Lifelong Learning: Practice and Possibility in the Pharmaceutical Manufacturing Industry

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This article seeks to address issues associated with lifelong learning from the perspective of teaching and curriculum practice in the areas of mathematics and technology in an Australian pharmaceutical manufacturing enterprise. Its aim is to reflect upon research-based innovative course delivery in the field specified to indicate possibilities in education for lifelong learning.

Following discussion of lifelong learning, issues important to the industry will be outlined. A brief description is given of some nationally accredited curricular modules for operators in this industry. In particular, the mathematics modules were perceived by operators as discouraging and even threatening. However, it was, and is, possible to work around atomised modules such as these to 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.

Lifelong Education

Although the notion of lifelong learning was posited by Dewey, 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.

Rubenson (1995) argued that this concept of lifelong learning has undergone fundamental changes in discourse since the late 1980s. He claimed that the original conception of lifelong learning/education, encompassing formal, in-formal and non-formal settings, would have moved towards a classless society through the reduction of educational gaps. 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 reducing the concept of lifelong learning to a narrow interpretation of equipping the workforce with necessary skills and competencies, in his opinion.
According to Rubenson (1995, p. 15) this second-generation lifelong learning “neglects to critically examine the underlying assumptions regarding work such as the link between education and work, and the combined effects of family and school, that hinders lifelong learning across class and ethnic lines.” He used Bourdieu’s concept of *habitus* to provide a perspective on this phenomenon: Socialisation within family, school, and working life provides a positive disposition towards adult education for some groups only. The work of 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.

Rubenson (1995) went on to express concerns about lifelong learning as a policy concept. Firstly, an individual’s readiness is primarily determined by factors outside the policy arena. Secondly, particularly under neoliberal governments, the imperative role of the state is diminished and, in contrast to earlier times, the burden is shifted on the individual to take responsibility for their own lifelong learning. This is certainly case in Australia and the United Kingdom — as can be seen from their respective websites (Australian National Training Authority, 1999; DfEE, 1999).

The more recent UNESCO report *Learning: The Treasure Within* (Delors, 1996) made the following statements which appear to contradict some, but not all, of Rubenson’s claims.

. . . education is at the heart of both personal and community development; its mission is to enable each of us, without exception, to develop all our talents to the full and to realize our creative potential, including responsibility for our own lives and achievement of our personal aims. (p. 19)

. . . it seems to us that the concept of an education pursued throughout life, with all its advantages in terms of flexibility, diversity and availability at different times and in different places, should command wide support. 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)

The concept of learning throughout life thus emerges as one of the keys to the twenty-first century. It goes beyond the traditional distinction between initial and continuing education. It meets the challenges posed by a rapidly changing world. . . . The need [for people to return to education in order to deal with new situations in their personal and working lives] is even becoming stronger. The only way of satisfying it is for each individual to learn how to learn. (p. 22)

However, Butler (1998, p. 69) warns that “readings of lifelong learning texts illustrate
both their persuasiveness and the contradictory positions available within their
discourses.” In a nationwide Australian study of feminised industries and occupations
there was evidence of the perpetuation of existing structural and workplace
discrimination related to the assessment and accreditation of workplace learning.
Depictions of mutuality, shared loyalty and trust are illusory, according to Butler. In
the adult and vocational education sectors “discourses of learning, and especially
learning for work, are colonised by the dominant discourses of globalisation and its
discursive practices associated with global competitiveness and late capitalism” (p.
69). And, as Butler, Jackson (1995), and others have observed, within the textual
representations of discourses such as curriculum documents, learners/workers are
often absent.

**Lifelong Learning in Mathematics in the Context of Changing Workplace
Organisation**

That workplace organisation is changing rapidly has been well documented, with
flatter management structures and the increasing value being placed on human capital.
Team work, communication, continuous learning at both the organisational and the
individual level are sought (Buckingham, 1997; Marsick, 1997). Competencies such
those described by NBEET/ESC (1996) include being sufficiently literate to combine
information collection and analysis, management skills, systems thinking, and meta-
cognition skills, in conjunction with information technology, to detect ‘signal’ from
‘noise.’ Without mathematics (or numeracy) these skills will remain under-developed.

Buckingham (1997) observed that, as a capacity to act, workplace numeracy is
part of an extended and developing knowledge system within communities of
learners. In addition to the need for broader generic skills, including higher order
mathematical thinking skills, specific numeracies (i.e., the capacity to use procedural
skills) in workplace are necessary, but not well defined because they include a wide
and changeable knowledge base. Noss (1997) claimed that sophisticated mathematical
skills are required for interpretation of results as well as error detection or retrieval
from catastrophic technological breakdown situations. He argued 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. There are complexities in relations between
professional and mathematical knowledge, and workplace decisions are based on an
interplay of these in any given situation. When decisions become contested or
problematic a workplace mathematics far broader than basic numeracy is required,
according to Noss.

Wedege (1995) defined technological competence in the workplace as the
possession of:

1. Professional qualifications: (a) to handle and develop techniques and
labour organisation; (b) to come to grips with the principles and the
knowledge basis of technology; and (c) to realise the relationships
between such techniques and organisation and general technological
development in society.
2. Social qualifications: (a) to assess critically and constructively; and (b)
to adapt and handle new situations which imply social and professional
challenges.

3. Democratic competence: to evaluate and take part in decision-making processes regarding new technology in the workplace. (p. 58)

These competences resonate with Onstenk’s (1998b) articulation of the interconnectedness of workplace competencies:

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)

Thus, training beyond day-to-day requirements is essential to the construction and acceptance of a new work organisation predicated on new techniques, both in the engineering sense of tools and machinery and in the socio-cultural sense of communication and participation in workplace decision-making. It calls for a complex array of skills and invites a more integrated and connected process than the prevailing models of hierarchical, linear, atomistic modules as found, for example, in vocational mathematics courses in Australia. Achtenhagen (1994) provided an insight into exemplary research-based integrative curricular projects being developed in Germany—although it must be acknowledged that the German vocational system is structured along very different lines from most Anglophone countries (Deissinger, 1994, 1996).

Lifelong learning does not begin after school days are over. As a result of time spent in formal mathematics education, many adults have formed negative self-concepts of themselves as learners particularly in mathematics (FitzSimons, 1994, 1997); calculators and, to a lesser extent, computers are feared by many. During their years spent in the classroom becoming enculturated (in the case of most first-world learners; otherwise acculturated) into the discourse of mathematics adults have been constructed as more or less successful learners and empowered mathematical subjects—through the mechanisms of curriculum (Popkewitz, 1997) and teaching discourses (Klein, 1998; Popkewitz, 1988).

For lifelong education to become a reality it is critical that people have the ability to learn how to learn—something which cannot be taken for granted from the schooling adults may have received in the past. Although recent school leavers continuing on to higher academic or vocational education may have been exposed to strategies of metacognition enabling them to reflect on their learning and thus focus on learning how to learn, it is unlikely that adults returning to study in the Australian vocational education and training (VET) or Adult, Community and Further Education (ACFE) sectors have had similar experiences. Adult students require the opportunity for careful reflection, analysis, and reporting on mathematical knowledge and behaviours in order to develop deep approaches to learning, personal construction of knowledge, and explicit metacognition strategies. Although there are potential benefits to adult students in the process of recognition of prior learning for accelerated progress towards the award of credentials—it was a strongly held principle of the earlier UNESCO report (Faure et al., 1972)—there remains the possibility of the adult returning to study missing out on the opportunity to learn about metacognitive strategies. A common request of adults returning to study mathematics is to “start at
the beginning” to regain confidence and rehearse learning strategies (FitzSimons, 1994).

Having outlined the broad picture of lifelong learning in relation to mathematics within the context of changing workplaces together with the particular needs of adult learners, this paper will now focus upon a case study of teaching in a particular enterprise in the pharmaceutical manufacturing industry.

The Training Needs of Pharmaceutical Manufacturing

Because of the extensive regulation associated with the pharmaceutical manufacturing industry, it is essential that workers at all levels are, at the very least, cognisant of the legal requirements and constantly changing operating procedures. In the Australian context there appears to be a direct relationship between the size of the company and the investment in formal training; many of the larger companies provide their own in-house training, and may even be Registered Training Providers in the Australian VET system (see, for example, Australian National Training Authority [ANTA] 1998b, n.d.).

Guthrie (1998) outlined the importance of training in the pharmaceutical industry. It is necessary, *inter alia*, for:

1. Good manufacturing practice (GMP): The Pharmaceutical Manufacturing Licence depends on GMP standards; training records are reviewed in regular GMP and Quality Assurance (QA) audits.
2. Pharmaceutical Industry requirements: All activities are documented. Records of production, equipment maintenance, and laboratory testing are considered as legally-binding documents.
3. Good business practice:
   (a) trained, skilled operators are needed to trouble-shoot and solve problems
   (b) processes are more reproducible
   (c) waste is minimised
   (d) skilled operators contribute to process development and scale-up activities.

As indicated by Guthrie, underlying every action in the pharmaceutical production process is the mandatory requirement for accountability and traceability — everything has to meet exact specifications as detailed in continuously updated standard operating procedures (SOPs), and to be checked and rechecked. All operators are acutely aware of the importance of this to their jobs.

In 1997 Swinburne University of Technology was contracted to ‘deliver’ the competency-based education and training (CBT) modules of *Calculations A* and *Basic Computer Skills* to pharmaceutical operators, both on-site and in the institution. As is the case with industry generally in developed countries, with the possible exception of the United Kingdom (Brown & Keep, 1999), workplace structures are changing in this enterprise. Although there is a strong training ethos emanating from company headquarters in Germany, the decision to participate in a formal, externally provided course was not taken lightly. After negotiations with the provider were completed, production workers were informed of the availability of training and offered encouragement through a combination of paid and unpaid study schedules. Organising
these schedules to fit in with production runs and rostered-days-off proved quite a demanding task for the company. Also the workers, many of whom had been out of formal education for many years, needed to be convinced of the value of further study and that it would not replicate their negative experiences of school education — particularly mathematics! For some, the inclusion of technology (calculators and computers) was of an initial concern. For others, the opportunity to gain recognition of their (plentiful) skills and to learn more through an officially accredited course provided a real morale booster. Although much literature on workplace education tends to polarise capital (or management) and workers, this company shows its workers respect and encourages a sense of belonging: it values and celebrates outstanding contributions, recognising that difficult working conditions are sometimes unavoidable (e.g., due to building refurbishment or to economic downturn elsewhere). Showing an insightful understanding of the workers’ broader educational needs, the operations manager requested that while some classes were to take place on-site, others were to be held in the formal institutional setting to provide familiarity and agency within this educational context (e.g., organising ID cards, using the library, locating classrooms).

Who are the operators?
In this particular enterprise the operators reflected to some extent the cultural diversity of Australia, with many being born overseas in Europe, South America, or New Zealand. Their educational backgrounds also reflected a diversity: from some having left school at minimum age without credentials to others holding degrees (perhaps a reflection of Australia’s unemployment problems). While it was obvious that RPL applied in some cases, the educational diversity of the group required a creative approach — in direct contrast to the transmission paradigm of most school mathematics classes — to overcome anxieties on the one hand and not to patronise those with greater knowledge and experience in some areas. As mentioned above, it is necessary for all operators to take the quality/legal aspects of their work very seriously, and they understand well that their own jobs, as well as public safety, depend on their efforts. An extraordinary sense of responsibility is shown by all, often enhanced by and reflecting prior experience in other industries. Innovation by workers is welcomed, as was the case with the Leading Hand who completely reorganised the Raw Materials warehouse to make it more efficient and then trained the other staff in the use of his computerised control system. In other words, the commonly used description of operators as ‘unskilled’ (O’Connor, 1994) is far from appropriate, as is training curriculum which is predicated on a ‘deficit model’ of what the worker cannot do. The functional analysis approach used in competency-based education and training curriculum design (Blackmore, 1999) not only fails to capture knowledge which workers possess and are capable of producing; it may also waste the precious time of workers and employers available for workplace education on meaningless tasks — as will be demonstrated below.

Calculations and Computing in the Pharmaceuticals Industry
The curricula accredited until 1999 for pharmaceutical operators specify 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. Operators found 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 (ACTRAC, 1994):

**Calculations A**

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.

**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

1 Of these first three modules, only Calculations A is core.
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 Communication 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. ...

How would a typical mature-age pharmaceutical operator respond to the Calculations documents? What encouragement is there for lifelong learning? It is difficult to justify the curriculum for Calculations A (the focus of this study, together with Basic Computer Skills) on economic or social grounds. How does it contribute to the survival of the enterprise (or the industry for that matter) in times of rapid economic change? It is clear to anyone with a working knowledge of the industry that, unlike all 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 1 operators in any section of the plant. How could it remotely be considered as setting the foundation for higher order thinking. On the other hand, Basic Computer Skills is noteworthy for its inclusion of the social dimension. The Quality Assurance module was, in the 1994 accreditation, completely dissociated from Calculations, although this has been remedied in the replacement Training Package (ANTA, 1998a).

How could these mathematics and computing curricula address the actual needs of this enterprise in the pharmaceuticals industry? I now outline an example of an attempt to integrate separate curriculum modules in such a way as to value learners’ previous experiences in and outside the workplace, while empowering them through the construction of new academic and technological knowledges and practices.

**Towards a possible solution.**

It is possible to work around this designated 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 (in press-a), 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.” This was supported by Kanes (1997) who claimed that numerical knowledge in the workplace is wholly contextualised, does not enter as a pre-given entity, and is fragmented and governed by the character of mediating artefacts within the performance of the task. These observations provide support for the introduction of a different form of mathematics curriculum for the workplace.

The first step was to spend time at the plant, particularly in each of the areas where operators were employed (or interacted with others) to observe, from the
perspective of a mathematical/technological gaze (Dowling, 1998), what was taking place on a daily basis. It was possible to frame the mathematical activities with the set of “six universals” that Bishop (1988) characterises as being an essential part of all cultures (and here I include the workplace culture): counting, locating, measuring, designing, explaining, and playing (or engaging in creative yet rule-bound suppositions).

One of the teaching strategies was to take the students on a guided tour throughout the production process of the enterprise, inspecting and analysing the work of operators at each station. At Inwards Goods parcels are received by mail or else unloaded from trucks. Accurate record keeping here, as in the rest of the plant, is essential. Packages delivered must be checked against orders, and coded according to carrier and eventual destination. Every box on a pallet must be accounted for, whether complete or partly full, and then stamped with a computerised label ready for storage in quarantine. Counting can incorporate the use of multiplication of whole boxes with addition applied to the part-boxes. And of course estimation skills (in combination with experience) are essential to assess the reasonableness of calculations. The labelling of boxes on large pallets can be problematic as not all are visible until they are finally unloaded: the operator needs to take account of obscured boxes and label them as soon as practicable. Location skills are needed for the immediate placement of these pallets as well as for the storage and retrieval of goods in quarantine. Communication skills are vital in the discussions with drivers concerning the unloading of pallets as well as checking of the order against the delivery docket. Some deliveries need to be redirected to other warehouses. Photocopies of paperwork are sent to stock control, and the Quality Assurance (QA) department needs to be notified of new deliveries. These activities are subsumed under explaining.

After unloading, the goods to be used in production processes are transferred to the Quarantine Store and eventually to the Raw Materials Warehouse if they pass QA checks. Tablets need to be converted from the measure of kilogram (used at the patent plant in Germany) to actual numbers — a conversion chart is used for this. Rolls of foil need to be converted from their known length in metres to their weight. In the warehouse each new delivery needs to be stored for easy identification and retrieval in a multi-storey set of locations, not unlike empty supermarket shelves, but reaching several times higher so that forklifts are necessary. Each location is then divided into sub-locations if necessary. Locations need to be allocated according to a principle of first-in-first-out (FIFO) in order to maximise currency of stock with limited shelf lives. Computers are used to record the sites of new stock and transfers and condensation of existing stock. SOPs provide sets of instructions for, among other things, the management of transfers. The warehouse is not a static place as transfers and removals (known as picking) are continually taking place. The skills of counting, measurement, location, explaining, and design come into play here.

In Production the compounding of creams and tablets needs the skills of accurate measurement of ingredients (always checked and re-checked). Final yields need to be calculated indicating the percentage of finished product compared to raw materials used. Quality control tests are run and interpreted by the QA department throughout the process. However, the characteristics of the machinery used (e.g., age, maintenance record) can also have a bearing on the quality regardless of the competence of operators. After completion of production packaging takes place —
sometimes in one continuous operation. Records need to be completed to ascertain that orders have been met, and yields calculated for packaging materials. Codes need to be checked and rechecked. Lids of jars need to be checked for ease of opening and strength of closing necessitating the reading of gauges on equipment designed for a torque test. Adequate estimates need to be made for the amount of glue required by labelling machines. Reject items need to be counted and all leaflets to be enclosed in packages need to be accounted for. Operators with advanced skills manage the high-technology automatic blister-packaging machine using a computerised monitor for initial programming and re-setting, and technological know-how for on-the-job adjustments. Counting, measuring, and explaining are in play here.

The Finished Goods Warehouse operates in a similar manner to its Raw Materials counterpart, except that there are also refrigerators and deep freeze units for some goods. Temperatures need to be monitored by the reading of thermometers and regular observations of continuously plotted graphs of multiple data sets. FIFO also applies, and goods cannot be distributed within six months of their use-by date. Again, accuracy of record-keeping is essential.

The Distribution section organises the packaging of orders and makes arrangements for various forms of transport according to the size and cooling requirements of packages, and customer preferences. Pick-slips need to be checked, orders are combined and packaged then weighed to the nearest kilogram. Carriers are notified by telephone or modem; records are kept for stock control, and connote numbers are entered for proof of delivery. Delivery deadlines are especially tight with chilled or frozen items. The skills of counting, measurement, location, explaining, and design come into play once more.

The final implemented curriculum was officially designated (for administrative reasons) at this time to include only Calculations A and Computing, but included important aspects of all modules listed above. Technology was the central focus. Using an activity of dice rolling as a starting point, the course also included computer simulations using a professional statistics package, Minitab, moving through to quality assurance and construction of control charts which are a regular part of workplace discourse — and a prime example of the need for detection of signal from noise. Calculations to analyse statistical data were performed in a natural manner, as were discussions reflecting on social issues of gambling together with industrial issues of quality management. Formal computer activities took place in the university (an important exercise in familiarising the workers with educational institutions, including the computerised catalogue system in the library).

All stages of the production process are clearly interdependent; the interconnectedness was underlined by the guided tour of mathematics and a second one to inspect the various uses of computers throughout the plant. The video series Against All Odds (COMAP, 1988) on statistics for undergraduates #13 and #18 provide insights into a similar model of manufacturing industry in the production of potato chips. In addition to the tasks listed above, pharmaceutical manufacturing operators are confronted with statistical control charts at Production meetings, and other graphical representations of their combined efforts (expressed in economic terms) at meetings with the Operations Manager. It is in cases such as these, where workers are confronted with mathematics used to evaluate their efforts, that they need
to be able to understand much more than basic numeracy in the form of the four processes for whole numbers, decimals, and fractions. Other workplaces are not necessarily as benign as this particular pharmaceutical manufacturing enterprise, and mathematical representations can be used more aggressively in an attempt to control the behaviour of workers (e.g., Buckingham, 1997; Wedge, in press-b). In lifeworlds outside of the workplace it is essential that all adults are able to critically evaluate mathematical information that concerns their social and community activities.

In this manner, the basic competencies were achieved, as well as higher order thinking skills and reflective thinking. There was no opportunity for formal evaluation of this innovative curriculum, but anecdotal evidence suggests that students were enthusiastic and management observed improved performance by at least some operators.

**Educational Implications**

The preceding section outlined routine tasks, but it is widely acknowledged that all workplaces encounter non-routine activities, emanating in part from breakdowns in technology, communication, and even regulation — as outlined by Onstenk (1998a, 1998b). New developments or innovations are another source of non-routine activities. It is then that a firm grounding in relevant underpinning mathematical knowledge is necessary, as Pozzi, Noss, and Hoyles (1998) demonstrated in the case of nurses.

As with workplace knowledge in general, part of the difficulty in identifying mathematical work is the tacit nature of much mathematical knowledge. In claiming that most personal knowledge in mathematics is tacit, Ernest (1998) described 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)

Ernest’s comment, directed towards the explicit teaching of mathematical thinking skills, resonates with the findings of research into professional and mathematical knowledge conducted by Noss, Hoyles, and Pozzi (in press). It underlines the impossibility of writing generic curricular content appropriate for all vocations — or even just one, given the idiosyncrasies of each work site.

Because of the rapid changes in workplaces, there is a premium on learning to learn — not only for current performance but also as an orientation on the future (Brown, 1998). Brown asserted that most employers preferred workers to have highly developed core skills (transferable skills and the ability to transfer them) above the necessary occupationally specific skills, recognising that training and skill development need to go beyond the narrow traditional industry interests. There is a need for learning contexts which draw attention to the significance of skill transfer, as well as the provision of a range of appropriate contexts. (See Billett (1996, 1998) and
Ernest (1998) for further discussion of transfer.) One of the most widely held misconceptions is that mathematical techniques, once mastered, will be able to be applied anywhere and any time they are appropriate — this is often described as the ‘tool box’ metaphor, but has been shown by researchers to be untenable.

**Conclusion**

In a reversal of traditional curriculum construction, the paper has described a small-scale attempt to utilise the affordances (contextual cues and properties) (Wong, 1997) of mediating artefacts of the workplace and the university computer laboratory to create meaningful learning experiences. The teaching approach has thereby attempted to ameliorate some of the more deleterious effects of a deficit model of the adult learner implicit in the accredited curricula. Worker/students, some of whom had never gained a formal educational credential, were now able to have their plentiful skills recognised — and many were thrilled by the graduation ceremony at the completion of the level I course. Although no formal evaluation took place there was anecdotal evidence of improved performance in solving workplace problems.

If the Australian VET system is to support industries at the cutting edge of technology, it must prepare workers, current and future, not only to operate in workplaces of the present (and past) but to initiate and accommodate technological change, albeit in a critical, evaluative manner. In order to achieve this, it must recognise the critical importance of lifelong learning — in particular, the need for ongoing learning in mathematics which operates in a dialectical relationship with technology. However, it must also be recognised that the issue of transfer is problematic: mathematics cannot be assumed to transfer automatically from the site of learning to any other.

Lifelong learning needs to be seen to have obvious benefits to both worker and employer, and ultimately to society in general. The curriculum and teaching of mathematics needs to be particularly well informed, not least because of the relatively disadvantaged backgrounds and alienating experiences of many learners in this discipline. Based on school curricula around the world, Niss (1996) outlined the following fundamental reasons for including mathematics which I would argue are consistent with the goals for lifelong learning put forward by Faure et al. (1972). The goals are:

— contributing to the technological and socio-economic development of society at large, either as such or in competition with other societies/countries;
— contributing to society’s political, ideological and cultural maintenance and development, again either as such or in competition with other societies/countries;
— providing individuals with prerequisites which may help them to cope with life in the various spheres in which they live: education or occupation; private life; social life; life as a citizen. (p. 13)

These goals are supported by the following aims, no less applicable to adults as they continue to develop intellectually and socially:
to focus on the needs and interests of the individual learner, in order to prepare him or her for active participation in all aspects of private and social life, including active and concerned citizenship in democratic society;

— to develop pupils’ personalities by engendering or enriching self-respect and self-confidence, independent and autonomous thinking (including logical thinking), the development of explorative and research attitudes, linguistic capacities, aesthetic experience and pleasure etc. (p. 32)

We must not lose sight of the tenets of lifelong learning in times of rapid economic change. The concept of equity is crucial and respect must be accorded adult learners in terms of their cultural, linguistic, social, and other backgrounds; their voices must be heard. It should also be recognised that the concept of work encompasses not only paid work in the official labour market (full-time, part-time, or casual) but also that which takes place in the home and the community (paid and unpaid). Each of these are potential sites for life-long education as well as formal institutions. It follows then that, insofar as education is a means of contributing to the maintenance and development of societal goals as well as individual ones, social concerns are no less important than economic.

The common practice of vocational educators going into a workplace — or even workplace personnel unqualified in education or mathematics — armed with off-the-shelf modules and teachers’ guides to present the kinds of atomised, disconnected curricula as shown above will not be of great benefit to students or to their employers. Research on adult learners (e.g., FitzSimons, 1994, 1997; Wedge, in press-c) suggests that it may even be detrimental. The teachers’ guides that are available for the pharmaceuticals and food processing industries show no apparent awareness of the issues of situated cognition (e.g., Lave, 1988; Lave & Wenger, 1991) or transfer (e.g., Straesser, 1998), presenting pseudo-contextualised examples and encouragement of memorisation of meaningless rules.

Rather, it is imperative that educators, properly qualified, make an effort to gain some appreciation of the cultural diversity within any workplace, in terms of the work done and the people who do it. They may even work to support workplace trainers. However, this can come at a price. Most vocational educators are only funded for the hours they actually teach in the workplace, so a way needs to be found around this.

Bishop’s (1988) six universals were used as a framework to examine the uses of mathematics in the case of a particular pharmaceutical manufacturing enterprise. The analysis was also framed within Onstenk’s (1998a, 1998b) concept of broad occupation competence, which highlights the multiply integrated competences in communication and regulation in addition to the more visible technical competences involved in production. The conclusion is that workers and adult citizens of the future, not just in manufacturing but also in knowledge and service industries, will require a mathematical education much broader than the so-called basic skills. Different kinds of mathematical knowledge and thinking from those associated with the commercial base established last century are required, especially in the performance of non-routine tasks. At the same time, the rhetoric of lifelong learning requires that vocational education addresses the cognitive and affective aspects of learning to learn, together with the ability to critique the uses of mathematics and technology in our
society. Is this a Utopian vision?

The alert reader will have observed that one of Bishop’s universals has not been mentioned so far: playing. That happened, if nowhere else, at lunch-times over a game of table tennis!

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