Economic Change and New Learning Demands: A Case Study from the Pharmaceutical Industry

Gail E. FitzSimons
Monash University

Lifelong Education

Although the notion of lifelong learning was put forward 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. 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.

Whatever the previous educational uptake and intellectual abilities of individuals, rapidly changing economic and social circumstances require that education be a lifelong endeavour, removed from particularities of time and location. There is a need to optimise professional mobility as well as to develop personal interest in education, in order to foster and maintain a sense of personal agency in areas such as reason, creativity, democratic competence, and a spirit of social responsibility.

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). Calculators and computers are feared by many. During their classroom apprenticeship into the discourse of mathematics they 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. This is something that cannot be taken for granted. According to Surman and Galligan (1993, p 1) metacognition has been interpreted by the mathematics education research community as 'an awareness of and conscious regulation of one's own thinking . . . knowing when you know and how best you come to know.' Although recent school leavers continuing on to higher or vocational education are likely to have been exposed to metacognitive strategies, it is unlikely that adults returning to study in the vocational education and training (VET) sector have had similar experiences.

As suggested by Surman and Galligan, adult students require opportunities 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 are vital. 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 UNESCO report (Faure et al., 1972) — adults returning to study might miss out on opportunities 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).

Uptake of the concept of lifelong learning among industries in the manufacturing sector has been uneven. However, in the pharmaceutical industry, extensive regulation makes it essential that workers at all levels are, at the very least, cognisant of legal requirements and constantly changing operating procedures.

The Economic Realities of Pharmaceutical Manufacturing

In Victoria there are a range of pharmaceutical manufacturing companies: some local, others multinational; some relatively specialised, others diversified. Pharmaceutical manufacturing may be just one arm of an array of petro-chemical products. The company discussed in this paper has an Australian head office in Sydney, and a range of plants in South East Asia providing potential competition for some of its products. The world headquarters is in Europe and is the size of a small city, with its own public transport, fire station, and even league soccer team. By comparison the Melbourne operation is very small and its viability cannot be taken for granted.

Guthrie (1998) outlined the importance of training in the pharmaceutical industry, 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.

If the goals of companies in the pharmaceuticals industry are, within constraints, to make a profit and increase market share, then there is a need to maximise the efficient use of both human and physical resources,. Production has to be streamlined, attuned to considerations such as meeting seasonal demands while remaining cognisant of the limited shelf lives of various products. As indicated by Guthrie (1998), underlying every action in the pharmaceuticals production process is the mandatory requirement for accountability and traceability: everything has to meet exact specifications detailed in (continuously updated) standard operating procedures (SOPs). All operators are aware of the importance of this in their jobs.

Although a strong training ethos emanates from headquarters, the decision to participate in a formal, externally provided course was not taken lightly by the company studied. After negotiations with a 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 demanding. Also many of the workers had been out of formal education for many years and needed to be convinced that further study was of value and would not replicate their negative experiences of school education. For some, the inclusion of technology (calculators and computers) provided an initial concern. For others, the opportunity to gain recognition of their (plentiful) skills and to learn more through an officially accredited course proved a morale booster.

Showing an insightful empathy for the workers' broader educational needs, the company requested that while many classes take place on-site, others be held in a formal institutional setting. This would provide familiarity and agency within an educational context (eg, organising ID cards, using the library, locating classrooms).

The company undertook to pilot the (then) newly accredited Certificate of Pharmaceutical Operations (Manufacturing) (ACTRAC, 1994a) for reasons related to productivity. The need for training was linked to the ability to respond to unexpected or unforeseen situations (and to initiation into routine procedures) encountered in the workplace. Production delays can be caused by serious events such as equipment malfunction, or simple failures, such as inadequate quantities of raw or packaging materials. Serious losses can be incurred through reworking, following error detection. Public recall of products can result in loss of sales, both immediate and long term as company reputation is damaged. Failure to comply with government regulations (through regular and random audits) can mean loss of operating licence. In any case, a lag in innovation, whether in product development or even local organisation, can reduce market edge. There are also possible social and economic consequences in terms of personal job loss, that have repercussions for the whole community.

As with industry in general, workplace structures are changing in this enterprise. 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.

Mathematics, Information Literacy, and Changing Workplace Organisation

The rapidly changing workplace, with its flatter management structures and increased reliance on human capital, has been well documented. Team work, communication, continuous learning at both the organisational and the individual level are sought (Buckingham, 1997; Marsick, 1997).

NBEET (1995) described the competency of information literacy as:

> 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)

This competency, which encompasses many of the Mayer (1992) Key Competencies including mathematics, is applicable at all levels of production, not just managerial.

According to Buckingham (1997), mathematics in the workplace is operational mathematics, a form of quantitative literacy, expressing a diversity of knowledge interests, and a capacity to work in mathematical ways for a range of purposes. As a capacity to act, numeracy is part of an extended and developing knowledge system within communities of learners. Specific numeracies (ie the capacity to use procedural skills) in the workplace are not well defined because they include a wide and changeable knowledge base. There is also a need for broader generic skills, including higher order mathematical thinking skills together with a critical appreciation of the many factors that make up a production environment.

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. Although in many work situations there is less reliance on traditional school mathematics skills (carried out more efficiently by computers), there is a greater reliance on an ability to think in a mathematical way. Workplace decisions are based on an interplay of professional and mathematical knowledge. When decisions become contested or problematic a mathematics far broader than basic numeracy is required.

Mathematics and technology.

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)

Workplace training thus calls for a complex array of skills. It invites a more integrated and connected process than the currently suggested accredited hierarchical, linear, separate-module course (ACTRAC, 1994a).

Chevallard (1989) elaborated the differences between explicit and implicit mathematics. 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 encountered by the general public. They are 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.

Keitel, Kotzmann and Skovsmose (1993) claim that mathematics education justifies the use of explicit and implicit mathematics, although the latter is never mentioned. Implicit mathematics is characterised by value systems that purport to be ideology-, conflict-, and interest-free, and therefore universal. Focussing on formal language and instruction which is characterised by rigour and precision, the subject becomes ‘object-related’ and impersonal. They continued that ‘. . . mathematics functions as an integrated part of technology. In a highly technological society mathematical competence therefore seems to constitute a major part of democratic competence’ (p. 270) — a competence included by Faure et al. (1972) in the development and maintenance of a sense of personal agency. However Keitel et al. assert that there are problems from an epistemological point of view: The type of knowledge used for developing technology is different from the type of knowledge necessary to analyse and evaluate technological constructions. Gaining mathematical or technological knowledge does not automatically lead to reflection about the use or function of technologies nor about the underlying mathematical models themselves. Their contention is that ‘democratic competence must be based to a great extent on reflective knowledge’ (p. 270).

The changing structures of workplaces have important implications for the future of workplace training both in terms of mathematics and computing to which I now turn.

The Vocational Mathematics Framework

With the introduction of the national curriculum in the vocational education and training (VET) sector in the early 1990s a national vocational mathematics curriculum framework was produced, based on the results of an audit of mathematical skills in technical and further education (TAFE) courses (Pantlin & Marr, 1992). The project recommended that a set of topic packages and an associated topic network be developed, with the 94 topic packages being assembled into modules or included in other mainstream modules as required. The explicit intention was to develop a mathematics curriculum which was nationally consistent across all vocational areas. The project was never intended to provide a critical interrogation of the underlying structure of the provision of mathematics in TAFE. As a result, there is a high degree of inbuilt inertia in the curriculum.

In the VET sector the apparent adoption of industrial values is to the exclusion of others concerned with the needs of the individual and/or other social groups (Stevenson, 1995). In the particular case of mathematics, Ernest (1991) was critical of those whom he termed ‘technological pragmatists’ whose utilitarian aims lack ‘a proper epistemological, moral or social foundation’ (p. 165), where knowledge is taken as given, the nature of society accepted without question, and technological development seen as neither problematic for society not the environment. Ultimately, he claimed, narrow aims for mathematics education may be counterproductive.

Confounding the problems of an inert curriculum framework, the implementation of CBT took place despite the fact that, according to Jackson, 1993:

> there exists nearly two decades of scholarship, including theoretical critique and empirical research . . . 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)

Jackson (1993, 1995) argued further that CBT was unlikely to provide industry with the competent workers, flexibility or responsiveness that the rhetoric suggests.

An unintended effect of a nationally consistent hierarchical curriculum is that it acts as a barrier to pharmaceutical workers at the operative level, because they are forced to revisit school mathematics. Fractions and decimals re-appear — because they are at the base of the extensive rational, linear topic framework — even though they are seldom used in the workplace. (They also form the first learning outcome at higher Australian Qualifications Framework (AQF) levels at level 4 (e.g., ACTRAC, 1994b).)

The assumption that basic levels of school mathematics are required at the lower levels of the AQF is not justified by the research. As Buckingham (1997) showed, workers are likely to be using and understanding different, broad, sophisticated mathematical and statistical ideas that are contextually significant, but may be unable to satisfy the competency requirements of a decontextualised skills test without the use of a calculator. In order to participate meaningfully in workplace decision-making, a sense of mathematical empowerment needs to be engendered (Wedege, in press) that includes higher order thinking as well as basic skills. However, it is questionable whether the accredited mathematics curriculum enables this.

Calculations and Computing in the Pharmaceuticals Industry

The accredited curricula for pharmaceutical operators specify generic core modules (calculations, quality assurance, and industrial communication), together with a range of pharmaceutical core modules (eg, good management practice, basic computer skills) and specialised electives in production, packaging, and materials handling. Operators found these to be of ascending relevance to their everyday work. The following are examples of elements and learning outcomes of some of these modules (ACTRAC, 1994a):

Calculations A[1]:
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

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

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 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. . . .

It is difficult to justify the curriculum for Calculations A (the focus of this study, together with Basic Computer Skills) on any grounds. How does it contribute to the survival of the enterprise (or the industry for that matter) in times of rapid economic change? Except for recording, it is certainly not a reflection of what most people do most of the time, and it cannot be considered as setting the foundation for advanced mathematical thinking. It is of completely different tenor from the other listed modules. Basic Computer Skills is noteworthy for its inclusion of the social dimension. Quality Assurance is completely dissociated from mathematics, even though the concept of representative samples is mathematically complex (though it could be reduced to a set of rules and procedures in a training environment).

This brings into question the relationship between the Australian Standards Framework (ASF) and the ACTRAC curriculum. The level 1 ASF descriptor (NTB, 1992), indicates that work is likely to be under direct supervision, but with some autonomy where working in teams is required. Competencies involve a limited application of knowledge and skills within a specified range of contexts, and are 'normally used within established routines, methods and procedures that are predictable' (p. 17). It is clear to those with a working knowledge of the pharmaceuticals industry that there is a discrepancy between the learning outcomes of Calculations A and what actually takes place on the job for level 1 operators in any section of the plant.

My conjecture is that the combination of the National Framework for the Recognition of Training and the National Vocational Mathematics Curriculum project, under a heavily bureaucratised system, has resulted in mismatches. Even the ACTRAC trainers' guide shows signs of artificial contextualisation (e.g., 'check your pay packet') and displays an ignorance of recent mathematics education research. To the best of my knowledge, there has been limited uptake of these modules; larger companies (from whom many industry representatives on the accreditation committee were drawn) tend to use in-house training (eg, Guthrie, 1998).

Towards a possible solution

It is 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 (in press), 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.'

Kanes (1997) made the following suggestions based on empirical research in the workplace:

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).

Similarly, Keitel, Kotzmann and Skovsmose (1993), note that:

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.

2. The knowledge is specific knowledge generated in specific contexts. It is potentially valid in this context but not necessarily in other contexts.
3. The knowledge is potentially useful for a specific audience.
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 studying the Melbourne pharmaceutical plant, a first step was to spend time 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 then possible to frame the mathematical activities within 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. Each was found to be an integral part of the workplace taken in its entirety of space and time over the range of workers' shifts.

The final curriculum was officially designated (for reasons of teaching allotment) 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 included computer simulations using a professional statistics package, *Minitab*, moving through to quality assurance and construction of control charts that are a regular part of workplace discourse. Calculations were performed in a natural manner, as well as discussions reflecting on social issues of gambling together with industrial issues of quality management.

While formal computer activities took place in educational institutions, another aspect of the program was the integration of workplace calculations and computer usage through guided tours of the plant. This was to provide greater insights for both teacher and students into the interactions and interdependence at the workplace. In this manner, the basic competencies were achieved, as well as higher order thinking skills and reflective thinking. Unfortunately 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 some operators.

Conclusion

This paper has argued that the accredited linear, hierarchical style of curriculum is inappropriate in the current climate of rapid economic change, particularly in the case of mathematics. It is unlikely to encourage the lifelong learning that has been promoted by governments since the 1972 UNESCO report, and does little to address the higher order thinking skills required in the new work order. The paper describes a small-scale attempt to use the mediating artefacts of the workplace and the university computer laboratory to create more meaningful learning experiences, thereby ameliorating some of the more deleterious effects of a deficit model of the adult learner.

The VET system prides itself on being responsive to industry needs, through pro-active as well as reactive strategies. The continual reproduction of a curriculum framework founded on school mathematics, garnished where possible with so-called contextualised applications, is epistemologically flawed in its failure to recognise the genesis and use of mathematics in the workplace and to address the issue of transfer (e.g., Billett, 1998).

To provide adequate curriculum and teaching in times of rapid economic change, the system needs to adopt innovative strategies, supported by sound educational research, to monitor and evaluate theoretically well-founded approaches in discipline areas such as mathematics for vocational education and training. These are currently lacking in focus where research funding is concerned (e.g., ANTARAC).

If the VET system is to support industries at the cutting edge of technology, it must prepare workers 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, the critical importance of the dialectical relationship between mathematics and technology must be recognised. Unfortunately mathematics curriculum and teaching has been allowed to languish in a virtual time-warp of a pre-technological era, with only minor concessions to the introduction of electronic calculating and computing devices into the workplace, and as educational tools in their own right. This is perhaps not surprising, given the sector's almost total isolation from the Australian and international mathematics education community.

Lifelong learning needs to have obvious benefits for both worker and employer, and ultimately for society in general. In the VET sector 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 of:

> — 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!

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