector help to explain, in frameworks consistent with my own experience, the structural and institutional changes which have taken place — in terms of the radical shift away from a public service ethos to a corporate, market-oriented ethos, and where what is now valued (from the perspective of teachers such as myself) seems antagonistic to that which has gone before, notably during the 1970s 'Kangan era'. There has been a de-institutionalisation of education itself, whereby the workplace not the academy is regarded as the major source of knowledge production, described as a transition from culturally concentrated knowledge to socially distributed knowledge (McIntyre & Solomon, 1998). There have also been massive changes to the organisation of teachers' working conditions, in a sustained effort towards deprofessionalisation. Teachers have become disenfranchised through massive, non-negotiable changes to curricula — firstly through competency-based training which is based on a functional analysis approach, and subsequently through the replacement of the concept of curriculum by industry standards and the introduction of User Choice. Teachers are coming to believe that their skills are redundant as they are replaced by lower paid education workers or tutors, and (in theory at least) by technologies of education as registered in the move towards flexible learning as a means of delivery. At the same time, other workers as (potential) learners have been cajoled into accepting responsibility for their own learning through the discourses of lifelong learning, and for accepting their own changing conditions of work through pedagogical discourses of workplace communication. However, as I suggested in chapter 4, the pedagogical discourses of mathematics education in the Australian VET sector may paradoxically be a means of maintaining a docile workforce at the same moment that there are public cries from politicians and industry representatives for more creativity, innovation, and so forth. Finally, the sector, through another technology of management, appears almost hermetically sealed to critical ideas from within and outside through its tight control over performance-based research funding, where research agendas stray little from the policy positions already established by the government of the day.

In their discussion of the transformation from a capitalist economy to a new work order, Gee (1994) and Drucker (1993) assert that the concept of 'customers' and 'knowledge' are critical, transformative agents. But these notions of customers and knowledge workers as the new industrial élite were unknown in vocational education two decades ago. Who are the knowledge workers now? And who are the customers?

Public image plays a crucial role in the technologies of management within adult and vocational education, not only in the accomplishment of ends but also in the mediation of relations. While the ends might be the (re)formation of identities of teachers and student/workers to better serve the needs of the global economy, the technology of public image formation attempts to ensure public acquiescence, even to construct 'public demand'. My concern here is also directed at the larger community of mathematics education researchers and practitioners — in order that they may be proactive rather than reactive in this situation. Two decades of experience as an adult and vocational mathematics teacher provides cause for sober reflection on the mathematics education practices of the past, for certain groups of students at least. I do not believe that anyone could argue that all is well with mathematics education for school students worldwide.

Strategic partnerships with industry — between vocational mathematics researchers and professional associations, for example — may provide the beginnings of a structural solution. These could be used as starting points in collaborative discussions between stakeholders in any new vocational mathematics education venture. However, vocational mathematics (and other) teachers need to regain strategic control over the current lifelong learning narrative. They need to understand, and to work with their students to enable them to understand, the structuring roles played by mathematics in a technological society, not least on their own historical and social formations as well as in the construction of their desires through public image formation. In other words, they need to develop a (self)critical perspective to challenge and combat pressures on them, without becoming cynically disengaged, to creatively foster and realise potentialities, but to remain cognisant of their positioning in educational sites as (relatively) empowered speakers.

There are certainly contradictions within and between systems of adult and vocational education and public policy administration, and between the workplace and the (vocational) academy, for example. If a political and cultural shift were to be possible, I believe that Yrjö Engeström's (1999) model of *Expansive Learning,* for example, may provide a direction for the future, in the opening up of communication between all stakeholders. However, as he acknowledges, these processes are risky and associated with major transformations. Such interconnected activity systems could profit from members engaging in meaningful dialogue, not necessarily to reach a consensus, but to work together in a cyclic pattern of questioning, model-building, implementation, and reflection. The most important shift would be towards all stakeholders having the possibility of co-/re-/constructing their own answers to the question: What counts as mathematics in adult and vocational education?

APPENDIX 1: GLOSSARY OF ACRONYMS

AAMT	**Australian Association of Mathematics Teachers**
ACFE[B]	**Adult, Community and Further Education [Board]**
ACOTAFE	**Australian Committee on Technical and Further Education**
ACTRAC	**Australian Committee on Training and Curriculum**
AEC	**Australian Education Council**
ALBSU	**Adult Literacy and Basic Skills Unit**
AMATYC	**American Mathematical Association of Two-Year Colleges**
ANTA	**Australian National Training Authority**
AQF	**Australian Qualification[s] Framework**
BTEC	**Business and Technician Education Council [UK]**
CBT	**Competency Based Training**
CEDEFOP	**European Centre for the Development of Vocational Training**
CGEA	**Certificates in General Education for Adults**
DEETYA	**Department of Employment, Education, Training and Youth Affairs**
DETYA	**Department of Education, Training and Youth Affairs**
DfEE	**Department for Education and Employment [UK]**
EFSC	**Employment and Formation Skills Council**
ESC	**Employment and Skills Council**
GNVQs	**General National Vocational Qualifications [UK]**
ICME	**International Congress on Mathematical Education**
ICMI	**International Commission on Mathematical Instruction**

ILSS	**International Life Skills Survey**
ISO	**International Standards Organisation**
ITAB	**Industry Training Advisory Body**
NBEET	**National Board of Employment, Education and Training**
NBPTS	**National Board for Professional Teaching Standards [USA]**
NCTM	**National Council of Teachers of Mathematics**
NCVER	**National Centre for Vocational Education Research**
NESB	**Non-English Speaking Background**
NFITC	**National Food Industry Training Council**
NTB	**National Training Board**
NTF	**National Training Framework**
NVMCP	**National Vocational Mathematics Curriculum Project**
NVQs	**National Vocational Qualifications [UK]**
OECD	**Organisation for Economic Co-operation and Development**
OPCETE	**Office of Post Compulsory Education, Training and Employment**
ORF	**Official Recontextualising Field**
OTFE	**Office of Training and Further Education**
PRF	**Pedagogic Recontextualising Field**
RME	**Realistic Mathematics Education**
RPL	**Recognition of Prior Learning**
RTOs	**Registered Training Organisations**
STB	**State Training Board of Victoria**

TAFE	**Technical and Further Education**
TIMSS	**Third International Mathematics and Science Survey**
TMCIG	**TAFE Mathematics Common Interest Group**
TQM	**Total Quality Management**
UNESCO	**United Nations Educational, Scientific and Cultural Organisation**
VEETAC	**Vocational Education, Employment and Training Advisory Committee**
VET	**Vocational Education and Training**

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