Mathematics in the Vocational Education and Training Sector: A Case Study

Gail E. FitzSimons
Swinburne University of Technology

In an industry-driven VET sector major educational decisions are made, not by educators, but by representatives of industry. Mathematics curricula for scientific industries have been designed under a positivist, technicist paradigm without an adequate research base. These are unlikely to be responsive to industry needs for a variety of reasons which include the methodologies used by two separate projects which impact on the curriculum framework, the superimposition of CBT requirements, and the failure to address the issue of transferability.

Introduction

The Vocational Education and Training (VET) sector describes itself as being *industry-driven*. This means that, in keeping with government policy, major educational decisions are made, not by educators, but by representatives of industry. In this paper I will argue that mathematics curricula for science paraprofessionals have been established under a positivist, technicist paradigm Competency Based Training (CBT) without adequate attention to the messages of the mathematics education and other research communities. Although intended to be responsive to the needs of scientific industries it is unlikely that this will actually eventuate for a variety of reasons. These include the methodologies used by two separate projects which impact on the design of the curriculum framework, the superimposition of CBT requirements, and the failure to address the issue of transferability.

The National Training Reform Agenda (NTRA): For the last decade the VET sector has experienced radical changes as a result of was originally known as the NTRA. The sector underwent a metamorphosis from the Kangan philosophy of development of the whole person (Kangan, 1979) to what is now known as a *training market*, where the language of business and industry has replaced the language of education as students and/or industries become 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* which strives for "continuous improvement through greater innovation, improved client choice and enhanced efficiencies" (Harmsworth, 1996, p. 3). The communities of interest represented in the corporatist alliance between industry, unions, and governments have been influential in shaping current Australian educational policy, which, in part, advocates closer links between education and industry, ostensibly to improve Australia's economic productivity and industrial competitiveness (Kell, 1993; Sachs, 1991). Education has been harnessed as a tool of micro-economic reform and its values have been largely ignored (Stevenson, 1995). As well as being industry-driven, the VET sector has also become nationalised, with major implications for curricula.

CBT: Since 1995 VET curricula have been required to have national accreditation in CBT format in order to obtain government funding. This is despite the fact that, as Jackson (1993, 1995) argued, there have been two decades of research to indicate that CBT has not and probably will not improve learning in most areas where it has been applied. Jackson argued further that CBT be viewed not as an instrument of curricular reform but as a an administrative means of keeping programs accountable: It is a textually mediated environment where what counts is not what individuals *do*, but what they can be shown to have done. In contrast to earlier eras important decisions about curriculum and teaching have been made, not by the teacher, but through documents which speak with an authoritative voice, according to Jackson. She concluded that CBT as a technicist solution was unlikely to serve the long-term interests of workers. Mulcahy (1996) also argued that CBT, constituted from a range of formal tools (analytic techniques; competency standards; competencies; modules), attempts to shape vocational curriculum practice in particular ways. This will be discussed in more detail below.

Mathematics Curricula for Science Paraprofessionals

The National Mathematics Curriculum Project (NVMCP): With a seemingly endless range of mathematics units being offered across the TAFE sector throughout Australia, and diverse regulations in each state, the NVMCP was set up in 1992. It conducted an audit of mathematical skills included implicitly and explicitly in TAFE courses. To assist further curriculum development it recommended a set of topic packages be developed and mapped onto an associated topic network; topic packages could be assembled into modules or included in other mainstream modules as required. The NVMCP had already commenced when the legislation requiring CBT format was passed, to which it was then required to conform. Its stated intention was to develop a mathematics curriculum which was nationally consistent across all vocational areas.

The audit's methodology was to collect and categorise mathematics curriculum documents from each state's TAFE system, although there were difficulties with this process (Pantlin & Marr, 1992). The final product is an extensive atomised topic network composed of 94 topic packages, from fractions and decimals to numerical methods (for example) arranged in a more or less linear progression of pre- and co-requisites. Although practitioners were employed as writers, the parameters had already been set.

The National Laboratory Science Technician (Scitech) Curriculum Project: Aimed at science paraprofessionals, this project consulted extensively with industry personnel and conducted sophisticated task analyses, collecting a wide range of data through a variety of techniques, to develop competency statements, study pathways, and appropriate (CBT) curriculum materials (Johnstone, 1993). The project developed a model that required "learners to be exposed to a rich domain of specific knowledge and given the broad problem solving strategies to facilitate its transfer" (Johnstone, 1993, p. 69). Findings revealed that industry desires attributes such as: "efficiency, persistence, client focus, adaptability, flexibility, independence, team work, concern for ethics and quality, and responsibility for their own work" (p. 68). The final product was intended to promote integration of skills across the curriculum.

The Scitech Project made a selection of what were considered appropriate mathematics packages from the NVMCP to form two mathematics and two statistics modules. However, as Harris (1991) argued, lists of mathematics topics generated by industry frequently overlook important mathematical skills that are invisible to those workers actually using them (see also Hogan, 1996), because they are embedded in the work context. Harris (1991), referring to workers at lower levels, noted:

> It is the lists of assessable skills that people remember as 'mathematics.' . . . In a climate that accepts that mathematics-for-labourers is minimal, numerical skills and little more, every new curriculum initiative for such a defined group generates or revives lists of skills all remarkably similar to those of previous projects and previous ages. The status quo is maintained and the popular and industrial image of workforce mathematics is fossilized in a state that is disowned by mathematicians and rejected by most in mathematics education. (p. 142)

Buckingham (1995a, 1995b, 1996, 1996 October), Hogan (in preparation), and Zevenbergen (1995) have established that the topics mandated for workers at the basic levels of the Australian Qualifications Framework (AQF) do not reflect the actual mathematical needs of industrial workers. In fact such workers are likely to be using and understanding much more sophisticated mathematics and statistics, simply because they are contextually significant (see also Dowling, 1991), but may be unable to satisfy competency requirements on a basic skills test without the use of a calculator. Similarly, many of the mathematics topics prescribed for science technicians, albeit at higher AQF levels, do not accurately reflect the work they will be likely to undertake either on the job or in other classes. For example, there are nine assessment criteria for one learning outcome which requires the solution of vocational mathematics problems using linear and quadratic functions and their graphs, and eleven assessment criteria for another involving exponential and logarithmic functions. These criteria mostly use the verbs "solve" and "sketch;" that is, skills which reproduce school mathematics techniques. At no stage are interpretive skills mentioned (except "interpret the meaning of a logarithm") and it could be assumed that such manipulative skills have been demanded by industry. Personal experience suggests that these skills are not used on the job, rather it is the interpretation of "messy" data, particularly the analysis of graphical data generated by sophisticated instruments including computers that will be useful. Ironically calculus units are strictly proscribed as they are not considered by industry to be relevant for workers at this level (I. Johnstone, personal communication, February 1996). Most of the suggested references are between 10 and 20 years old, while no reference is made to innovative work such as Barnes's (1991) Investigating Change series. This series has gender equity as one of its underlying principles, a concept barely addressed in these projects, or by the VET sector at large (see FitzSimons, 1997). In addition, the series uses a problem solving approach to understand and interpret patterns; collaboration, communication, and reflection are actively encouraged — exactly the kinds of attributes which are, as noted above, demanded by industry. In contrast to Johnstone's assertion, problem solving skills are not mentioned in the four mathematics/statistics units: The only problems are of the traditional textbook kind.

The selection of content relevant to students is confounded by the Scitech project having to simultaneously address the needs of six specialisations (animal technology, biological sciences, chemical laboratory technology, food science, geoscience, and medical laboratory technology), while the NVMCP packages have to be available to *every* industry group in the system. There is clearly a large distance from the detailed task analyses provided by incumbent workers or their supervisors to the final text which is mediated by the categorisation processes of the Scitech project as well as the NVMCP network, in addition to having to conform explicitly with detailed requirements of CBT (see, for example, Porter, 1993) which operates under a positivist paradigm. Such a circuitous route can only exacerbate the problem of accurately describing the mathematical ideas and techniques actually relevant to an occupation and transforming them into meaningful curriculum documents. This would appear to be one of the major problems (if not *the* major problem) of mathematics in the VET system, as it attempts to make curricula relevant to the system's *client group*: learners and (potential) employers. Billett (1996) has identified the problem as one of transfer of knowledge between different communities of practice: embedded in the social practice of the workplace, and disembedded in the sociocultural level of the TAFE college (see also Adler, 1996).

An example of text: The following is an application of the learning outcome: "Solve vocational mathematics problems using linear and quadratic functions and their graphs:"

> A researcher in physiology has decided that a good mathematical model for the number of impulses fired after a nerve has been stimulated is given by the quadratic function
>
> $$y = - x^2 + 20x - 60,$$
>
> where y is the number of responses per millisecond, and x is the number of milliseconds since the nerve was stimulated.
> (a) When will the maximum firing rate be reached?
> (b) What is the maximum firing rate?
>
> (ACTRAC, 1994, p. 29)

This example appears to be contrived, and makes no attempt to explain the physical model from which it was supposedly derived. Even students who are enrolled in the subject of *Anatomy & Physiology* can find no meaning in it; they strip away the words and proceed to solve the quadratic equation in a similar manner to the contiguous examples. It is clearly an example from a school mathematics text. One of the intentions of the Scitech project was for students to have transferable skills, yet the issue of transferability is the subject of much debate (Billett, 1996) and cannot be assumed to take place automatically. Examples such as the above almost preclude such a possibility.

Dowling (1996) argued that school mathematics textbooks have the ability to position students according to perceived abilities and to distribute different messages accordingly. It would appear that VET mathematics curriculum texts, although seeking to organise mathematics according to an industrial setting, actually organise it according to the principles that predominate within the recontextualising activity that is strongly allied to school mathematics. They also position adult students (young and old) as school children once more. Dowling (1995) argued 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 noted 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). Willis (1992) also attacked the spurious claims to contextualisation through so-called industrial applications. There is clearly a need for mathematics curricula which address the needs of students not only to have a repertoire of mathematical skills but to know which mathematics to use, how, and when, and to what level of precision; to recognise when one's skills are not enough and to seek further help; to evaluate the reasonableness of one's calculations or judgements and follow up this evaluation in a constructive manner by iterating or abandoning the strategy adopted. In social settings as well there is a need for people to exhibit a personal confidence in their own abilities to solve problems they perceive as mathematical, in contrast to the generally held belief that they are more or less incompetent in this domain (Benn, in press; Coben, in press).

Relationship of mathematics to technology: Mathematics underpins the technological formation (FitzSimons, Jungwirth, Maaß, & Schloeglmann, 1996), but needs to be considered as more than simply a theory of techniques (Maaß, in preparation). Consistent with the situation in Europe as described by Maaß, current VET mathematics curricula rely too heavily on an instrumental approach: It would be appropriate for adult students to include a critical reflection on the uses to which mathematics is put. Skovsmose (1994) used the word *mathemacy* to encompass mathematical, technological, and reflective competencies. According to Wedege (1995), technological competence encompasses three components: professional, social and democratic competencies. These distinctions were based on two theses of Skovsmose. Firstly, the knowledge required to develop technology is different from the knowledge needed to analyse and assess it. Secondly, learning mathematics does not necessarily teach the learner how to use it; that is, technological knowledge cannot be reduced to mathematical knowledge. According to Wedege simply inserting mathematics into the curriculum for (potential) workers does not ensure technological competence.

Innovative Curriculum Programs

This paper has addressed some issues associated with prescribed mathematics curricula within a CBT context. (See also FitzSimons, 1996a, 1996b.) Achtenhagen (1994a, 1994b), Noss and Hoyles (1996), and Sefton, Waterhouse and Deakin (1995) provide models of innovative, integrative curriculum development and implementation in the business, banking, and automotive industries respectively. Achtenhagen's model has been developed in Germany, and is the result of many years' research and development — a luxury not available in Australia, where research in the VET sector is mainly concentrated on managerial issues. Although Buckingham's research has addressed generic numeracies in the workplace, there is no provision for research into the teaching of mathematics subjects within the college environment, particularly at the higher AQF levels. Professional development at this level is also virtually non-existent (see FitzSimons 1995a, 1995b).

Conclusion

This paper has investigated aspects of mathematics curricula for science paraprofessionals to illustrate some of the problems which exist in the VET sector, where a solid research base for the teaching and learning of mathematics is lacking. The sector has also adopted a CBT model of curriculum and assessment despite the lack of research evidence that it will successfully achieve its intended outcomes, particularly at the higher AQF levels. The major problem for mathematics curricula appears to be associated with the identification of relevant mathematical content to reflect actual industrial needs and the subsequent didactical transposition into meaningful curriculum so that transfer will be optimally facilitated. In this way, it may be possible to begin to address the key competency *Using Mathematical Ideas and Techniques* in its fullest sense.

References

Achtenhagen, F. (1994a). How should research on vocational and professional education react to new challenges in life and in the workplace? In W. J. Nijhof and J. N. Streumer (Eds.), *Flexibility in training and vocational education* (pp. 201-247). Utrecht: Uitgeverij Lemma.

Achtenhagen, F. (1994b). Vocational education and training. (P. Mann Trans.). In *Education 49/50* (pp. 19-39). Tübingen, FDR: Institute for Scientific Co-operation.

ACTRAC (1994). *National Laboratory Science Technician Curriculum Project: Laboratory Mathematics module descriptor and assessment package*. Frankston, Vic: Author.

Adler, J. (1996). Lave and Wenger's social practice theory and teaching and learning school mathematics. In L. Puig, & A. Gutiérrez (Eds.), *Proceedings of the 20th Conference of the International Group for the Psychology of Mathematics Education, Vol. 2* (pp. 3-10). Valencia: Universitat de València.

Barnes, M. (1991). *Investigating change: An introduction to calculus for Australian schools*. Melbourne: Curriculum Corporation.

Benn, R. (in press). Silent murmurings. In G. E. FitzSimons (Ed.), *Adults (returning to) study mathematics: Papers from the 8th International Congress on Mathematics Education (ICME 8) Working Group 18*. Adelaide, SA: Australian Association of Mathematics Teachers.

Billett, S. (1996). The transfer problem: Distinguishing between sociocultural and community of practice. In *Learning and work: The challenges: 4th Annual International Conference on Post-Compulsory Education and Training (Vol. 4)* (pp. 21-36). Brisbane, Qld.: Centre for Learning and Work Research, Griffith University.

Buckingham, E. (1995a). A sense of social agency influencing the uptake of numeracy in workplace education: A work-in-progress. In B. Atweh & S. Flavel (Eds.), *MERGA 18: Galtha* (pp. 135-142). Darwin: Mathematics Education Research Group of Australasia.

Buckingham, E. (1995b). *Investigation of industrial workers' interests in the uptake of numeracy and communication skills*. Paper presented at the 2nd Vocational Education and Training Research Conference, Research and Practice: Building the Links, Melbourne, 12-13 October.

Buckingham, E. (1996). Challenging the conceptions of mathematics for the industrial workplace: Raising the profile of specific and generic numeracies (A work-in-progress). In *Conference Papers of the 4th Annual International Conference on Post-Compulsory Education and Training: Learning and Work: The challenges, Vol. 1* (pp. 143-151). Brisbane, Qld.: Centre for Learning and Work Research, Griffith University.

Buckingham, E. (1996, October). *Specific and generic numeracies of the workplace: How is numeracy learnt and used by workers in production industries, and what learning/working environments promote this? (A work in progress)*. Paper presented at the ANTARAC conference, Melbourne.

Coben, D. (in press). Mathematics or common sense? Some reflections on research into adults' mathematics life histories. In G. E. FitzSimons (Ed.), *Adults (returning to) study mathematics: Papers from the 8th International Congress on Mathematics*

Education (ICME 8) Working Group 18. Adelaide, SA: Australian Association of Mathematics Teachers.

Dowling, P. (1991). The contextualizing of mathematics: Towards a theoretical map. In M. Harris (Ed.), *Schools, mathematics and work* (pp. 93-120). London: Falmer Press.

Dowling, P. (1995, January). *Against utility in school mathematics and in educational research: A voice from the twilight zone*. Plenary address delivered at the annual conference of the Southern African Association for Research in Mathematics and Science Education, Cape Town.

Dowling, P. (1996). A sociological analysis of school mathematics texts. *Educational Studies in Mathematics, 31*, 389-415.

FitzSimons, G. E. (1995a). Barriers and boundaries associated with the professional development of mathematics teachers in the vocational and educational training sector. In *Conference Papers of the 3rd Annual International Conference on Post-Compulsory Education and Training: Barriers and boundaries in adult, vocational and post-compulsory education and training: Goals, values, knowledge, structures, participation and outcomes, Vol. 1*. Brisbane, Qld.: Centre for Skill Formation Research and Development, Griffith University.

FitzSimons, G. E. (1995b). Issues associated with the professional development of mathematics teachers in the Vocational Education and Training sector. In B. Atweh & S. Flavel (Eds.), *MERGA 18: Galtha* (pp. 247-251). Darwin: Mathematics Education Research Group of Australasia.

FitzSimons, G. E. (1996a). Does it add up? Adult education, mathematics and economic rationalism. *Education Links, 53*, 20-24.

FitzSimons, G. E. (1996b). Mathematics learning and work: Towards a critique of Vocational Education and Training mathematics curricula. In *Learning and work: The challenges: 4th Annual International Conference on Post-Compulsory Education and Training (Vol. 1)* (pp. 91-101). Brisbane, Qld.: Centre for Learning and Work Research, Griffith University.

FitzSimons, G. E. (1997). *Gender and adult education*. Manuscript submitted for publication.

FitzSimons, G. E., Jungwirth, H., Maaß, J., & Schloeglmann, W. (1996). Adults and mathematics (Adult numeracy). In A. Bishop, K. Clements, C. Keitel, J. Kilpatrick, & C. Laborde (Eds.), *International handbook of mathematics education* (pp. 755-784). Dordrecht: Kluwer.

Harmsworth, P. (1996). The training market. *Training Facts, 4*(6), 3.

Harris, M. (1991). Looking for the maths in work. In M. Harris (Ed.), *Schools, mathematics and work* (pp. 132-144). London: Falmer Press.

Hogan, J. (1996). A methodology for using classroom teachers to gather information about using mathematics from the work place. In P. Clarkson (Ed.), *Technology in education: Proceedings of the 19th annual conference of the Mathematics Education Research group of Australasia (MERGA)* (pp. 283-289). Melbourne, Vic.: MERGA.

Hogan, J. (in preparation). *Final report of the Rich Interpretation of Using Mathematical Ideas and Techniques Key Competency Project.*

Jackson, N. (1993). If competence is the answer, what is the question? *Australian & New Zealand Journal of Vocational Education Research, 1*(1), 46-60.

Jackson, N. (1995). 'These things just happen': Talk, text, and curriculum reform. In M. Campbell & A. Manicom (Eds.), *Knowledge, experience, and ruling relations: Studies in the social organization of knowledge* (pp. 164-180). Toronto: University of Toronto.

Johnstone, I. (1993). Models for competency and competency-based curricula for science technicians. *Unicorn, 19*(4), 66-71.

Kangan, M. (1979). A comment on 'TAFE in Australia.' In D. McKenzie & C. Wilkins (Eds.), *The TAFE papers* (pp. 6-20). Melbourne: Macmillan.

Kell, P. (1993). Reform in TAFE: Can a leopard change its spots? In *After competence: The future of post-compulsory education and training, Vol. 1*, (pp. 180-192). Brisbane: Centre for Skill Formation Research and Development, Griffith University.

Maaß, J. (in preparation). *Technology transfer — A useful metaphor for university level mathematics courses for engineers and scientists.*

Mulcahy, D. (1996). Performing competencies: Of training protocols and vocational education practices. *Australian & New Zealand Journal of Vocational Education Research, 41*(1), 35-67.

Noss, R., & Hoyles, C. (1996). The visibility of meanings: Modelling the mathematics of banking. *International Journal of Computers of Mathematics Learning, 1*(1), 3-31.

Pantlin, K., & Marr, D. (1992) *National Mathematics Curriculum Project: Stage I report.* Canberra: ACT Institute of TAFE.

Porter, B. (1993). *Developing competency based curriculum modules: A guidebook for TAFE teachers and curriculum writers.* Sydney: NSW TAFE Commission.

Sachs, J. (1991). In the national interest? Strategic coalitions between education and industry. *Australian Journal of Education, 35*(2), 125-130.

Sefton, R., Waterhouse, P., & Deakin, R. (Eds.). (1994). *Breathing life into training: A model of integrated training.* Doncaster, Vic.: National Automotive Industry Training Board.

Skovsmose, O. (1994). *Towards a philosophy of critical mathematics education.* Dordrecht: Kluwer.

Stevenson, J. C. (1995, October). *The metamorphosis of the construction of competence.* Inaugural professorial lecture. Brisbane: Griffith University.

Wedege, T. (1995). Technological competence and mathematics. In *Mathematics with a human face: Proceedings of the second international conference of Adults Learning Mathematics — A Research Forum* (pp. 53-59). London: Goldsmiths College, University of London.

Willis, S. (1992, October). *Being numerate: Whose right? Who's left?* Keynote address presented at Australian Council of Adult Literacy (ACAL) conference, The Right to Literacy: The Romance, the Rhetoric, the Reality.

Zevenbergen, R. (1996). The situated numeracy of pool builders. *Critical Forum, 4*(2), 34-46.