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

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