Vocational education and training, innovation and globalisation

Richard Curtain

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Key messages

- ✧ Australia has improved its innovative capacity, but performance is uneven and has still not kept pace with key international competitors. While Australia is ranked in the top six OECD countries for government expenditure on research and development, business investment in innovation is far below comparable OECD countries. Leaving innovation to market forces alone will not help Australia improve its performance. A whole-of-government approach supporting a national innovation system is needed. A key feature of such a system is active cooperation within and between levels of government.
- ✧ There is a danger in focusing *only* on those innovations concerned with a small number of high-technology sectors as contributors to economic growth. The benefits of innovation to the Australian economy also come from ensuring that new technologies and work processes are adapted widely throughout all sectors of the economy. The VET sector should have a more direct role in promoting and diffusing smaller scale innovations focused on processes and development rather than the sector seeking to engage in pure research. This would enable the VET sector to diffuse business innovation and enhance its links with business, particularly with small and medium-sized enterprises in general and especially those in regional areas. This requires appropriate funding support as part of a more diverse set of performance targets for VET providers.

Executive summary

Australia, over the past quarter century, has come from being a classical 'imitator' of others' innovations to a 'second-tier innovator economy' (Gans & Stern 2003, p.3). However, Australia's track record as an innovator is still uneven: 'while Australia has improved its innovative capacity over time, it has not done so as fast as key international competitors' (Gans & Stern 2003, p.3). Indeed, some countries, such as Finland and Singapore, have started from a lower base than Australia and leapfrogged ahead. International comparisons, therefore, offer the potential for major insights into what elements of the policy framework are missing or underemphasised in Australia.

The particular focus of this report is on the role the vocational education and training (VET) sector has played in economies with strong track records in innovation. The examples of Finland and Singapore, in particular, are drawn on to show the importance of the concept of a national innovation system as a framework for guiding public policy. This concept emphasises the importance of having a broader concept of what innovation involves—including diffusing new technologies, processes and products. It also supports the view that low and medium technology industries harness the research and development of others to support their own innovations.

The lesson for Australia is not only to expand its efforts to develop an effective pool of technical expertise in the form of tertiary-educated scientists and engineers. Attention has to be paid to the type of skills required at the para-professional level. The fostering of entrepreneurial skills both in work and in education at all levels is also important for encouraging innovation across the economy and society. This report highlights the value of using the concept of a national innovation system to give the VET sector a more direct role in promoting innovation.

From the perspective of innovation as a series of small changes diffused widely, vocational education and training has a much more definable role by supporting the diffusion of new technologies. However, in order to do this well, suitable performance indicators for technical and further education (TAFE) institutes are required to show that this is an important priority and to show what progress has been achieved.

TAFE institutes, like their Finnish counterparts, could be major diffusers of innovation in their regions; for example, by playing a major role in assessing the technology needs of small and medium-sized enterprises and helping them to develop appropriate solutions. However, this requires incentives in the form of specific funding to do this. One way to provide these incentives is to highlight innovation diffusion as an explicit objective in national policy, with corresponding funding allocated to support this direction. Then, in turn, federal and state governments could ask TAFE institutes, through their Performance Agreements, to meet certain performance targets, with funding allocated to help meet these targets.

A whole-of-government approach is needed to support a national innovation system. This requires new arrangements, such as pooling funds from relevant departments.

The whole-of-government approach refers to not merely coordinated action between departments at one level of government; it also refers to coordinated actions between levels of government at state and federal levels. The TAFE sector is a state government responsibility, with funding provided by the federal government as well. It is important that this division of responsibility not undermine TAFE institutes enhanced role as a supporter of innovation in industry. This applies particularly to its role of supporting small to medium-sized enterprises, which are at the crux of the innovation economy but which often have less training capacity than larger enterprises. It is this whole-of-government approach to the use of publicly funded resources such as the TAFE sector that is a defining feature of the Finnish and Singaporean innovation policies.

Innovation: Australia's comparative performance

Why innovate?

Up to half of the economic growth of the 20th century, according to the Organisation for Economic Cooperation and Development (OECD), has been the result of innovation and invention rather than simply improvements in productivity or processing more resources (Leadbeater 2002, p.35). Investment in science and innovation is creating more products and services as well as entirely new industries. Consumers are demanding not just low prices but high quality, good design, effective customer service and products that combine several technologies (Departments of Trade and Industry and Education and Skills UK 2001, ch.1). The resulting global pressures on resources and the environment are also generating a faster trend towards the use of greener technologies.

The impact of these pressures to innovate on workforce skills is significant. There is both greater demand for people with high-level occupational and technical skills and, at the same time, a growth in demand for people with low skills (Shah & Burke 2003). While manufacturing will remain important in the foreseeable future, the line between manufacturing, technology and services is blurring.

Today, the competitiveness of enterprises and of national economies depends increasingly on their capability to innovate new products and processes continuously to better meet more sophisticated customer demand. Customised innovation is an important competitive strategy, in addition to productive efficiency and cost cutting (Hämäläinen & Schienstock 2000, p.1).

What is innovation?

Innovation refers to the process where businesses create new products or implement new processes for the provision of goods and services, using science and technology (ABS 2003). However, this does not explain how it comes about. Innovation refers to the process which brings together the scientist with his or her invention, an entrepreneur to get the invention to market, and the investor willing to risk his or her money (*The Economist* 2003, p.83).

In other words, innovation comes not merely from research, or science and technology, or hard work and ingenuity—although these are often important contributing factors. Innovation—especially successful innovation—also depends on organisational, social, economic, marketing and other knowledge at the enterprise level (European Commission 2003a, p.8). It also depends on a supportive environment such as government support for research and development and a good skills supply, appropriate legal protection for intellectual property as well as other elements of a regulatory framework. These elements together can be described as a national innovation system.

The Department of Industry, Science and Resources (1999) defines innovation as 'the process that incorporates knowledge into economic activity'. Australia's chief scientist claims that 'Innovation is the driver of every modern economy—it is the key to competitiveness, employment growth and social well-being' (Batterham 2000, p.9). The Australian Government sees 'innovation, defined as developing skills, generating new ideas through research, and turning them into commercial success', as the 'key to Australia's future prosperity' (Commonwealth of Australia 2001, p.7).

Three generations of national innovation policy have been identified (European Commission 2003a). The first-generation policies focused on a linear process for the development of innovations. This view of the innovation process begins with the research end of the research and development process leading to an invention and then moves through successive stages till the new knowledge is built into commercial applications that diffuse in the economic system. The emphasis in this approach is on fostering critical directions of scientific and technological advance, and enhancing the flow of knowledge down along the innovation chain.

A second-generation policy approach to innovation recognised the complexity of the process and highlighted the many feedback loops required between the different stages, starting with the invention up to successful marketing. This policy approach sought to promote communication across different points in the innovation 'chain' to produce better informed decisions connecting research, commercialisation, technology adoption and implementation.

The third-generation approach by governments promotes the need for better coordination between the different elements of public policy to support the innovation process. It is recognised that this process of coordination cannot be achieved by applying a simple formula. The coordination to support innovation requires acceptance by government or other stakeholders of their responsibilities for bringing together relevant evidence and benchmarking progress. It also involves governments ensuring that all policy areas take on the message of the centrality of innovation. Not least, it also requires a capacity for governments and agencies to learn from trial and error (European Commission 2003a, p.11).

> The third generation innovation policy will result in innovation concepts being embedded in many policy areas. This requires much more than the issuing of pronouncements about a new policy. It will be necessary to identify and involve key stakeholders in the process, and to develop interfaces that allow for pooling of knowledge, learning from experience and evidence, and further co-ordination of policy initiatives. Though the third generation policy will need to be developed interactively, rather than imposed from on high, this process will require leadership and vision, with high profile and high level innovation 'champions' sustaining it. (European Commission 2003a, p.12)

How is innovation generated?

Innovation is often a product of a geographical concentration of complementary resources. This can be viewed as a paradox, as the cost of communication has decreased markedly, seemingly making it less important to have resources concentrated in one geographical location. However, it is important to make a distinction between information transfer and knowledge transfer. The former can be easily codified, made into a tangible good and transmitted electronically at low cost. In contrast, knowledge transfer, which is based on hard-to-codify 'tacit knowledge', requires geographical proximity, as it is best transferred through face-to-face interaction and frequent contact.

Since knowledge is generated and transmitted more efficiently via local proximity, economic activity based on new knowledge has a high propensity to cluster within a geographic region. This has triggered a fundamental shift in public policy towards business. The shift is away from policies constraining the freedom of firms and towards a new set of enabling policies, which are implemented at the regional and local levels.

A growing literature suggests that who innovates and how much innovative activity is undertaken is closely linked to the phase of the industry life cycle. In addition, the propensity for innovative activity to cluster spatially will be the greatest in industries where tacit knowledge plays an important role. As noted above, this is due to the requirement that tacit knowledge, as opposed to information, can only be transmitted informally, requiring direct and repeated contact.

The significance of clusters is to recognise that it is not knowledge itself that is sufficient. Just as important is the underlying economic and institutional structure supporting the promotion of knowledge transfer as well as the microeconomic linkages across agents and firms. The European Union, in its innovation policy, has highlighted the importance of 'clusters of excellence', defining them as a conjunction of factors, including infrastructures, availability of skills and expertise, research and technology centres, and enterprises with innovation potential (European Commission 2003b, p.20).

Finegold has outlined four conditions for establishing a high skill ecosystem that is based on a study of the biomedical and computer clusters in northern and southern California. The four requirements are: a catalyst to trigger the start of the development, ongoing nourishment, a support host environment and a high degree of interdependence between the actors in the system (Finegold 1999).

Clusters of excellence

The Italian 'industrial districts' illustrate how regions specialising in specific sectors and dominated by small firms are able to grow rapidly and develop global leadership in their sector. Industrial districts are characterised by high productivity and specialisation in complementary phases of production, founded on the presence of subcontractors, component suppliers and fierce competition among them. Accumulation of know-how is an important factor behind the lasting competitiveness of such clusters.

A well-known example is the Prato region near Florence, an international leader in the production of yarns for knitwear, and knits and textiles for the garment, upholstery and other industries. This success is complemented by the construction of textile machinery, which is also highly export-oriented. Italian 'industrial districts' demonstrate how global leadership can be achieved by close interaction and sector-specific patterns mixing cooperation with competition ('co-opetition') among SMEs, and by a type of creativity that absorbs R&D inputs without entirely relying on them.

Source: European Commission 2003b, p.20

The European Commission's report in 2000, entitled 'Innovation in a knowledge-driven economy', identified five priorities to steer member state and European Union-level actions to promote innovation. These are:

- ensure coherence of innovation policies
- provide a regulatory framework conducive to innovation
- encourage the creation and growth of innovative enterprises
- improve key interfaces and linkages in the innovation system
- promote a society that is open to innovation.

More recently, the European Union Commission has focused on the importance of public policy changes as well, supporting the concept of a national innovation system (European Commission 2003b, pp.13–15). The four key elements of these changes are:

- The need for member states to strengthen their national innovation strategies by adopting a more coordinated approach across all government departments with responsibility for aspects of a national innovation strategy. Coordination should take place at a high political level, to ensure the maximum commitment from the departments involved, and will require administrative support from a 'light' central structure.
- European Union institutions and member states need to also emphasise 'vertical' coordination, so that policies interlock at European Union, national and regional levels.
- Efforts at member state and European Union-level must be supported by upgrading of knowledge on innovation, innovation systems and innovation performance, through improved statistics on innovation and through analysis … data collection and analysis should take account of the different routes to innovation and the importance of diffusion. Member states should consider setting targets for some indicators as a means to help mark progress towards achievement of specific national objectives.

- ✧ Existing processes enabling member states to learn from each other's experience in innovation policy development and implementation need to be strengthened.

National innovation systems

Innovation is more than the product of scientific or technological discovery. Recent analyses of the factors that produce innovative enterprises have identified two key features. First, innovation is a non-linear process, involving not just research but a complex mixing of many related activities, such as training, design, finance, marketing and so on (Smith 2003, p.26). Innovation relies on access to specialised competence in each of these areas, and successful innovation requires integration of all of these activities (Smith 2003, p.26).

Second, innovation comes from the interaction between firms and their external environments. Enterprises do not innovate alone, but do so by interacting with universities, technological institutes, consulting companies, suppliers and even competitors. This process of continuous interaction is what lies at the heart of what are called national or regional 'systems of innovation' (Smith 2003, p.26).

The major elements of a national innovation system have been identified. One element is an interactive social process that integrates market opportunities with the design, development, financial, and engineering capabilities of enterprises. This is done in ways that are both uncertain and complex. Another element is that continuous feedback loops are built into these linkages. In addition, the process of interactions produces a cumulative effect and the outcome is greater than the sum of the parts. The result is an environment that is able to produce incremental changes to technology and occasional major transitions in technologies, although in a non-linear way (Smith 2003, p.27).

Innovation depends heavily on the flows of knowledge, resources and people between public and private domains of knowledge and the mechanisms by which information on specific innovations is shared, developed, commercialised and diffused (Sachs 2002, pp.7–8). The incentive structure that causes different parties to become involved and stay committed needs careful attention by policy-makers.

Two basic features of a national innovation system are the amount and concentrations of research and development and the role of government in funding research facilities and making use of its outcomes. Jeffrey Sachs has highlighted these two aspects in his paper: 'The Global Innovation Divide' (Sachs 2002). One aspect is that technological innovation requires a 'critical mass' of resources in terms of access to funding and research skills—'because the economies of agglomeration in the production of ideas, scientists tend to congregate—in universities, science parks, and in regions such as Silicon Valley' (p.7). The further concentration of resources is hard to replicate in countries where these resources do not already exist in basic forms.

The other aspect is that research and development not only requires funding by private enterprise but also by government.

> Innovators include private businesses, government laboratories, and not-for-profit academic institutions. Increasingly, innovations emerge from the complex interplay of all three sectors.
>
> (Sachs 2002, p.5)

Sachs highlights two types of technological innovation. One element of science and technology ends up as commercialised technologies; the other output results in improved public goods. Examples of the latter are advances in meteorology such as climate forecasting, atmospheric chemistry, environmental management, infectious disease control and geology. These result in better long-term climate forecasting, earthquake monitoring and detection, air quality management by public agencies, public health surveillance, fisheries management, and environmental protection.

The sources of innovation in the latter case are 'exclusively, or heavily, governmental agencies and other non-market organizations' (Sachs 2002, p.5).

Learning and skills are only one element of technological innovation. Other aspects are improving the policy environment; building human capabilities; promoting enterprise development; investing in research and development; and looking ahead through foresight activities. Nevertheless governments can play a valuable role as learning facilitators, particularly in terms of fostering closer collaboration between the different elements that go to make up an innovation system. The role of the government in all its policies must be to enhance learning through strengthening other learning institutions such as schools, universities, government research organisations, firms and community-level technology diffusion initiatives (Srinivas 2003, p.26). The development equivalent of the 'triple helix' is a mix of firms, universities and government:

> The web of capabilities stays meshed and effective 'systems' of innovation use a variety of skills from many sources at every stage. No one component stays isolated, seeking either appropriate supply or demand of inputs. Thus, science, technology and innovation policies become a core of the industrial, agricultural and services policies and create explicit links between market and non-market institutions, for example linking universities, state R&D laboratories, to unions, to community development organizations and to firms.
>
> (Srinivas 2003, p.25)

Innovation—how Australia fares

The Australian Bureau of Statistics (ABS) uses several indicators to measure knowledge and innovation. These refer to expenditures on research and development, education and computer software. Also used are measures of the current take up of information and communication technologies such as business use of the internet and the number of knowledge-based workers (see table 1).

Expenditure on research and development

In relation to research and development expenditure, Australia rates below the top performers in terms of international standards. In 1998–99, Australia's research and development expenditure was 1.50% of its gross domestic product, ranking it below Japan (3.04%), Finland (2.89%), the United States of America (2.60%), Korea (2.55%), Germany (2.31%), France (2.18%), Iceland (2.04%), The Netherlands (1.95%), the United Kingdom (1.83%) and Canada (1.71%) (ABS 2002b).

In terms of business enterprise research and development, Australia's ratio of research and development expenditure to gross domestic product in 1998–99 (0.68%) is below the ratios for other industrialised countries. For government sector research and development as a percentage of the gross domestic product, Australia ranks higher. A research and development to gross domestic product ratio of 0.35% places it fifth in the group of Organisation for Economic Cooperation and Development (OECD) member countries for which data are available, behind Iceland (0.76%), Korea (0.45%), France (0.41%) and Finland (0.36%). Compared with the United States and Canada, government sector research and development as a percentage of the gross domestic product is much higher for Australia (ABS 2002b).

In relation to research and development in the higher education sector, Australia, with a research and development to gross domestic product ratio of 0.44%, ranks fifth behind Finland (0.57%), The Netherlands (0.53%), Iceland (0.51%), Japan (0.45%) and Canada (0.45%) among OECD countries (ABS 2002b).

Other measures of knowledge and innovation

Education expenditure as a proportion of the gross domestic product has remained fairly steady. Investment in computer software has increased markedly over the last decade, nearly doubling despite a fall in software prices. In relation to the proportion of knowledge-based workers, their share of all occupations has increased from 31% in August 1991 to 38% in August 2001 (ABS 2002a, p.110). Business take-up of the internet has increased in recent years—businesses with a website or home page have increased from 6% in 1997–98 to 16% in 1999–2000. For large businesses (100 or more employees), the proportion with a website has increased over the same period from 58% to 68% (ABS 2002a, pp.110–111).

Table 1: Measures used by the ABS on knowledge and innovation

Knowledge and innovation	✧ Expenditure on research and development expenditure, as a proportion of GDP
	✧ Expenditure on education, as a proportion of GDP
	✧ Managers and professionals, as a proportion of total employment
	✧ Investment in software, as a proportion of GDP
	✧ Proportion of businesses with a website or homepage

Source: ABS 2002a, pp.109–111
Note: GDP = gross domestic product

Surveys of innovation in Australia 1993–94 and 1996–97

A broader measure of innovation in Australia is provided by two ABS surveys of businesses in 1993–94 and 1996–97. The latter survey results show that just over a quarter of all manufacturing businesses undertook technological innovation in 1996–97 (ABS 2002c). The rate of technological innovation varied with the size of business. Large businesses (200 or more employees) are over three times more likely to undertake technological innovation than small businesses. This also means that innovative businesses, in total, contributed about two-thirds of the total employment and three-quarters of the total turnover of all manufacturing businesses (ABS 2002c).

Of businesses which undertook technological innovation, over half undertook both product and process innovation—that is, they introduced new, or significantly technologically changed, products and used new, or significantly technologically changed, processes to produce their products. Only 3% of businesses introduced new processes without introducing new products. Over 8% of businesses introduced new products without using new processes (ABS 2002c).

The survey results also showed that almost two-thirds of large businesses had staff dedicated to innovation work, while less than one-quarter of small businesses had staff dedicated to this work. Large businesses were almost three times more likely than small businesses to take staff off-line to undertake innovation work (ABS 2002c).

Australia in the international ratings of innovation

The OECD's Science, Technology and Industry Scoreboard 2003 reports comparative data on investment in knowledge (OECD 2003a). This is defined as the sum of expenditure on research and development, on total higher education from both public and private sources and on software. In 2000 investment in knowledge in all OECD countries amounted to 4.8% of the gross domestic product. However, Australia's investment in knowledge only stood at 4.0% of the gross domestic product, which placed it 14th in rank order. The high performers are Sweden with 7.2% of the gross domestic product, followed by the United States (6.8%), then Finland (6.2%), Korea and Canada both on 5.4% (see table 2). In the United States, Australia and Canada, gross fixed capital formation (investment in structures and machinery and equipment) grew more rapidly than investment in knowledge.

In terms of the annual average growth between 1992 and 2000, Australia's growth rate in knowledge investment was 4.5% per annum. This was the same as the OECD's growth rate and slightly ahead of the European Union's growth rate (4.2%). However, Australia was far behind the annual growth rate over this period of the top investment performers—Sweden (9.7%), United States (6.1%) and Finland (8.8%).

Table 2: Investment in knowledge, as a proportion of GDP, 2000, %

	R&D	Software	Higher education	Total
Sweden	3.9	2.4	0.8	**7.2**
United States	2.7	1.8	2.3	**6.8**
Finland	3.4	1.7	1.1	**6.2**
Korea	2.7	0.5	2.3	**5.4**
Canada	1.9	1.7	1.8	**5.4**
Switzerland	2.6	1.9	0.6	**5.2**
Denmark (1999)	2.2	1.7	1.1	**5.0**
OECD (1999)	**2.3**	**1.3**	**1.3**	**4.8**
Germany	2.5	1.6	0.6	**4.8**
The Netherlands	1.9	2.2	0.7	**4.8**
Japan	3.0	1.1	0.6	**4.7**
France	2.2	1.7	0.7	**4.6**
Belgium (1999)	2.0	1.6	0.8	**4.3**
United Kingdom	1.8	1.8	0.6	**4.3**
Australia	1.5	1.4	1.1	**4.0**
EU	**1.9**	**1.4**	**0.7**	**4.0**

Note: R&D = research and development; EU = European Union; GDP = gross domestic product

Source: OECD, National Accounts, Economic Outlook, MSTI and Education databases; International Data Corporation, June 2003

Another comparative indicator of Australia's ranking in relation to innovation and the knowledge economy used by the OECD's Science, Technology and Industry Scoreboard 2003 is the proportion of the workforce in professional and technical occupations (OECD 2003a). This indicator refers to the proportion of workers actively involved in the creation and diffusion of knowledge and technological innovation. Table 3 shows that Australia, with 36% of its workforce in professional and technical occupations, ranks third—behind Sweden and Switzerland. However, if technician occupations are ranked separately, Australia ranks ninth in relation to the proportion of the workforce in these occupations. The countries with higher proportions of technician occupations are: Norway, Denmark, Germany, Switzerland, Sweden, Czech Republic, France and Italy.

In the period 1996–2001, Australia's professional and technical occupations grew at an annual growth rate of 3.1%, compared with a 1.8% growth rate for total employment. The growth rate of workers actively involved in the creation and diffusion of knowledge and technological innovation in Australia over this period is ahead of the United States (2.0%), Germany (2.0%) and the United Kingdom (2.5%) but behind that of Ireland (7.1%), Italy (4.3%), The Netherlands (3.9%). Australia's growth rate in knowledge-based occupations over this period is similar to that of Denmark (3.5%), Korea (3.4%) and Sweden (3.4%).

Table 3: Human resources in science and technology occupations as a percentage of total employment, 2002

	Professionals	Technicians	Total
Sweden	17.9	19.8	**37.7**
Switzerland	16.1	20.0	**36.1**
Australia (2001)	18.2	17.4	**35.6**
Denmark	14.4	20.9	**35.3**
Norway (2001)	11.7	23.0	**34.7**
The Netherlands	17.1	17.2	**34.3**
Germany (2001)	13.0	20.5	**33.5**
United States	15.8	16.9	**32.7**
Finland	16.0	16.4	**32.5**
Belgium (2001)	19.2	10.8	**30.1**
Czech Republic	10.5	19.3	**29.7**
France	11.2	18.0	**29.2**
Canada	15.9	13.1	**29.0**
Italy	10.9	17.5	**28.4**
New Zealand (2001)	15.6	10.4	**26.0**
United Kingdom	12.9	12.3	**25.3**

Source: OECD calculations and estimates, based on data from the Eurostat Community Labour Force Survey, the US Current Population Survey, the Canadian and Japanese labour force surveys, the Korean Economically Active Population Survey and the Australia and New Zealand censuses, May 2003

The challenge of gearing an economy to innovation

Economies are no longer shielded from the impact of external and low wage production. Globalisation and the telecommunications revolution have triggered a shift in the comparative advantage of the leading developed countries in favour of innovative activity. This shift in comparative advantage has increased the value of knowledge-based economic activity (Audretsch 1998, p.1). The alternative to low wages, therefore, must be a more innovative approach to production and product design and quality.

The challenge for nations, therefore, is to achieve a high value-add output across industry sectors exposed to global competition. This is dependent upon high levels of skill, research and development, and innovation. The idea of a high skills economy is associated with high levels of investment in education and training. Ashton and Green (1996, p.11) identified the following five requirements to avoid the low skills gap:

- government commitment to achieving and investing in a high skills economy and in education
- a significant number of employers who demand high skills and support workers to provide skills in the workplace
- an adequate regulatory system to control the quality and quantity of work-based training
- significant incentives to gain qualifications and continue learning
- sufficiently developed education system to allow training on and off the job.

There is a wide consensus that high levels of investment in education and its wide distribution have significant implications for human capital and the growth of economies (Bassanini & Scarpetta 2001) and possibly for social capital (OECD 2001b) and social cohesion (Green & Preston 2001).

Michael Porter, the Harvard-based expert on national innovation systems, was in Australia in 2002 and offered the following comments on the weaknesses in the Australian economy's capacity for innovation:

> … there was a need to do much more to take it to the next level and this started with a new longer-term national economic vision … Corporate strategies (need to … focus on innovation and international expansion rather than domestic dominance …
>
> Government should play its part in more focused regional economic co-ordination, more tax changes to free international expansion, and spending on education and infrastructure instead of business subsidies …
>
> Australian research and development spending is growing quite quickly … but it still accounts for less than 2 per cent of GDP, which suggests there is something wrong with the system. Australian companies ranked poorly in terms of inside researchers employed by the company and in the number of scientists and engineers on staff. (Durie 2002, p.15)

Implications of growth in the innovation economy and vocational education and training

Type of jobs required by an innovation economy

What are the implications for Australia's vocational education and training (VET) system of economic growth based on innovation and knowledge? The first issue to consider is the type of jobs that are likely to be needed to support innovation. The significance of the growth of the professional and technical occupations was highlighted above. However, this categorisation of relevant occupations is too broad, as many of the professions, for example, are not linked to the sectors that rely on innovation to grow.

A projection of job openings likely to be created by the growth of the innovation and the knowledge sectors in Australia makes a distinction between two types of knowledge-based jobs: conceptual and technical (Shah & Burke 2003). Jobs defined as conceptually based are managers, financial dealers, and various professional groups such as scientists, media and arts occupations. Jobs defined as 'technical' are mostly to be found in the technician and other associate professional occupations. Another job cluster not seen as related to the global knowledge economy because of their domestic market orientation is the advanced skills—referring mainly to trades-based occupations (Shah & Burke 2003, p.2).

The two globally advantaged occupation clusters are projected to grow considerably above the average for all occupations in the period 2002 to 2006. The so-called conceptually based occupations are projected to grow at a rate of 1.9% per annum over this period, and the technically based occupations are projected to grow at 1.8% per annum (see table 4).

Table 4: Forecasts of employment growth forecasts in 2002–06, by the nine occupational groupings

Occupational grouping	Employment 2001	Growth	
		Average annual rate	
	('000)	*('000)*	*(%)*
All occupations	9090.4	570.9	1.2
Globally advantaged occupations	*1993.6*	*191.1*	*1.8*
Conceptual	1478.6	144.0	1.9
Technical	515.0	47.1	1.8

Source: Extracted from table 1 in Shah & Burke 2003

It is estimated that the conceptually based occupations will contribute a quarter of the new jobs (25%), and the technically based occupations will contribute an estimated 8% of the new jobs. However, a projection of the advanced skill occupations, not reported in table 4, show a meagre growth rate of 0.2% and an increase of only 12 700 jobs over the 2002 to 2006 period, or 2.2% of all the new projected job growth.

The projections presented in table 4 suggest that the technician and other associate professional occupations are an important element of the skill pool required to support the expansion of the innovation-based sectors of the economy. These are the occupations traditionally supported by the VET sector.

Innovation and vocational education and training: Key findings from country case studies

This chapter highlights the key conclusions of the background country case studies undertaken for this study. The policies and practices in relation to innovation of the United States and the United Kingdom (England), Korea, Finland and Singapore are referred to in this chapter. Two country case studies receive particular attention—Finland and Singapore—and these are presented as attachments to the report. The case studies illustrate the importance of a national coordinated approach to the innovation process. Policies are discussed under the broad headings of understanding the origins of the innovation process, key ingredients of innovation and the specific implications for vocational education and training.

In relation to understanding better the origins of the innovation process, the important role of research and development is highlighted. However, the case studies also make clear that the innovation process can apply to more industries using other than so-called high technologies. Another important point illustrated by the case studies is the pivotal role of enterprises. Governments can provide incentives for more research and development; however, if enterprises are not able to respond by developing the product or service and bring it to market, then the innovation process stalls. This is often said to be the case for Australia.

Even though Australia is in the top six OECD countries for research and development expenditure in the public sector, business investment in innovation is far below other OECD countries, resulting in poor capacity to commercialise ideas (Gans & Stern 2003, p.41). Efforts to strengthen the links between science, research and development, industry and business in Australia have been at the forefront of recent government policy (Commonwealth of Australia 2001, p.19). However, in contrast to Australia, the case studies provide evidence of the importance of a great sense of urgency to underpin the development of national innovation strategies. This sense of urgency was clearly important in Finland in the early 1990s and in Singapore in the present era.

The key ingredients of the innovation process, identified from the case studies, are the important role of government in providing a supporting environment, and the need for a broad and deep skills pool based on a combination of hard and soft skills. The case studies also provide information about new, more responsive skills formation arrangements, including the importance of focusing on international benchmarks, and closer ties to the workplace. The role of VET providers as intermediaries in industry or regional clusters is noted, based on the Finnish case study in particular.

Understanding better the origins of innovation

Important role of research and development

The case studies show that research and development is a major contributor to innovation, generating a flow of technical ideas and continually renewing the pool of technical skills. In both Finland and Singapore, high levels of investment in research and development, by both public and private sources, have been an important feature of the climate promoting innovation. In Finland, for example, the volume of research and development investment over the past 10 to 15 years has grown more quickly than in other OECD countries, at an annual rate of about 10%. In 2000, the private and public sectors in Finland invested in research and product development approximately 3.3% of the gross national product, putting Finland at the top of the list of research and development investors.

International comparative data for 1998–99 shows that Finland spent, in relative terms, twice the amount on research and development than Australia did (3.04% of the gross domestic product compared with 1.50%). While government and higher education expenditure on research and development was very similar, the big difference in Finland's favour was in business-funded expenditure (1.94% of the gross domestic product compared with 0.68%) (ABS 2002b).

Finnish researchers are at the leading edge of developments in a number of fields, including forest improvement, brain research, neural networks, low-temperature physics, new materials, biotechnology, and genetic technology (<http://virtual.finland.fi/finfo/english/innovat.html> viewed 30 June 2003). Product development work has spawned numerous important and innovative new products. Finnish engineering companies have manufactured icebreakers, cruise liners, lifts, diesel engines, sailing yachts, compasses, fishing lures, frequency transformers, stone drills, harvesters, contraceptives, pipettes, and scissors and axes. Other information technology-based products developed in Finland include internet encryption systems and the Linux operating system developed by Linus Torvalds.

In Singapore, research and development in electronics, engineering and life sciences has been important, and has received both public and private investment contributions. Singapore's research and development expenditure, expressed as a percentage of the gross domestic product, has risen steadily from 0.9% to 1.9% between 1990 and 2000 (Government of Singapore 2002, p.60). However, in terms of outputs from the research and development process, Singapore's patents record is weak. While it has improved steadily over the last decade, from 25 United States patents in 1990 to 304 patents in 2001, Singapore's performance is still weak by international standards. Singapore registered 74 new United States patents per million population in 2001, whereas Canada and Taiwan had 131 and 294 patents, respectively. Australia recorded only 52 United States patents per million population in 2001. The United States ranked first with some 350 patents per million population (Government of Singapore 2002, p.61).

Enterprises working in the life sciences in Singapore now account for the largest investment in research and development. The Singapore Government has underwritten the involvement of 'star scientists' with the firms working in life sciences to help them make commercial breakthroughs in biotechnology. The presence of a strong local research and development sector has been a prerequisite for attracting these 'star scientists' to work in Singapore (Asia-Pacific Economic Corporation Economic Committee 2003, p.12).

However, research and development need not refer merely to the outputs of laboratory investigations. Research and development can also refer to developing improvements to existing products and processes, resulting in cost-cutting efficiencies and hence making a value-added contribution to an enterprise.

This broader understanding of research and development suggests that VET providers can also be part of research and development efforts. This point is elaborated further below.

Innovation applies to more than high-tech industries

The United Kingdom and United States experiences with the types of innovation that contribute to economic growth show that there is a danger of focusing only on the high-technology variety. Other industries with technologies classified as 'medium-low' and 'low', such as petroleum refining, pulp and paper, textiles, or food and beverages, are also potentially highly innovative, drawing on many fields of knowledge (European Commission 2002, p.7). These sectors often innovate through the purchase of advanced manufacturing technology or by developing sophisticated production and delivery systems. In Europe, for example, several low-technology sectors, such as food and beverages, are of far greater economic significance than high-technology sectors such as aerospace or pharmaceuticals (European Commission 2002, p.7).

The application of new knowledge and processes to such low-tech industries as vegetable production and marketing and office cleaning can have a marked effect on the success of an enterprise. In the case of a vegetable farming enterprise in East Gippsland, for example, the application of international best practice standards to genetic selection, fertiliser, water and pesticide regimes, harvesting and handling has turned a local producer into a price maker on national and international markets. Also important have been changes involving improvements to business management skills, logistics management, marketing, branding, quality management and staff training (Griffiths 2003, p.9). Similarly, more than 300 jobs have been created in a company in the same region that can process fresh salad vegetables through the use of modified atmosphere packaging—a new technology offering longer shelf life for fresh vegetables (Griffiths 2003, p.9).

A good example of the new recognition of the role of knowledge in generating processes for a labour-intensive production mode is the Danish company ISS—International Service Systems. The company provides, among other facility services, commercial cleaning services in 38 countries. The company has built up a strong reputation for its attention to detail supported by its extensive training programs. International Service Systems has recently expanded into Australia. It has more than 250 000 employees and more than 125 000 business-to-business customers (<http://www.issworld.com> viewed 25 November 2004).

The possibility of the application of new processes to medium and low technologies with dramatic results has major implications for the type of markets traditionally served by VET providers. Vocational education and training provision needs to be aware of, and involved in, the development of new processes so that they can be incorporated in the training services they provide. By waiting for a process to become well established in an industry sector before it is offered as a course based on standardised competencies, the VET sector may be assured of having little relevance to innovating enterprises.

If vocational education and training aims to be at the forefront of developments, the shelf life of courses needs to be short, with constant revision to content built into the design of the course. Vocational education and training providers also need to create entirely new courses based on new processes that have been recently developed. How this might be done is discussed below.

Innovation is driven by enterprises

The outstanding success of Finland's Nokia in becoming a world company within a decade suggests that enterprises, not governments, are at the heart of the innovation process. These are the entities that take new ideas, turn them into a product or service and then market the result. In Korea, four conglomerates—Hyundai, Daewoo, LG and Samsung—account for over half of the country's exports. Multinational corporations play the same role in Singapore. However, it needs to be acknowledged that in both Korea and Singapore, small and medium-sized enterprises find it much more difficult to survive and prosper.

Where the enterprise is seen as the key agent of the innovation process—as in the United States and, to a lesser extent, in the United Kingdom—a broader definition of what constitutes innovation is often applied. Enterprises also practise incremental innovation—as they seek out ways to update their products and processes. An enterprise may innovate by taking an idea from another business sector and adapting it for use in its own production processes or market. Examples are the use in the automobile industry of high performance materials originally developed for aerospace applications, or the spread of computer-aided design into the textile and garment industries.

The search for new, untapped market space is another driving force. This may rely on technological innovation, or on reconfiguring existing products and services so as to present a radical change that will be perceived by customers as offering more or better value ('value innovation'). The 'reinvention' of the wristwatch as a low-cost fashion accessory is an example of this form of innovation that was not technologically demanding (European Commission 2003a, p.6). It may be through the introduction of a comprehensively new approach to a business, such as the new business models of on-line retailers, with the objective of creating new market space, or increasing profitability in an existing market (European Commission 2003a, p.6).

Organisational change is another source of innovation. New ways of organising work in areas can also have a positive influence on competitiveness. This refers to changes such as involving employees in ways to make the workplace a collective resource for innovation. It can also refer to improving existing systems of distribution, finance, and manufacturing. 'Presentational innovation' is another term used to refer to innovation of existing processes through design and marketing (European Commission 2003a, p.7). Innovation defined as organisational change or presentation change provides obvious openings for VET providers to be involved. This issue is taken up more in the following chapter.

Importance of a national sense of urgency

The promotion of innovation by the Government of Finland in the 1990s as a national strategy was a direct response to the dramatic and painful changes following a number of important structural shifts in the economy that the Finnish economy underwent in the early 1990s. These included the disappearance of Finland's status as one of the main Western gateways to the Soviet Union's economy. Output growth dropped from an annual rate of 5.1% in 1989, to 0% in 1990, and then plunged to –6.3% in 1991. Unemployment rose from 3.2% in 1990 to 6.6% in 1991, peaking at 16.6% in 1994 (<http://virtual.finland.fi/finfo/english/populat.html> viewed 30 June 2003).

By the end of the decade of the 1990s, a substantial turnaround had been achieved, with much of the growth coming from high-technology products—in particular from telecommunications equipment. As a result of the increasing specialisation in high-tech sectors, Finland's trade balance in high-tech products turned from a large deficit in the early 1990s to a significant surplus by the year 2000 (Blomström, Kokko & Sjöholm 2002, p.8).

In relation to Singapore, the relocation of electronic and other manufacturing facilities to lower cost countries such as China and Malaysia in the 1990s has resulted in massive job losses, which reached a 17-year high in 2002. The small island state with no natural resources other than its location has turned to the high-tech biomedical sector to generate new growth. Other areas designated as having the potential for growth are high value-added activities in photonics, nanotechnology, alternative fuels and performance materials. However, a major constraint on moving into new high-tech areas is the need for a broad and deep skills pool.

Key ingredients of a national innovation system

A supporting environment is required

The capacity of enterprises to be innovative depends on a supporting environment in which to operate. The fluidity of knowledge flow between individuals, firms, organisations and also national economies is a key feature of a supportive environment. Knowledge networks reduce the cost of research and development and speed up the innovation process. Empirical studies have shown the success of collaboration in the discovery, application and diffusion of technologies. Foreign direct investment (FDI) has been recognised as a means of importing innovation (OECD 2000).

The development of clusters of excellence, when there is a conjunction of factors such as infrastructure, availability of skills and expertise, research and technology centres, and enterprises with innovation potential, is of paramount importance for innovation performance. However, the case studies also show that government's role in promoting innovation has to go beyond simply providing incentives or funding more research and development.

Finland's case study shows that innovation arises from complex interactions between individuals, organisations and their operating environment. An essential element of an enterprise's capacity to innovate in Finland and Singapore is a set of interactions with other enterprises, organisations and public bodies. Enterprises seeking to be innovative rely on external inputs in the form of skills, advice, proprietary technologies, cooperation networks, etc. (European Commission 2003a, p.8). These external links are often best provided by clusters of like-minded enterprises—geographic concentrations of complementary, interdependent, yet competing enterprises, their suppliers, service providers and associated institutions.

Importance of skills

The country case studies of Finland and Singapore both demonstrate how reforms to skill formation processes are an important element of governments' efforts to promote national innovation systems. An enriched skills pool is a central feature of the innovation process.

The knowledge and learning capacities of people are instrumental for innovation processes—as are their powers of creativity, initiative and drive—determining to a large extent the innovation capability of organisations.

Indeed, the absence of appropriate skills is a major constraint on growth. High-tech companies in Finland still suffer from a chronic shortage of educated labour: 'total employment in the cluster would certainly have been much higher without this restriction' (Blomström, Kokko & Sjöholm 2002, p.18). The pressure from evidence of skill shortages in high-tech enterprises still underpins the pressure on the Finnish Government to improve the efficiency and effectiveness of the higher education system.

Singapore has also sought to foster a highly skilled workforce as part of its strategy to attract foreign direct investment in high-technology industries. The Government of Singapore has recently invested heavily in tertiary education by setting up a third university—the Singapore Management University. In addition, it has increased enrolment in the two existing universities by establishing multiple campuses specialising in various disciplines, and has expanded Nanyang Technological University beyond its focus on engineering to become a fully comprehensive university.

These reforms have focused not only on identifying the new skill sets needed such as composite skills—especially related to new blends of technology—but also on putting in place arrangements for developing these skills, which are very different to those required in industrial models of development.

What sort of skills?

Innovation requires a system of skill formation, according to the OECD and the World Bank Institute study entitled *Korea and the knowledge-based economy: Making the transition* that is based on continuous learning (World Bank & OECD 2000). This focus on continuous learning encompasses providing basic skills to those who do not have them. It also requires developing core skills that encourage creative and critical thinking for problem solving for those with technical skills. Another feature is developing additional specialised skills for those already possessing high level technical skills.

According to the World Bank and OECD study, successful implementation of a 'cradle-to-grave' approach to lifelong learning displays four characteristics:

- individuals are motivated to learn on a continuing basis
- individuals are equipped with cognitive and other skills to engage in self-directed learning
- individuals have access to opportunities for learning throughout life
- individuals have financial and cultural incentives to participate in lifelong learning.

They recommend that the Korean system of education focus more on the learner. This means in the context of a lifelong learning approach, education providers need to take into account the individual learner's goals as they change over a person's lifecycle.

As noted above, the skills required to support innovation need to have a solid theoretical basis to engage in problem solving. This means that where the development process is open-ended and often uncertain in terms of future direction, standardised skills that are common in routinised maintenance work or rule-driven production systems are no longer needed. The new focus is on a skill set to underpin the economic drive to innovation that is multifaceted and ever changing.

According to Richard Florida's analysis of the 'creative class':

> The key difference between the Creative Class and other classes lies in what they are primarily paid to do. Those in the Working Class and the Service Class are primarily paid to execute according to plan, while those in the Creative Class are primarily paid to create and have considerably more autonomy and flexibility than the other two classes to do so.
>
> (Florida 2002, p.8)

Florida defines the creative class as including people in science and engineering, architecture and design, education, arts, music and entertainment whose role it is to create new ideas, new technology and/or new creative content. Associated too are said to be a broader group of creative professionals in business and finance, law, health care and related fields. 'These people engage in complex problem solving that involves a great deal of independent judgment and requires high levels of education or human capital' (Florida 2002, p.8).

However, Florida also acknowledges that creativity in the workplace is not limited to members of the creative class:

> Factory workers and even the lowest-end service workers always have been creative in certain valuable ways. Also, the creative content of many working-class and service-class jobs is growing—a prime example being the continuous-improvement programs on many factory floors, which call on line workers to contribute ideas as well as their physical labor. On the basis of these trends, I expect that the Creative Class, which is still emergent, will continue to grow in coming decades, as more traditional economic functions are transformed into Creative Class occupations. (Florida 2002, p.8)

In support of Florida's analysis of the importance of the creative class, Singapore has identified as major skills deficits the lack of creative engineers and creative professionals in advertising, media and banking services (Brown, Green & Lauder 2001, p.40, see also Government of Singapore 2003).

Crucial skills to promoting innovation are those related to entrepreneurship. In Finland, the need for the polytechnics to provide education in entrepreneurship skills from the small and medium-sized enterprise point of view was identified as an important focus in the new arrangements.

The dearth of entrepreneurial skills in Singapore has been recognised by the government: 'Of these three dimensions needed for an innovative economy—skills and research capabilities, competitive markets governed by rule of law, and an entrepreneurial culture—our biggest shortfall in Singapore is in entrepreneurship'.[1] A government committee has proposed a comprehensive set of initiatives for nurturing entrepreneurship. These include promoting greater creativity in the education system, attracting global entrepreneurial executives to Singapore as 'mentors', the development of the venture capital market, as well as making the legal environment more conducive for new start-ups.

New skill formation arrangements

Both Finland and Singapore have substantially upgraded their systems for providing technical skills. In Finland, the demand for higher level technical skills led the government to reform its vocational education and training sector.

> Provision of vocational education had been divided into separate fields, each with its own schools and institutes. These were often very small and there was little co-operation between

[1] 'Building an Innovative Society', Mr Tharman Shanmugaratnam, Senior Minister of State for Trade & Industry and Education, at The Tan Kah Kee Foundation 20th Anniversary Public Seminar on 'Entrepreneurship and Education: The Tan Kah Kee Spirit in Today' on 6 September 2002.

> fields of study … The Finnish vocational education system was difficult to describe and grasp, and in particular there was little understanding of the role of postsecondary vocational education and its standing. (OECD 2003b, p.50)

The aims of the reforms to the VET system were threefold:

- provide an alternative route into higher education with a more practical emphasis, alongside the universities.
- increase the international comparability of vocationally oriented higher education in Finland; and
- strengthen regional development and co-operation with SMEs.

(OECD 2003b, p.139)

The changes involved setting up new institutions in the form of tertiary level polytechnics with a strong emphasis on good performance and high quality outputs. This was done by upgrading the qualifications of staff and the engagement in research and development. The mission of the polytechnics states that they are 'to engage actively in the development of working life and to produce relevant new knowledge' (OECD 2003b, p.110). Another aim of the reform process was to set up institutions in locations where they could promote regional development (OECD 2003b, p.110).

Compulsory education and post-secondary education still has a separate technical education stream in Singapore. The secondary school system incorporates a technical stream to Year 10 level that prepares students for study at the Institute of Technical Education or for apprenticeships. The curriculum focuses on proficiency in English and Mathematics. An option exists for students from this stream to continue on to tertiary study as well.

Post-secondary technical education is provided by the Institute of Technical Education (ITE), which took over the functions of the Vocational and Industrial Training Board of Singapore. The institute, in 2002, had 17 468 students, with 16% of the relevant age cohort graduated from the Institute of Technical Education in 2002 (Singapore Ministry of Education 2003). However, a greater number of students attend the five polytechnics that were established from the early 1990s onwards. In 2002, there were 54 689 students studying at the polytechnics, with 35% of the relevant age cohort graduating from a polytechnic (Singapore Ministry of Education 2003). The prominence of the new polytechnics suggests a similar pattern to Finland, where a desire to upgrade technical skills lead to the establishment of polytechnics and the use of a range of incentives to encourage students to go to them.

Use of international benchmarks

As noted above, international benchmarks for vocational education and training were set. This was done to raise the quality of the education provided and to enable students to study abroad. The government set an objective that at least one-third of all students in higher education should complete part of their degree studies abroad, with a focus on long-term exchanges lasting over three months.

The focus of lifting vocational education and training to international standards was important because graduates from the former post-secondary vocational colleges often experienced major difficulties in international mobility. Finnish polytechnic graduates, however, are said now to have no problem in going on to study or work abroad (OECD 2003b, pp.126–127).

Focus on the workplace

An important part of the new arrangements involving the establishment of polytechnics in Finland is a focus on the 'actual needs of working life'. The practical goals of research and development in the polytechnics are on creating new or improved products, production tools or methods and services. Research and development is also seen as an important way to improve the competence of the teaching in the polytechnics. This is achieved by improving the knowledge being taught through providing opportunities for teachers to work more closely with a relevant sector. An important part of linking more closely to workplaces is through students' final year projects (OECD 2003b, p.161).

The same emphasis on better linkages to workplaces can be seen in the new arrangements for recasting the engineering degrees at Singapore's Nanyang Technological University. A key element of the engineering degree for 20 years has been a six-month industrial placement as part of the formal requirements for the degree. The placement is offered mainly in semester 2 of the third year.

A new focus in the industrial placements from 2003 is to put more emphasis on achieving designated learning outcomes. These refer to a range of possible suggested academic, professional, and personal outcomes (Ng & Loh-Goh 2003, pp.3–4). Each student during the first two weeks of the industrial placement is to develop a work plan outlining specific self-directed learning objectives outlined. Students are to be supervised by a site supervisor, preferably an engineer, and an academic supervisor. Assessment is through scrutiny of a logbook, an oral interview, as well as a final report (Ng & Loh-Goh 2003, pp.5–7).

VET providers as intermediaries in clusters

Fostering closer ties between enterprises is an important role of the new regional polytechnics in Finland. Research and development is regarded as an important part of the services that are provided by polytechnics to the wider community and local economy. Polytechnics are to focus not only on new small and medium-sized enterprises, but also on traditional small and medium-sized enterprises that have not undertaken research and development of their own.

Extending innovation and the principles and practice of research and development to this rather large group of small and medium-sized companies is seen as an important challenge for the new polytechnics. It is acknowledged that the small and medium-sized enterprises in relation to innovation have particular problems in funding research and development. So the polytechnics are expected to provide expert help in developing research and development capacity in this group of enterprises (OECD 2003b, p.120).

Another role set by government for the new polytechnics in Finland is to promote regional development and to meet regional needs for higher education. In most cases, the objectives of research and development at polytechnics have been linked to regional objectives, with an emphasis on supporting small and medium-sized enterprises. As a result, they have become part of the regional innovation systems which are concentrations of centres of expertise around institutions of higher education, national programmes for centres of expertise, technology centres, science parks and other organisations benefiting from the expertise of higher education institutions (OECD 2003b, p.110).

Education-based intermediaries are prominent in industry or regional clusters in the United States as well. In Silicon Valley, for example, community or technical colleges play a key role in performing this function (Pastor, Leete & Dresser 2003, p.35). Much of the training provided through the community college system in the United States is for new entrants to the labour market. However, community colleges also play a crucial role as a labour market intermediary in relation to people who are returning to community colleges for mid-career training.

In order to help them perform their roles as labour market intermediaries, the community colleges in Silicon Valley have established contract training and economic development assistance arms. These provide customised training and assistance to firms in the region. Intermediaries based around community colleges with strong information and industry connections and the accessible delivery of a current curriculum provide the most promising models of intermediary activity (Pastor, Leete & Dresser 2003, p.71).

These intermediary efforts by community colleges had specific characteristics. These included:

- targeting particular occupations or industry sectors
- maintaining communication with workers over an extended period
- building strong relationships with employers
- deliberately focusing on workers' long-term needs
- providing both formal training and informal on-the-job learning opportunities over extended periods of time.

One major benefit for the community colleges from closer ties with specific groups of enterprises was the good prospect for job placements for graduates of their programs (Pastor, Leete & Dresser 2003, p.71).

Specific implications for vocational education and training

Use of international benchmarks

The Finnish case study suggests that one way to raise standards in the VET sector is to use international benchmarks. The justification for this was to meet the needs of innovating enterprises. In addition, it was undertaken to enable students to study abroad during their program of studies and to obtain a qualification that would be well regarded in innovation sectors of other countries.

Australia has been criticised for poor linkages to its neighbours compared to the Scandinavian countries:

> … Australia is less connected to the innovative efforts of its neighbours. For example, while several East Asian nations such as Singapore and Taiwan have substantially enhanced their innovative capacity over the past decade, the key clusters in these countries are quite different than leading Australian clusters. Enhanced investments in the common innovation infrastructure, the innovation environment for clusters, and linkage mechanisms will be required for Australia to improve its innovative capacity position over the medium term.
>
> (Gans & Stern 2003, pp.40–41)

One way for Australia to improve its linkages with other countries is to promote student exchanges with its neighbours that have strong innovative sectors, such as Singapore, Taiwan and Hong Kong, as well as Malaysia and Thailand.

Other opportunities for the VET sector to engage in knowledge transfer could also be explored through staff exchanges with polytechnics in Finland and community colleges in the United States.

Use distance learning linked to innovation clusters

Vocational education and training for the innovation sector has to provide students with skills that are in demand in the world economy. It is now possible, through technology, to access knowledge by using textbooks that meet international standards. It is also possible to use distance learning to access courses in other countries on topics such as nanotechnology or biomedical sciences. A BioScience Workforce Development Centre, for example, has been funded by the State of California to assist the biotechnology industry to move from research and development and capacity building activities, into production. This is done by providing training services to enterprises around the issues of bioprocessing and bio-manufacturing education, training, and other forms of direct technical assistance.

New skills need new training arrangements

The United States case study of the role of community colleges in promoting innovation shows that the following criteria are important in developing new training resources to supply the skills needed.

The following eight criteria have been identified (see Pastor, Leete & Dresser 2003, pp.62–64 for supporting evidence):

1 Course developers need close ties to the innovating workplaces to understand what is required—this is likely to require some period in the workplace to absorb the tacit skills as well as the more standardised skills used.

2 Participation in research and development projects may be an important way to identify the new skills required.

3 Specific research and development projects may need to be undertaken by course developers to identify how 'high trust, high performance workplaces' pass on tacit skills.

4 The turnaround time for developing a course may need to be short, as the shelf life for the course itself may be short.

5 Course developers may need to operate in institutional settings which are divorced from traditionally defined disciplines; this is necessary to develop courses that may cut across the traditional boundaries—one way to do this is to be part of a virtual community of practice that operates across state and national borders.

6 All students should have access to on-the-job training, to ensure that their theoretical learning is workplace-grounded and often task-specific.

7 VET providers also need to identify ways to foster entrepreneurial skills alongside other skills sets being offered. This was a feature of all the United States cases examined—entrepreneurial skills are an essential element in innovation.

8 Teaching entrepreneurial skills may require use of different teaching techniques, including the use of real life entrepreneurs to provide a better understanding of what risk taking does and does not involve.

VET providers as innovation cluster intermediaries

The case studies of Finland and the United States suggest there is considerable scope for VET providers to act as intermediaries in an innovation system. As noted in the case of the United States, this requires that VET providers target particular occupations or industry sectors, and maintain communication with workers and their representative associations in those sectors or occupations over an extended period. This means helping to identify employees' long-term training needs, and providing both formal training and informal on-the-job learning opportunities. The major benefit for the VET providers from closer ties with specific enterprises will be access to job placements for the graduates of their programs.

Conclusion

It has been claimed that Australia, over the past quarter century, has come from being a classical 'imitator' of other's innovations to a 'second-tier innovator economy' (Gans & Stern 2003, p.3). However, Australia's track record as an innovator is still uneven. While Australia has improved its innovative capacity over time, it has not done so as rapidly as its key international competitors (Gans & Stern 2003, p.3). Indeed, some countries, such as Finland, Korea and Singapore, have started from a lower base than Australia and leapfrogged ahead. International comparisons, therefore, offer the potential for major insights into what elements of the policy framework are missing or underemphasised in Australia.

The examples of Finland and Singapore in particular have shown the important role human capital plays as part of a national innovation system. In relation to vocational education and training, the example of the United States was cited to show the important role that community colleges can play as intermediaries with local enterprises.

The case studies have highlighted a more proactive role for VET providers. Acting as intermediaries with small and medium-sized enterprises is one way for VET providers to carve out a clear role in the national innovation system. What this might involve in the Australian case is spelt out in the following chapter.

Implications for vocational education and training in Australia

In their different ways, Finland and Singapore have highlighted what it means to conceive of innovation as a complex system of interconnected parts involving both the private and public sectors. This broader concept of innovation offers a contrasting perspective to a more market-oriented focus of innovation policy in Australia (Sheehan & Messinis 2003).

Using this broader concept of a national innovation system, what role do and could TAFE institutes and other VET providers play in contributing to innovation in Australia? An assessment of available public information, based on interviews with key people involved in innovation diffusion in Canberra, Melbourne and Brisbane, suggests that TAFE's role has been a somewhat limited one, largely confined to skills provision.

The following assessment of Australia's national innovation system and the implications of vocational education and training are based on a review of recent research and 14 face-to-face interviews (see appendix 3). The people interviewed included key policy-makers in the federal and state departments concerned with innovation policy in Victoria and Queensland. The focus of most interviewees is on innovation awareness and diffusion. Also interviewed were an important group of innovation brokers in Victoria who are responsible for identifying the technology and training needs of firms, especially small and medium-sized enterprises. The role of these innovation brokers is to work with enterprises so as to develop an appropriate solution. In most cases, the brokers interviewed have been funded to deliver technology and training solutions independently of training providers.

TAFE involvement in the innovation economy

Several interviewees referred the author to a whole-of-government report in 2003 called *Mapping Australian science and innovation* (Commonwealth of Australia 2003). This was said to provide a comprehensive stocktake, or inventory, of the current dimensions of Australia's efforts to promote innovation. However, in relation to vocational education and training, there is little evidence of a significant contribution, with only two pages devoted to vocational education and training in a 400-page report. Under the heading 'Supply of skills for science: vocational education and training', one reference in the report notes that of the 1.4 million course enrolments in 2002 leading to a credential awarded under the Australian Qualifications Framework, or equivalent, approximately a third are in science and technology courses. These covered the natural and physical sciences; information technology; engineering and related technologies; agriculture, environmental and related studies; and health (Commonwealth of Australia 2003, pp.202–203).

The only substantive reference to the role of TAFE in the report notes that in relation to photonics, there are four TAFE courses, 20 undergraduate degree courses and 44 postgraduate courses (21 by coursework, 23 by research).

A search for other evidence of VET involvement with innovation showed meagre results. The Australian InnovationXchange is a web-based database funded by the Commonwealth Government to list 'Australia's innovation capabilities through technology, knowledge diffusion, education and training' (<www.innovationxchange.com.au> viewed 24 July 2004). A search of the database for the word 'TAFE', in July 2004, produced 12 results, 11 of which referred to facilities available at one TAFE college, Central TAFE in Perth, Western Australia.

Another web-based database, the Victorian Biotechnology Directory, which is funded by the Victorian Department of Innovation, Industry and Regional Development, lists biotechnology firms. It provides information under several headings, one of which is 'collaborations'. A search for the word 'TAFE' on this database in July 2004 produced only one result. This was a reference in relation to one company's collaboration with the NSW TAFE Hunter Institute.

Why is vocational education and training, and the TAFE system in particular, not more prominent in the innovation economy? One reason, explained further below, is that the science-based technologies at the leading edge of the innovation economy have characteristics that make them poorly suited to make use of the VET system.

Another factor behind the poor showing of TAFE, however, may be the use of a narrow definition of innovation. A broader concept based on the diffusion of new technologies and processes offers a more central role for the TAFE system. What this might involve is elaborated further on below.

Technical and further education represents a major investment from public funds to support the capacity of the economy to grow though innovation. This is done through three main ways. The first is broad-based vocational preparation for full-time students or training for entry level, employment-based arrangements in the form of apprenticeships or traineeships. The second is through short specialist courses aimed at upgrading the skills of existing workers. The third is enterprise-based training aimed often at meeting enterprise needs.

The first and second forms of support for the economy are applicable to enterprises seeking to adopt new technologies or new ways of working. The extent to which enterprises turn to TAFE or to graduates of applied science or applied engineering university courses for technician level skills, for example, will depend on several factors. One is likely to be the perception by enterprises of how well either institutional setting is providing the appropriate blend of theoretical and practical skills.

However, it is in relation to the third role of provider of services to enterprises that the greatest potential for support for innovation exists. The results of the interviews with a range of participants in policy-making related to innovation and innovation diffusion indicate that TAFE could take up a more active role as a supporter of new technology and process diffusion among small and medium-sized enterprises, especially in regional areas.

Limited concept of innovation used by Australian policy-makers

Recent critical assessment of Australian innovation policy has highlighted a narrow focus on science or knowledge-based industries as the way to tap innovation as a source of economic growth (Sheehan & Messinis 2003; Marsh 2004; Smith 2004). On the other hand, the concept of a national innovation system is more inclusive of other industries, which are defined as low or medium technology users. This broader, more comprehensive understanding of innovation acknowledges the importance of changes to mainstream industries in manufacturing and services as a source of innovation. While industries such as food-processing, timber products, textiles and clothing, transport, health and finance have low expenditures on research and development, this overlooks their indirect use of knowledge intensive inputs. Other evidence shows that many enterprises in these industries are adopting new technologies and processes (Smith 2004, p.35).

This picture of Australian Government policy towards innovation is perhaps too one-sided. The 2001 and 2003 government policy statements called, respectively, Backing Australia's Ability One and Two do represent a coordinated approach by the federal government to innovation. The second statement, in particular, was preceded by a whole-of-government mapping exercise of all component parts contributing to innovation. The value of technology diffusion has also been highlighted as a focus for the new ‘Commercial Ready’ program which builds on the previous Innovation Access program of the 2001 policy statement.

The state programs in Victoria and Queensland support both science-based innovation, commercialising the products of this innovation and technology diffusion. A broader concept of innovation is employed: ‘Innovation is not just about high-tech industry and research laboratories—it is about developing new ideas, processes and services in our workplaces, our schools, our communities and our homes’ (Queensland Department of State Development and Innovation, http://www.sd.qld.gov.au/innovation/innov/default.asp> viewed 25 November 2004). However, closer scrutiny of the Queensland expenditure profile shows that most funding is directed at research and development and commercialisation of new products.

Low and medium-tech industries are also an important part of an innovation system

The Finnish case study in particular suggests that innovation as a generator of economic growth needs to be more broadly understood as support for small and medium-sized enterprises in a range of industries. Dissemination and adaptation of new technologies from the knowledge intensive industries to mainstream industries are central to the spread of innovation. This requires attention to linkages and junctures that extend beyond those mediated by markets (Marsh 2004, p.6). According to Marsh, markets are necessary but not sufficient agents in the diffusion of innovation.

> One legacy of tariff-based industry development is an industry structure based around a few large firms and a wide base of small and medium-sized enterprises (SMEs). The dissemination of technologies offers a bright future for these firms, but policy frameworks have yet to match the challenge. (Marsh 2004, p.6)

Smith, an expert who has evaluated the Finnish Innovation Support System for the Finnish Ministry of Trade and Industry, claims that Australia, as in other OECD countries, focuses too narrowly on a science-based model of innovation. This results in a heavy focus on information and communications technology, biotech and nanotechnologies to the exclusion of the areas of knowledge that produce changes in the mainstream industries.

> Growth is based not just on the creation of new sectors but on the internal transformation of sectors which already exist; that is, on continuous technological upgrading. This internal transformative capacity rests, in turn, on complex innovation systems that create, distribute and maintain advanced (often scientific) knowledge. (Smith 2004, p.43)

Smith suggests that an industry’s innovation capacity is not only evident through the size of its research and development inputs. Attention also needs to be paid to enterprise expenditures on market research, training and skill development, design, the purchase and use of new capital equipment and patents and licenses. Where industries are spending on the above items, it indicates that they are intensive users of other industries’ research and development, embodied as imported new technologies or processes. In other words, the so-called low and medium technology industries are making use of the ‘knowledge infrastructure’ of the wider society through access to a well-educated technical skills pool and links with education and research institutions (Smith 2004, p.36). The scope for innovation to diffuse throughout the economy depends on the effectiveness of these wider supports—otherwise known as the national innovation system.

Smith contends that many so-called low-tech sectors are intensive in their use of scientific knowledge. Industries such as food production, machinery, printing and publishing, wood products and a range of services industries are all seen as having significant indirect science inputs. These industries are able to innovate by benefiting from knowledge disseminated by agents, institutions and knowledge fields in the national innovation system.

Role for TAFE as promoter of innovation in low and medium-tech industries

This broader conception of innovation suggests that the VET sector—and TAFE, in particular, as the publicly funded resource in that sector—has two potential roles. The first appears to be an obvious one of extending and deepening the technical skills pool, which is so important a part of a national innovation system. However, this role is more complex than a simple emphasis on meeting the needs of the innovating sectors might suggest.

The second potential role is for the TAFE institutes to support the diffusion of new technologies. TAFE institutes, because of their community and equity charters, are more likely to operate from regional areas. Indeed, TAFE institutes represent a major form of investment by government in regional economies. It is these regionally based institutes in particular that can potentially play a major role in assessing the technology needs of small and medium-sized enterprises and help them develop appropriate solutions. The following sections discuss these two roles in turn.

Vocational education and training and skill formation related to innovation

The strength of the VET sector is its focus on imparting standardised skills to a large number of people in a low cost way. The economics of public funding of skills acquisition justifies public investment when the skills themselves are generic in nature. In other words, public investment is acceptable if the benefits from the skills are not captured by individual enterprises but accrue to the economy as a whole.

With this focus on standardised skills go other features of a publicly funded VET system. These are that the resources allocated have to extend as widely as possible to benefit the greatest number. This also means that the costs of each place in the publicly funded VET system have to be kept low. The result is a system whose defining features are an emphasis on standardised skills, offered to the largest number at the lowest cost.

On the other hand, science-based technologies have characteristics that are the opposite of the technologies in the industries and enterprises traditionally served by TAFE. Science-based technologies such as biotechnology rely on highly specialist skills, which, in turn, are based on advanced research skills. These skills are used in a relatively small number of enterprises at considerable cost.

In a similar vein, Royle and Lindhjem (2004) have identified three factors that limit the VET system's engagement with emerging technologies. The first is that VET providers have structures built around models of mass-market education. The second limiting factor is that VET providers find it hard to supply appropriate training related to the new skills. This is due to their reliance on traditional classroom-based delivery models. The focus on a broadly accepted curriculum requires extended time lags to consult with a range of providers to develop new courses. Third, VET providers have difficulties in delivering high cost specialised skills training across a broad range of subjects because of their low cost pricing structure and lack of resources to deliver small run, resource-intensive courses.

Development of the so called 'frontier technologies' such as nanotechnology, biotechnology, information and communications technology, photonics, genomics/phenomics, and related complex systems requires high level research skills. In addition, they are focused on enterprise-specific learning systems and are costly to fund. Other new technologies—for example, in relation to advanced materials development—are science-based and, hence, often have similar characteristics. This applies to new technologies using ceramics, organics, biomaterials, smart materials and fabrics, composites and polymers, as well as light metals for applications in construction, communications, transport, agriculture and medicine.

The number of enterprises operating with these advanced technologies in Australia is small. One study records only 24 firms based on biotechnologies that were listed on the Australian Stock Exchange in the period 1998 to 2002 (Vitale & Sparling 2004, p.73). These are firms that have got their development work to a point where they believe that they can attract investors to support them. Other estimates suggest that the number of listed firms may be three times larger, at around 60. Whether it is 24 or closer to 60, the number of firms is small compared with other industries. Not only are they few in number, they are also small in size. The average number of people employed per publicly listed biotech enterprise is only 33 staff (Vitale & Sparling 2004, p.85). If this is extrapolated to the 60 firms, this represents less than 2000 employees.

Working at the cutting edge of science-based innovation is an inherently risky undertaking. The skills required are based on a solid grounding in fundamental research and 'learning by doing' in high-powered team environments. A feature of science-based innovation is its radical departure from past assumptions and approaches to produce new concepts and products. However, this radical change is built on a large investment in experimentation, using the most sophisticated use of scientific techniques. This operating environment is not conducive to the use of standardised skills, based on low costs inputs.

The lack of connection between TAFE and science-based innovation has been acknowledged by the Office of Training and Tertiary Education in Victoria in its document *New and emerging skills needs*:

> TAFE has a low profile and is virtually unknown in the research community that spawns most of the new businesses in high technology areas. Its core purposes do not include scientific or technological research, and its links with research into new areas are often tenuous, sometimes non-existent. (There are exceptions to this, such as Viticulture and Water Management.) (Office of Training and Tertiary Education 2003, p.9)

However, this lack of connection between TAFE and science-based innovation is not merely an oversight, or, indeed, a lack of effort, on the part of either party. It is more related to TAFE's brief to focus on the delivery of standard skills to large numbers at low cost. This focus, with its emphasis on extensive consultation with all relevant stakeholders, often results in long lead times to develop appropriate training: 'with new workplace development taking up to five years to be recognised and even longer to be implemented' (Office of Training and Tertiary Education 2003, p.9).

The lack of involvement of TAFE in supporting science-based innovation through the provision of skills is also to do with the early stage of the development of these technologies. Enterprises working in science-based innovation have developed specialist knowledge and skills in-house. This means that they are not about to provide information about their competitive advantage publicly until they have captured sufficient returns in the form of a commercial product. As the Office of Training and Tertiary Education document on *New and emerging skills needs* notes: 'Intellectual property has become the most important commodity in the innovation economy, and protection takes precedence in the business community' (Office of Training and Tertiary Education 2003, p.9).

TAFE and emerging skills needs

Interviews with the industrial liaison agents in Victoria suggest that there is also an intermediate level of skill formation between the research-based skills required to develop 'frontier' technologies and the standardised skills needed to support the widespread adoption of new technologies. The role of the six industry liaison agents is to set up clusters or networks of small and medium-sized enterprises in leading edge sectors and to work with these networks to identify their specialist training needs. The sectors are: automotive, food, precision engineering, chemicals and plastics, biotechnology and general manufacturing.

The intermediate stage of skill formation is focused on the adoption of new technologies by a small cluster of firms. The new technologies are fully commercial products that have been developed by specialist firms serving niche markets in leading industrial economies. Their adoption by small and medium-sized enterprises presents particular problems in sourcing the appropriate skills.

The role of clusters

Precision engineering provides examples of the diffusion of new technologies that are not frontier technologies. These refer, for example, to computerised numerical control—metal-cutting machines with advanced capacities. The focus at this intermediate stage of skills formation is to identify a critical mass of small and medium-sized enterprises interested in using the advanced technologies. This is to enable the costs of developing appropriate training to be spread across a number of companies. The benefits of the training can be captured by specific enterprises, such as not having to pay for staff to go overseas to receive training to operate a laser cutter.

In these cases of early adopter firms serving niche markets, the demand for emerging skills is small and geographically concentrated. In the case of the two precision engineering clusters formed in Melbourne, the industry association representing both the end users and suppliers of the new technology has agreed to fund the development of the new training and to offer the course on a fee-for-service basis. It is anticipated that over a two-year period, the diffusion of the new technology will be much more widespread and the course can be released for use by other training providers.

Role of specialist centres in TAFE

The interviews conducted for this study also identified another way to assist the skills formation process at this intermediate stage. This is through the establishment of specialist centres within TAFE institutes that focus on these advanced technologies. This has been done in Victoria. The key role of these specialist centres in Victoria is to develop and deliver a diverse range of specialised training related to key strategic industries and technologies. Much of the centres' activities are dependent on the generation of substantial leveraged investment from industry (Office of Training and Tertiary Education 2004a). The strategic industries and technologies are manufacturing, food processing, building, environmental design, hospitality, and services to small and medium-sized enterprises, textiles and biotechnology.

Beyond the initial set-up costs of $5m, a further $12m has been distributed to 20 TAFE institutes for the purchase of specialised teaching equipment. Items to be purchased include equipment for specialist centres in biotechnology, new manufacturing technology, renewable energy generation and new specialised equipment for apprentice training (Office of Training and Tertiary Education 2004b).

The real value of the specialist centres is not as places to conduct research and development, as the Finnish polytechnics do. Their key role is more to diffuse new technology and processes to small and medium-sized enterprises. The kinds of activities planned by the Biotechnology Specialist Centre at Box Hill Institute of TAFE, for example, includes the development and delivery of training to biotechnology and related industries; as well as the enhancement of the research and development skills of TAFE staff working in biotechnology-related fields. Efforts will also be made by the Biotechnology Specialist Centre to foster a greater awareness of TAFE training capabilities within the biotechnology sector, promote within schools the career opportunities in biotechnology and related areas, and to market TAFE as a viable training option (Office of Training and Tertiary Education 2004a).

Specialist centres and their role in technology diffusion

More support may be needed to establish closer links between these specialist centres and small and medium-sized enterprises. The Centre for New Manufacturing at the TAFE Division of Swinburne University has noted the 'low level of market awareness and slow take-up in the "sunrise" years of new technologies' (<http://www.tafe.swin.edu.au/eng/cnm.htm> viewed 25 November 2004). An explicit focus on 'extension work' with small and medium-sized enterprises is also needed to help them to appreciate its benefits and how to minimise the costs.

However, this extension role for TAFE specialist centres needs to be funded. Interviews with the industry liaison agents came up with the recommendation that small and medium-sized enterprises need to be identified as a client group of the TAFE system, with targets set for small and medium-sized enterprises contacted, and training needs identified and responded to. The way to do this on a permanent basis is through a change to the profile funding agreements between state training authorities and TAFE institutes. As small and medium-sized enterprises may be seen as being outside an education ministry's funding responsibilities, specific funding may need to be allocated from an industry department at state or federal level to fund this extension work. Given the existence of different funding silos, it is possible that this role of TAFE as a diffuser of new technologies may not be adequately funded or, indeed, seen as having the same priority as its focus on entry level training or workforce skills upgrading.

TAFE and standardised skills

At the third stage of skills formation, TAFE has a clear role. This refers to the stage at which new technologies are adopted more widely throughout an industry sector. It is important, however, to identify the point at which new technologies have reached the point of wider diffusion.

This role of supporter of technology diffusion is not necessarily an easy one to pursue for TAFE because of the low cost nature of TAFE operations. The existing system of profile funding means that there is little incentive to take up new areas of training delivery (Office of Training and Tertiary Education 2003, p.9). In addition, bureaucratic procedures and the extensive consultations in relation to the development of new training packages can build in unnecessary delays in the capacity of TAFE to respond to new and emerging skills (Office of Training and Tertiary Education 2003, p.9).

Royle and Lindhjem (2004) have proposed an opportunity analysis model to help VET providers to identify the point at which they can intervene to develop or modify appropriate training. Four key elements of the model are presented. The first is the relationship of the emerging industry to the key objectives of the VET system. For example, is the emerging industry under examination likely to create a demand for new skills on a large scale?

Second, the Royle and Lindhjem model proposes that the potential commercial scale of the training likely to be needed has to be considered. The third factor to consider is the scale of competition from other providers. Finally, but not least, is the importance of the capacity of a VET provider to deliver the training in terms of the skills of staff and the facilities to deliver the training. Related to capacity is the provider's closeness to the industry in question to tap 'tacit knowledge' to enable the new training to be developed (Royle & Lindhjem 2004, p.7).

Changing the internal culture of TAFE

Technical and further education institutes carry in their operating systems the imprint of their origins as low cost providers of generic skills. In a number of respects, these structures still reflect the industrial economy that existed at its early stages of development. In most cases, TAFE still relies on traditional delivery models and standardised curriculum. The challenge is to change this staid, backward-looking culture to one that rewards internal innovation and responsiveness to new developments in the economy.

Professional development strategies need to be developed that emphasise the value of a range of new approaches. These include the importance of fostering partnerships with small and medium-sized enterprises, participating in industry conferences, undertaking research for higher degrees, and, not least, participating in work rotation within institutes and with small and medium-sized enterprises. One way an innovation-oriented mindset can be fostered is through participation in networks or communities of practice. These can be set up and maintained through online communications such as dedicated websites and blog-type software.

One good example of efforts to introduce more innovation capacity into a TAFE institute is the program undertaken at Kangan Batman TAFE in Melbourne (see Browne, O'Sullivan & Julian 2004). Starting with a new set of innovation competencies, the program developed a new management framework for the institute's automotive group. As a result of the initiative, new markets, curriculum, training models and learning resource materials are being developed. The new emphasis on innovation skills opened teaching staff up to new ideas as well as giving them the opportunity to come up with ideas. It gave them a feeling of having some control over change rather than being the servant of change and resenting it (personal communication, Tess Julian, 15 July 2004).

Two approaches to teaching that can help change the internal culture of TAFE are Practice Firms and the Innovation Design Challenge. The former emphasises the skills relevant to running a business and operating as an entrepreneur. The latter emphasises cutting edge design skills using state-of-the-art software and prototype development. Both initiatives are delivered within a 'learning by doing' context and are outlined further below.

Fostering entrepreneurship skills with TAFE

The eminent United States economist, William Baumol, has recently highlighted the important difference between the education backgrounds of those engaged in science-based innovation and entrepreneurs (Baumol 2004). The former have advanced technical training based on higher academic degrees. In contrast, he notes that successful entrepreneurs and independent inventors frequently have had only a basic education. In other words, there is an important distinction to be made between the type of education required for the mastery of received knowledge compared to the type of education required to generate innovative ideas that are outside the conventional wisdom. Although high levels of education may be valuable for producing incremental or routinised innovation, major breakthroughs, according to Baumol, are more likely to come from people who are not burdened by years of immersion in traditional methods of investigation and problem-solving (Baumol 2004, p.6).

Thus, the conclusion drawn is that education needs to also offer alternatives to the mastery of currently available scientific and technical methods. Education needs to foster risk taking, the exercise of originality and the power to imagine different possibilities to current theories and practices. It is also suggested that small enterprises, in particular, appear to have played a major role in promoting breakthrough innovations, while large corporations with their large research and development expenditures are more likely to produce incremental innovations (Baumol 2004, p.14).

The policy implications from the above analysis for promoting innovation are the value of entrepreneurial education and supporting small and medium-sized enterprises. In relation to the first suggestion, the forms of education need to be geared to learning by doing. This is the basis for the Practice Firms concept.

The Australian Network of Practice Firms, supported by the Canberra Institute of Technology, is part of a worldwide network of practice firm programs that seek to link students to business. This is done by setting up virtual enterprises where students learn to 'trade' in a simulated economy. They learn about what skills are required in business by exchanging goods and services, through a website, with students in practice firms across Australia and even potentially across national boundaries. Members of the network participate in regional, national and international fairs. At a recent trade fair in June 2004 in Canberra, 37 TAFE institutes and schools participated in the face-to-face event.

The skills imparted are: skills in marketing, business planning, office management, personnel work, purchasing, and finance. Students work in a team and are supported by a real business partner. One important skill imparted is the capacity to reflect on what is a better way of doing things. The areas they work in are information technology, retail, hospitality and business services such as event management.

Practice firms have been set up in TAFE but the take-up has not been evenly spread throughout Australia. Some 55 practice firms operate in TAFE institutes, although their geographical spread is uneven—with a much stronger presence in New South Wales compared with other states. Of the 150 registered practice firms, only 22 are from Victoria—or 15% of the total. There also tends to be more of a regional presence than in the metro areas, except in Victoria where they are all in Melbourne and Mildura.

There would appear to be considerable scope to expand the number of practice firms operating in TAFE institutes. This would offer the opportunity for those receiving technical training to also learn basic matters related to setting up an enterprise, such as guidance on appropriate sources of finance and how to manage cash flow.

Promoting new approaches to skills acquisition

Another initiative that also puts the emphasis on learning by doing is the Schools Innovation Design Challenge (<http://www.rea.org.au/> viewed 25 November 2004). The competition commenced in 2003 and is aimed at design and technology students aged 12 to 17 years. The program seeks to develop the creativity and innovation of high school students through a structured engineering design project based on the development of a model racing car.

Through this program students gain an understanding of the modern manufacturing cycle (PLM—Product Lifecycle Management)—starting from the idea, design, manufacture and testing of the prototype product, and finally the proof of the design by racing the cars! Students have the opportunity to use advanced software CAD/CAM facilities to develop their car designs. Manufacturing of the cars is by up-to-date computerised numerical control (CNC) machines. These are centrally located at selected 'Technology Hub' facilities such as the Centre for Advanced Manufacturing at the TAFE Division of Swinburne University.

Students are able to test their designs in special 'real' wind and smoke visualisation tunnels. Finally, the cars are raced on specially designed 25 metre tracks timed to one-thousandth of a second!

VET role in technology diffusion

The interviews with key brokers in the diffusion of new technologies and processes suggest that there is an important role for publicly funded agencies such as TAFE institutes that is not now realised. This role is to assist in the spread of new technologies and processes by supporting enterprises in the low and medium-tech sectors to invest in new capital purchases and to introduce new processes. This requires an in-depth understanding of why some firms in these industries are more successful than others in learning and innovation and then draw the lessons for the laggards (Smith 2004, p.44).

Diffusion of innovation

Technology diffusion is the transfer of technology across a firm's boundary to another firm in the same industry or to other industries. Such technology usually arises from commercially focused innovation and generates returns for the companies that develop it. The diffusion of technology between companies allows the diffusion of knowledge and new ideas in the business sector, the commercialisation of technological advances, and the implementation of new processes by firms. The process constitutes the downstream commercial application of the technology and is vital to innovation.

Equipment has been the most important source of innovation capabilities acquired by manufacturing firms from outside their businesses. Conferences, publications, consultants and skilled employees are also major external sources of innovation capabilities.

Source: Commonwealth of Australia 2003, p.77

Encouraging small and medium-sized enterprises to innovate

The initial innovation statement of the Commonwealth Government in 2001, *Backing Australia's ability*, allocated $6 million, in a $3 billion, five-year package, to set up a free national technical advisory service, called Industry TechLink.[2] The purpose of the program is to assist industry, especially small and medium-sized enterprises, by assessing their technology needs. Industry TechLink was funded under *Backing Australia's ability* 1 in 2001 to contact all businesses in Australia and offer them a free consultation of up to four hours on any matter related to technology upgrading or improvement. The service is free to registered businesses—that is, with an Australian Business Number. The funding is $6 million for four years and the project has been operational for 18 months. The project's offices are located in Melbourne.

Industry TechLink sends out 10 000 brochures a month, targeting different geographical regions of Australia. In addition, 10 000 emails are sent out a day. A database of 180 000 businesses has been compiled, although this is believed to be merely 20% of all eligible businesses in Australia. Out of scope are education, health, government, universities, TAFE institutes and agriculture where it does not relate to technology.

The main benefit that Industry TechLink offers to businesses is disinterested advice on appropriate forms of technology that they might adopt to improve productivity. Although large metropolitan areas have a number of sources of advice on appropriate technology solutions, there is a need for the honest broker to offer impartial advice. A particular strength of the service, however, is its capacity to reach regional businesses. About half of the calls received come from regional small and medium-sized enterprises.

How Industry TechLink works

Industry TechLink has three levels of engagement with prospective clients.[3] In response to calls to a 1800 number, enquiries are filtered according to their relevance to the project's brief which is to provide 'impartial, confidential and expert link to technical information, products and people' to make businesses more profitable. Callers are referred to other agencies where the inquiry is not directly related to technology. In other words, the project provides an impartial service as an information broker with specific reference to new technologies or processes.

[2] A related program funded by the Commonwealth Government is Commercialising Emerging Technologies (COMET). This program is delivered by private sector consultant business advisers to support businesses and individuals to increase the commercialisation of innovative products, processes and services. The program has been extended to 30 June 2011 and a further $100 million has been provided.

[3] The following information is drawn from an interview with Neil Nyholm, Project Director Industry TechLink, 29 June 2004.

Where the inquiry is relevant to some aspect of technology, the caller is entitled to up to four hours of consultation from a technology analyst. This can be by phone, but, in most cases, it is conducted face to face. The project has 12 generalist consultant technology analysts and 50 to 60 private sector consultants at call. New technology refers to control systems and new process technology, logistics innovation, new materials, machinery choice, and information technology for the office, including access to the internet.

The level 2 consultation offers not only the diagnosis requested, but also the analyst can look sideways to identify other issues that may need a response. If the issue is within the consultant's expertise, they can offer the diagnosis. If not, another, appropriate consultant is called in.

The third level of service is additional consultation time to help develop a brief to enable paid assistance to be offered. This is limited to a further two-hour consultation by a technology analyst. Industry TechLink, however, is forbidden, by the terms of its contract, to provide additional paid service beyond this, as the technology analysts are not permitted to offer their services for a six-month period to a business to which they have provided free advice.

Types of technology transfer

Three levels of technology transfer are the focus of the service. The first level relates to commonly available technology, such as computers or access to the internet. This transfer involves helping slow adopters to take up the new technology, such as moving from using dial-up modems to access the internet to using ADSL (asymmetric digital subscriber line) or broadband access.

The second level of technology transfer refers to enabling technology or process technology. This encompasses the use of non-core technology or processes to improve the operation of core technology. The third level refers to the introduction or upgrading of core technology. This involves making a major change to the core technologies used by small and medium-sized enterprises in a particular industry at an early stage of adoption. One example is the use of computerised laser cutting in metal or other materials.

Industry TechLink relationships with other entities

The project is seeking closer ties with industry associations, Cooperative Research Centres and service providers to small and medium-sized enterprises such as business enterprise centres. Efforts have been made to work with industry associations to offer this service to their members. The Furnishing Industry Association is one example of such an approach.

No relationship with TAFE currently exists. There are two possible ways the project could link with TAFE institutes and other VET providers. The first is to set up an arrangement to permit TAFE instructors to make use of the service. The second is to make it possible for TAFE instructors with relevant expertise to offer their services to Industry TechLink as consultants, especially in regional areas.

As noted above, Industry TechLink does not market its services to TAFE. This is because of the focus of the service, which is technology assistance for small and medium-sized enterprises. The basis for eligibility for the service is registration as a business in the form of an ABN (Australian Business Number).

However, if individual TAFE instructors wanted to make use of the service to identify new equipment used in the industry that they are servicing, for example, this could be the subject of a separate arrangement.

Potential role for TAFE instructors as technology assessors

The second form of engagement with TAFE could be through TAFE instructors with a specific expertise offering to make their services available as technology analysts so as to carry out the diagnostic assessment. The rate is $100 per hour, up to a maximum of four hours for a level 2 consultation. Industry TechLink is interested in identifying expertise in regional areas, as 50% of the inquiries received come from this source. It is expensive to send a consultant from a metropolitan area; therefore, the use of relevant expertise from a regional location is likely to be more cost-effective. The project is also interested in tapping TAFE instructors who may have specific expertise that is easily available elsewhere. The use of TAFE instructors in metropolitan or regional areas would always depend on the enquiries Industry TechLink receives; therefore, offers of consultancy work to TAFE instructors cannot be guaranteed.

Businesses in regional locations also have particular technology needs dictated by their location. The lack of commercial viability of more expensive technology makes finding intermediate technology solutions a necessity. One example offered related to the cost of a laser cutting tool that might be viable in a large metropolitan market. However, in a regional setting, other, less costly forms of cutting metal at a required angle for a single business will be required.

To date, no state training system or individual TAFE institute has sought to use Industry TechLink as a source of advice on new technologies. In relation to the role of TAFE teachers as technology assessors, individual TAFE instructors are welcome to register their expertise on Industry TechLink's database of consultants. Expertise is defined by a person's capabilities and the specific scarcity value of the expertise held. Industry TechLink is keen to identify who the foremost expert is in a particular field. The second aspect defining the value of the available expertise is the geographical location of the expert.

Of particular interest to Industry TechLink are the TAFE teachers located in regional areas. The two possible benefits of a regional location to Industry TechLink can be identified. One is to reduce the costs of sending a consultant from a major city. The second is to be able to access an expert with a better awareness of local conditions. Regional businesses want a solution that meets needs that are often based on operating in a lower cost environment and with more limited access to support services.

Identifying TAFE staff with particular expertise in technology assessment and supporting them to enhance their expertise and diagnostic skills may be valuable ways that TAFE institutes can support the spread of innovation through technology diffusion.

Conclusion

A more comprehensive understanding of what innovation entails is not only developing and applying new ideas in the form of products and services but also using existing ideas in new ways to encourage organisations to deliver different outcomes. While most innovations are small in their impact, it is their diffusion throughout the wider economy that produces the biggest changes. The importance of the diffusion of incremental innovations has been underemphasised in recent Australian policy. Instead, the focus of government policy has often been on lifting expenditure on research and development. This has been attractive to policy-makers because of the links between research and development and science-based innovation with its uncertain promise of major breakthrough products.

As noted above, several recent commentators have highlighted the value of a broader concept of innovation compared with the bias towards a science-oriented and market-based approach of Australian government policy (Sheehan & Messinis 2003; Marsh 2004; Smith 2004). The concept of a national innovation system of interlinked supporting services offers the VET sector a more integral role that is based on its own strengths.

From the perspective of innovation as a series of small changes diffused widely, vocational education and training has a much more definable role. However, in order to do this well, more attention to innovation diffusion by the VET system requires suitable performance indicators to show that this is an important priority and to show what progress has been achieved.

TAFE institutes, like their Finnish counterparts, could be major diffusers of innovation in regional areas. However, this requires incentives in the form of specific funding to do this. One way to provide these incentives is to highlight innovation diffusion as an explicit objective in national policy, with corresponding funding allocated to support this direction. Then, in turn, TAFE institutes, through their performance agreements, could be asked by the Commonwealth Government and state governments to meet certain performance targets, with funding allocated to help meet these targets.

A whole-of-government approach is needed to support a national innovation system. This requires new arrangements, such as pooled funds from relevant departments on a regional basis. It also requires setting performance targets for agencies such as TAFE institutes based on a comprehensive understanding of what fosters innovation in all its forms.

The whole-of-government approach refers to not merely coordinated action between departments at one level of government, but also to coordinated actions between levels of government at state and federal levels. The TAFE sector is a state government responsibility, with funding provided by the federal government as well. It is important that this division of responsibility does not undermine TAFE's enhanced role as a supporter of innovation in industry. This applies particularly to its role supporting small and medium-sized enterprises that are at the crux of the innovation economy. It is this whole-of-government approach that is a defining feature of the Finnish and Singaporean innovation policies.

References

ABS (Australian Bureau of Statistics) 2002a, *Measuring Australia's progress*, cat. no.1370.0, ABS, Canberra.

—— 2002b, 'Science and innovation expenditure on R&D—how does Australia compare internationally?', *Year Book Australia 2002,* cat.1301.0, ABS, Canberra.

—— 2002c, 'Science and innovation statistics 2002', *Year Book Australia 2002*, cat. no.1301.0, ABS, Canberra.

—— 2003, 'Science and innovation: Innovation statistics', *Year Book Australia 2003*, cat. no.1301.0, ABS, Canberra.

Asia-Pacific Economic Corporation Economic Committee 2003, 'Economic contributions of research and development in Singapore', in *The drivers of the new economy in APEC: Innovation and organizational practices*. APEC Secretariat, Singapore, ch.2, viewed 9 June 2004, <http://www.apec.org/apec/news___media/2003_media_releases/171003_knowledgenewprdnfactor.html>.

Amsden, A, Tschang, T & Goto, A 2001, 'Do foreign companies conduct R&D in developing countries?', Asian Development Bank Institute Working Paper No.14, March, viewed 14 June 2004, <http://www.adbi.org/archive/arch_wp.htm>.

Ashton, D & Green, F 1996, *Education, training and the global economy*, Edward Elgar, Cheltenham.

Audretsch, D 1998, 'Agglomeration and the location of innovative activity', *Oxford Review of Economic Policy*, vol.14, no.2.

Bassanini, A & Scarpetta, S 2001, 'Does human capital matter for growth in OECD countries? Evidence from pooled mean-group estimates', OECD Economics Department Working Papers 282, OECD Economics Department, Organisation for Economic Cooperation and Development, Paris.

Batterham, R 2000, *The chance to change: Final report of the chief scientist*, November, Office of the Chief Scientist, Canberra, viewed 26 May 2004, <http://www.dest.gov.au/ChiefScientist/Reports/Chance_To_Change/default.htm>.

Baumol, W 2004, 'Education for innovation: Entrepreneurial breakthroughs vs. corporate incremental improvements', National Bureau of Economic Research Working Paper 10578, Cambridge, Massachusetts, viewed 6 July 2004, <http://www.nber.org/papers/w10578>.

Blomström, M, Koklo, A & Sjöholm, F 2002, 'Growth and innovation policies for a knowledge economy: Experiences from Finland, Sweden, and Singapore', working paper 156, Stockholm School of Economics, October.

Brown, P, Green, A & Lauder, H 2001, *High skills: Globalisation, competitiveness and skill formation*, Oxford University Press, Oxford.

Browne, R, O'Sullivan, S & Julian, T 2004, *Innovation at Kangan Batman TAFE: From product development to change management*, National Centre for Vocational Education Research, Adelaide.

Castells, M & Himanen, P 2002, *The information society and the welfare state: The Finnish model*, Oxford University Press, Oxford.

Commonwealth of Australia 2001, *Backing Australia's ability: An innovation action plan for the future*, The Department of Industry, Science and Resources, Canberra.

—— 2003, *Mapping Australian science and innovation: Main report*, The Department of Industry, Science and Resources, Canberra.

Department of Industry, Science and Resources 1999, *Shaping Australia's future*, Innovation Framework paper, Department of Industry, Science and Resources, Canberra.

Departments of Trade and Industry and Education and Skills (UK) 2001, *Opportunity for all in a world of change, a white paper on enterprise, skills and innovation*, ch.1, viewed 10 May 2004, <http://www.dti.gov.uk/opportunityforall/pages/chapter1.html>.

deVol, R 2001, 'Connected Clusters Stick', *BrainHeart,* viewed 25 March 2004, <www.brainheartmagazine.com>.

Durie, J 2002, 'Michael Porter in Australia', *The Australian Financial Review*, August 2.

Dutta, S, Lanvin, B & Paua, F 2003, *The global information technology report 2002–2003: Readiness for the networked world*, World Economic Forum and Oxford University Press, New York.

European Commission 2000, 'Innovation in a knowledge-driven economy', Communication from the Commission to the Council and the European Parliament, COM (2000) 567 final, viewed 26 May 2004, <ftp://ftp.cordis.lu/pub/innovation-policy/communications/communication_2000_en.pdf>.

—— 2002, 'European Innovation Scoreboard', EU Commission Staff Working Paper, Brussels, SEC (2002) 1349, 9 December.

European Commission 2003a, *Innovation tomorrow. Innovation policy and the regulatory framework: Making innovation an integral part of the broader structural agenda*, Innovation Papers No 28, Director General for Enterprise, Brussels.

—— 2003b, 'Innovation policy: updating the Union's approach in the context of the Lisbon strategy', communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the committee of the regions, Brussels, 11.3.2003 COM (2003) 112 final.

Finegold, D 1999, 'Creating self sustaining, high skilled ecosystems', *Oxford Review of Economic Policy*, vol.15, no.1, pp.60–81.

Florida, R 2002, *The rise of the creative class: And how it's transforming work, leisure, community and everyday life,* Pluto Press Australia, Melbourne.

Gans, J & Stern, S 2003, *Assessing Australia's innovative capacity in the 21st century*, Intellectual Property Research Institute of Australia (IPRIA), University of Melbourne, 27 June.

Georghiou, L, Smith, K, Toivanen, O & Ylä-Anttila, P 2003, *Evaluation of the Finnish innovation support system*, Ministry of Trade and Industry, Finland Publications 5/2003.

Government of Singapore 2002, *Mapping Singapore's knowledge-based economy. Economic survey of Singapore, third quarter,* Ministry of Trade and Industry, Singapore.

—— 2003, *Economic contributions of Singapore's creative industries. Economic survey of Singapore first quarter*, Ministry of Trade and Industry, Singapore.

Green, A & Preston, J 2001, 'Education and social cohesion: Re-centering the debate', *Peabody Journal of Education*, vol.76, pp.247–84.

Griffiths, R 2003, 'Presentation to Youth Employment Strategies Forum. Mission Australia', East Gippsland Institute of TAFE, Bairnsdale, Victoria.

Hämäläinen, T & Schienstock, G 2000, 'Innovation networks and network policies', Organisation for Economic Co-operation and Development, Paris.

Leadbeater, C 2002, *Up the down escalator*, Penguin, London.

Marsh, I 2004, 'Overview: Renewing Australia's industry development strategy: Innovation and the "knowledge economy"', in *Innovating Australia,* ed. I Marsh, Growth 53 Committee for Economic Development of Australia (CEDA), Melbourne.

Nanyang Technological University 2004, 'History', viewed 12 July 2004, <www.ntu.edu.sg/publicportal/about+ntu/about+us/history.htm>.

Ng, Boon Hwang & Loh-Goh, Ai Hwa 2003, 'The role of the university based education in NTU in the remaking of Singapore', Nanyang Technological University, Singapore.

OECD (Organisation for Economic Co-Operation and Development) 2000, *A new economy? The changing role of innovation and information technology in growth,* OECD, Paris.

—— 2001a, *Innovative clusters, drivers of national innovation systems,* OECD, Paris.

—— 2001b, *The well-being of nations: The role of human and social capital,* OECD, Paris

—— 2003a, *OECD Science, Technology and Industry—2003 Scoreboard: Towards a knowledge-based economy,* OECD, Paris.

—— 2003b, *Reviews of national policies for education: Polytechnic education in Finland,* OECD, Paris.

Office of Training and Tertiary Education 2003, *New and emerging skills needs,* OTTE, Ministry of Education, Victoria, viewed 12 July 2004, <http://www.otte.vic.gov.au/employers/docs/emerging%20skills%20needs.doc>.

—— 2004a, 'Specialist centre profiles 2004', Specialist Centres' Seminar, William Angliss Institute of TAFE Conference Centre, Melbourne, 31 March & 1 April.

—— 2004b, '$12m for specialised teaching new equipment' *Newsbrief,* no.19, February, viewed 12 July 2004, <http://www.otte.vic.gov.au/ettenews/issue19.htm#article1>.

Pastor, M, Leete, L & Dresser, L 2003, 'Economic opportunity in a volatile economy: Understanding the role of labor market intermediaries in two regions', final research report to the Ford, Rockefeller and Russell Sage Foundations, May, viewed 7 April 2004, <http://www.willamette.edu/publicpolicy/lmi/>.

Royle, J & Lindhjem, A 2004, *Vocational education and training engaging with emerging industries: An opportunity analysis model*, NCVER, Adelaide.

Sachs, J 2002, 'The global innovation divide', in *Innovation policy and the economy*, vol.3, Innovation Policy and the Economy (IPE) group, National Bureau of Economic Research (NBER), Boston.

Shah, C & Burke, G 2003, 'Future job openings: Australia in the knowledge economy', Centre for the Economics of Education and Training working paper no.48, April, CEET, Monash University and Australian Council for Education Research, Melbourne.

Sheehan, P & Messinis, G 2003, 'Innovation in Australia 2003', in *Cambridge handbook of social sciences in Australia*, eds I McAllister, S Dowrick and R Hassan, Cambridge University Press, Cambridge.

Singapore Ministry of Education 2003, 'Educational Factsheet 2003', Planning Division, Ministry of Education, Singapore, viewed 26 March 2004, <http://www.moe.gov.sg/esd/Default.htm>.

Skidén, Ulla 2003, ‘Finland tops global network readiness report’, viewed 10 October 2004, <http://www.centerdigitalgov.com/international/story.php?docid=51819>.
Smith, K 2003, 'Evaluating innovation policy in Finland’, presentation to the Innovation Management and Policy Programme, National Government School of Management, The Australian National University, August.
—— 2004, ‘Perspective on the knowledge economy in the Australian context’, in *Innovating Australia,* ed. I Marsh, Growth 53 Committee for Economic Development of Australia (CEDA), Melbourne, pp.35–44.
Srinivas, S 2003, ‘Background paper of the Millennium Project Task Force on Science, Technology and Innovation’, Task Force on Science, Technology and Innovation, United Nations Millennium Project, Columbia University, New York.
The Economist 2003, ‘Eugene Kleiner, pioneer of venture capitalism: Obituary’, 6 December.
United National Development Program 2001, *Human Development Report 2001: Making new technologies work for human development*, United National Development Program and Oxford University Press, New York.
Vitale, M & Sparling, D 2004, ‘Australian biotechnology IPOs: Too early, too small?’ in *Innovating Australia,* ed. I Marsh, Growth 53 Committee for Economic Development of Australia (CEDA), Melbourne, pp.73–91
World Bank and OECD 2000, *Korea and the knowledge-based economy: Making the transition,* OECD and the World Bank Institute, Paris and Washington DC.

Appendix 1

Finland: New linkages between vocational education and training and a national innovation system

From crisis to outstanding success

Finland is a small Nordic country, in terms of its population of 5.2 million, and has few natural resources with a harsh climate. However, during the 1990s, Finland became a highly successful participant in the global economy. Finland's medium-term growth performance has been among the best in the OECD (OECD 2003b). Success has come not only from its most visible company, Nokia, but also from other high-technology initiatives. The country has a high level of investment in research and development, resulting in one of the highest per capita publication rates for science and technology in the world, as well as a high patenting profile (Srinivas 2003, p.3).

Finland tops Global Network Readiness Report

Finland scored high in two recent reports from the World Economic Forum, the 'Global Information Technology Report 2002–2003—Readiness for the Networked World' and the 'Global Competitiveness Report 2002–2003.' The small Nordic country is doing better than all other nations, topping one of the prestigious surveys and ranking second in the other, only surpassed by the US. In the report 'Network Readiness' Finland is emerging as the strongest country in the world among 82 nations, followed by the US, Singapore and Sweden.

Source: Ulla Skidén 2003, <http://www.centerdigitalgov.com/international/story.php?docid=51819>.

The Global Information Technology Report 2002–2003 rated Finland third out of 82 countries in terms of 'capacity for innovation', first in terms of the quality of local information technology training programs, and fifth in terms of firm level technology absorption (Dutta, Lanvin & Paua 2003, p.216). Finland is rated the most technologically advanced country in the world, according to the United Nations Development Program's 2001 Human Development Report. The report placed Finland ahead of the United States because of its greater internet availability and the population's better technological know-how on average.

The 2001 United Nations Development Program report also listed 46 'global hubs of technological innovation', of which 13 were located in the United States. Finland has two regional technology clusters, one in the Helsinki region and the other in Oulu, in the province of East Bothnia. In Australia, both Melbourne and Brisbane were also identified as hubs of technological innovation (United Nations Development Program 2001, p.43).

In the early 1990s, the Finnish economy underwent dramatic and painful changes following a number of important structural shifts in the economy. These included the disappearance of Finland's status as one of the main Western gateways to the Soviet Union's economy. Output growth dropped from an annual rate of 5.1% in 1989, to 0% in 1990, and then plunged to –6.3% in 1991. Unemployment rose from 3.2% in 1990, to 6.6% in 1991, peaking at 16.6% in 1994 (OECD 2003b, p.242).

The Finnish Government not only engineered a reversal of the economy's slump in the early 1990s, but also produced a major new direction in restructuring the economy. Between the 1980s and the 1990s, the metal and engineering share of total exports rose from 25% to 40%, while the forestry and paper products share declined. Within the forestry and paper sector, there was a shift from primary goods to manufactured goods with higher value-added. Moreover, while the investment share of the gross domestic product declined from about 25% to 15% in the mid 1990s, investment shifted towards smaller, more flexible, and skill-intensive production units (OECD 2003b, p.144).

Raw materials-based industry such as paper, wood products, and metal industry had traditionally dominated the manufacturing sector. However, growth in the decade of the 1990s came mostly from high-technology products, in particular from telecommunications equipment. As a result of the increasing specialisation in high-tech sectors, Finland's trade balance in high-tech products turned from a large deficit in the early 1990s to a significant surplus by the year 2000 (Blomström, Kokko & Sjöholm 2002, p.8).

Finland has developed a high level national consensus on a coordinated approach to innovation that is an important element in Finland's success (Castells & Himanen 2002). Another prominent feature of the Finnish model is the combination of a technologically dynamic economy with a Nordic welfare state.

Key focus on research and development

The volume of research and development investments in Finnish industry over the past 10 to 15 years has grown more quickly than in other OECD countries, at an annual rate of about 10%. With this pace of growth, Finland had reached the top level of small industrial countries by the end of the past millennium (<http://virtual.finland.fi/finfo/english/innovat.html> viewed 30 June 2003). In 2000, the private and public sectors in Finland invested a total of some EUR 4.3 billion in research and product development, equivalent to approximately 3.3% of the gross national product. In relative terms, this puts Finland at the top of the list of research and development investors.

Another measure of innovative capacity is the number of patents taken out. Finnish individuals, research teams, and companies file around 2500 patent applications annually, of which around half result in patents. Per capita, this places Finland in the fourth position in the world after Japan, Germany, and the United States (<http://virtual.finland.fi/finfo/english/innovat.html> viewed 30 June 2003).

Finnish researchers are at the leading edge of developments in a number of fields, including forest improvement, brain research, neural networks, low-temperature physics, new materials, biotechnology, and genetic technology (<http://virtual.finland.fi/finfo/english/innovat.html> viewed 30 June 2003). Product development work has spawned numerous important and innovative new products. For example, Finnish engineering companies have manufactured icebreakers, cruise liners, lifts, diesel engines, sailing yachts, compasses, fishing lures, frequency transformers, stone drills, harvesters, contraceptives, pipettes, and scissors and axes. Some of the information technology-based products developed in Finland include internet encryption systems and the Linux operating system developed by Linus Torvalds.

The Finnish innovation system

The ultimate source of productivity growth is said to be innovation—defined as product, process and organisation change (Castells & Himanen 2002, p.46). In order to achieve this, a substantial public and private investment in education is required. However, also included is a culture of innovation which promotes and rewards creativity (Castells & Himanen 2002, pp.46–47).

Finland's success as an information economy is largely the result of two parallel but interrelated processes that have promoted research, innovation, and diffusion of knowledge across broad segments of the economy (Blomström, Kokko & Sjöholm 2002, pp.9–24). First, Finnish industrial policy and technology policy has focused on fostering five industry clusters. These are: information and communications technology, paper and pulp, metal products and engineering, food products, and construction. These sectors produce about 75% of the value-added production in Finnish industry.

Second, Finnish technology and innovation policy has consciously sought to coordinate the efforts of different agencies in order to highlight interdependency and mutual interaction between a range of key inputs, such as research and development, higher education and science and technology policy. The role of networks between enterprises with different competencies, between industry and government, or between industry and universities has been crucial in determining the efficiency of research and development investment (Blomström, Kokko & Sjöholm 2002, pp.9–24).

The Finnish approach has been called 'connected clusters' (deVol 2001). This involves the widespread use of open and numerous public–private partnerships so as to make better use of limited resources and the formation of joint ventures (deVol 2001). Other important elements of the Finnish national innovation system are an open telecommunications competition and a high quality educational system (Castells & Himanen 2002).

The main public elements of the system are the Finnish National Fund for Research and Development (SITRA), founded in 1967; the National Technology Agency, set up in 1983; and a revamped Science and Technology Policy Council (1986) (Castells & Himanen 2002, p.49). The latter is organised directly under the prime minister, who chairs its meetings. It also includes eight key ministers, ten of the highest level representatives of the universities, industry chief executive officers, such as the head of Nokia, major agencies and employer/employee organisations at the highest level (Castells & Himanen 2002, p.51).

One feature of the national innovation system is the focus on support services to small and medium-sized enterprises. This is mainly provided through Employment and Economic Development Centres (TE-Centres) (Georghiou et al. 2003, p.145). TE-Centres were established in 1997 and employ about 250 people. They consist of a network of 15 regional offices that supply business support services, consultation and advice, as well as finance. TE-Centres also partially finance enterprise investment and development projects via direct aid. TE-Centres also offer entrepreneurship grants for unemployed people to become self-employed.

The tasks of the TE-Centre business departments are to promote, in particular, small and medium-sized enterprise operations and operating conditions as well as their technological development and internationalisation. More specifically, this means that they support and advise small and medium-sized enterprises at the various stages of their life cycles; promote technological development in enterprises; assist in matters associated with export activities and internationalisation; and support regional development in general (Georghiou et al. 2003, p.145).

University education and research in Finland is very technology oriented. Just over a quarter (27%) of students are in science, mathematics and engineering—twice the proportion of comparable countries (Castells & Himanen 2002, p.51). An evaluation of Finland's national innovation system concluded that one important contributor to its success was the plentiful supply of scientists and engineers (Smith 2003). Finland is aiming to have 70% of its population educated to degree level (Smith 2003).

The role of vocational education in the national innovation system

By the early 1990s, the shortage of educated manpower was evident in Finland and so an expansion program in higher education was initiated. In the early 1990s, in the midst of a major economic slump, the Finnish Government embarked on a strategy to remould Finland into a knowledge society.

A key element in this strategy was to raise the knowledge and skill levels of the population by doubling higher education enrolments by the end of the century. Recognising that it would be neither affordable nor desirable to double traditional university enrolments, the government created a new sector of higher education with a different content, degree structure, and governance from universities—the 'Ammattikorkeakoulut' AMK (polytechnics) (OECD 2003b, p.138).

One way this was done was by upgrading secondary education level VET institutes into degree level polytechnics. This involved a decade-long process of setting up 29 higher education institutions by amalgamations of about 215 secondary vocational schools and colleges. By 2004, there will be 25 000 entrants annually to the AMKs, representing about two-thirds of those entering higher education.

Between 1993 and 1998, the number of students in polytechnics tripled, while the total intake in universities nearly doubled in the same five-year period (Blomström, Kokko & Sjöholm 2002, p.18). The Finnish Government consciously raised the status of vocational education and increased public resources for on-the-job learning. Since 1999 all three-year degree level vocational courses have had to offer six months' work experience to every student (United Nations Development Program 2001, p.85).

A recent OECD review has noted:

> The AMK policy in Finland has been remarkably successful. There is general acceptance of the existence and value of a sector of higher education with a distinctive educational mission, though controversy exists about the future development of the sector. In general, the programmes are relevant to working life, innovative, and well received by employers and students … There is a substantial consensus in Finland for provision of higher education different from that traditionally provided by universities, and directed towards the needs of working life. (OECD 2003b, p.133)

Key features of the new polytechnics

The new polytechnics are intended to concentrate on the education and training of 'high quality experts in working life' (OECD 2003b, p.139). The main aims of the policy included:

- providing an alternative route into higher education with a more practical emphasis, alongside the universities
- increasing the international comparability of vocationally oriented higher education in Finland
- strengthening regional development and co-operation with small to medium-sized enterprises (OECD 2003b, p.139).

The ever-growing demand for university-level education was the outcome of a growth in upper secondary education in the 1980s. So an important aim of the reforms which began in the early 1990s was to channel the increase in higher education provision to polytechnics rather than universities. Another objective was to improve the quality of the available vocational education and training by addressing the structural rigidity of vocational education in general.

> Vocational education was divided into separate fields, each with its own schools and institutes. These were often very small and there was little co-operation between fields of study … The Finnish vocational education system was difficult to describe and grasp, and in particular there was little understanding of the role of post-secondary vocational education and its standing. (OECD 2003b, p.50)

The reforms involved setting up new institutions in the form of polytechnics, upgrading the qualifications of staff and the engagement in research and development. The mission of the polytechnics states that they are 'to engage actively in the development of working life and to produce relevant new knowledge' (OECD 2003b, p.110). As noted above, another aim of the reform process was to set up institutions in regional locations to promote regional development (OECD 2003b, p.110).

The reform process for vocational education

The reform of vocational education and training began in 1991 with the approval of legislation establishing an experimental period, under which 22 temporary polytechnics were set up in the early 1990s. The aim of the experimentation phase was to gain experience that could be used later in building up a permanent system, and the temporary polytechnics were given the chance of eventually gaining permanent status. A number of research projects were also launched for monitoring the experimental phase. The basic assumption was that licences for permanent polytechnics would only be granted after they could demonstrate high quality and good performance during this experimental stage. The core of the strategy would thus be constant development, and gradual attainment of permanent status. The national parliament approved permanent legislation to establish a polytechnic system in February 1995 (OECD 2003b, p.52).

In the course of a process that took a full decade, about 80% of volume of education provided by the old post-secondary vocational schools and institutes was raised to a standard high enough to qualify for admission into the polytechnic system. The remaining 20% continued to function in the upper secondary vocational education stream (OECD 2003b, p.52). Before the reforms, Finland had about 250 post-secondary vocational institutions. In the reform, 29 polytechnics were formed, most of them multidisciplinary.

In the initial phase of the reform process, funds went mainly into improving the qualifications of teachers at the temporary polytechnics and in developing links for students to study abroad and foreign students to study in Finland. As the system became more permanent, the support programme expanded and grew more systematic. Integral elements included raising teachers' qualifications, developing library and information services, developing online learning environments and information networks, career and recruitment services, and internationalisation (OECD 2003b, p.53).

The aim of international cooperation in education is to raise the quality of education and provide students with study opportunities abroad. The objective of the government development programme is that at least one-third of all students in higher education should complete part of their degree studies abroad. Student and trainee exchanges at the polytechnics aim especially to increase the proportion of long-term exchanges lasting over three months.

The focus of lifting vocational education and training to international standards has been important because graduates from the former post-secondary vocational colleges often experienced major difficulties in international mobility. Finnish polytechnic graduates, however, are said to have had no problem in going on to study or work abroad (OECD 2003b, pp.126–7).

A new role: Polytechnics' involvement in research and development

Role of new polytechnics in innovation

New innovations emerge from a foundation of broad high-quality basic research, the main responsibility for which lies with universities and research centres … The polytechnics have a natural role in innovation alongside the universities, complementing them particularly in the area of applied research. Finnish higher education policy makes regional development a particular responsibility of the polytechnics. It is also important to take education in entrepreneurship skills from the SME point of view sufficiently into account in education and research. The polytechnics have a central role in improving SME operations and entrepreneurship.

Source: OECD 2003b, p.124

An important new thrust in the setting up of the polytechnics is their involvement in research and development. The VET institutions that were the predecessors of the polytechnics rarely did anything that could be described as research and development. On the other hand, some of them had a strong tradition of cooperation with business, including selling training services to companies and providing other business services.

The government education and research development plan for 1999–2004 includes the following target:

> The capacity of polytechnics for producing new knowledge about working life, professional expertise and its development will be improved. To this end, measures will be taken to develop professional postgraduate degrees and applied R&D jointly undertaken with business and industry. The increase in R&D will be especially geared to promoting regional development, supporting the SME sector and developing welfare services.
>
> (OECD 2003b, p.119)

In 1999, EUR 3.89 billion were spent on research and development in Finland; this is equivalent to 3.2% of the gross domestic product. Research expenditure amounted to EUR 700 million at universities and EUR 27 million at polytechnics. The percentage of outside funding was 48% at universities and 73% at polytechnics. The total number of research personnel at higher education institutions was about 20 000, of which 470 were employed at polytechnics.

By the end of 1999, all polytechnics had drawn up a research and development strategy of their own, on funding from the Ministry of Education. In 2001, the Ministry of Education for the first time allocated a total of EUR 5 million in funding to polytechnics to create a basic research and development framework. Furthermore, in the target and performance agreements the polytechnics and their maintaining bodies undertook to increase their own funding allocations to research and development by a total of EUR 3.4 million. The Ministry of Education will be increasing basic research and development funding for 2002 by a further EUR 0.8 million, and the polytechnics have likewise undertaken to increase their own funding. The Ministry of Education funding is intended to lay the foundation for research and development. It is intended that the funding for actual research must be found from other public and private sources (OECD 2003b, p.119).

The research and development focus at polytechnics is an applied one, based on the 'actual needs of working life' (OECD 2003b, p.161). The practical goals include creating new or improved products, production tools or methods and services. Research and development is also seen as an important way to improve the competence of the teaching staff in the polytechnics. This is achieved by providing opportunities for teachers to examine working arrangements in a relevant industry sector. Another important vehicle for teachers to foster closer links to workplaces is through students' final year projects (OECD 2003b, p.161).

Polytechnics and local clusters

Research and development is regarded as an important part of the services provided by polytechnics to the wider community and local economy. In research and development, polytechnics focus not only on new small and medium-sized enterprises, but also on traditional small and medium-sized enterprises that pursue little or no research and development of their own. Extending innovation and the principles and practice of research and development to this rather large group of companies is an important challenge for polytechnics. Problems found in the small and medium-sized enterprise sector are different from the problems and development needs of large companies. Polytechnics are expected to provide expert help in addressing these problems and help develop the business of small and medium-sized enterprises (OECD 2003b, p.120).

The network of polytechnics covers the whole country. As noted above, one goal of the reform was to promote regional development and meet regional needs for higher education. The regional aspect is a central feature of research and development at polytechnics. In most cases, the objectives of research and development at polytechnics have been linked to regional objectives, with an emphasis on supporting industrial small and medium-sized enterprises and service production.

Polytechnics, as a result, have become part of the regional innovation systems which are concentrations of centres of expertise around institutions of higher education, national programmes for centres of expertise, technology centres, science parks and other organisations benefiting from the expertise of higher education institutions (OECD 2003b, p.110).

In 2001, the government funded centres of expertise in regional development at polytechnics. Factors cited as strengths of those polytechnics selected as centres of expertise include a dense network of connections with their environment, response to regional labour market needs through educational provision and the creation of a foundation for growth industries. Extensive adult education was also seen as a benefit. A focus on the implementation of regional strategies in project work was also seen as a strength. Other factors important for the evaluation of regional development impact were the construction of clusters of expertise jointly with local authorities and businesses in the region, and the assumption of a central role in regional strategy development, European Union programme work, internationalisation of the region and development of a regional innovation system (OECD 2003b, p.111).

Conclusion

Finland underwent a major upheaval in the 1990s that demanded major changes from the public sector as well as the restructuring of the economy. One important element of the changes introduced by the civil service was a substantial upgrading of vocational skills training to meet the needs of a restructuring economy. This involved setting up a new higher education sector focused on vocational skills with a more demanding, degree level set of courses.

The reform process required existing post-secondary vocational training institutions to meet higher quality standards, such as improved staff qualifications, offering more internationally comparable courses and to demonstrate a new strategic focus in terms of better linkages with enterprises.

Polytechnics in Finland play an important part in the national and regional innovation systems because they are actively encouraged and funded by the national government to engage in research and development. The research and development focus is closely aligned to the polytechnics' aim to apply knowledge to the workplace. One important way this is achieved is the students' final year projects in enterprises.

The majority of eligible school leavers in Finland now elect to go to a polytechnic rather than a university. This, together with higher completion rates than universities and high post-graduation employment, indicates strong acceptance of the reforms among both young people and employers. The continued high performance of the Finnish economy demonstrates the overall success of this strategy to provide a more distinct and more demanding pathway for the acquisition of vocational skills.

Appendix 2

Singapore: The high skills path to a knowledge economy

Singapore has, in recent years, sought to move up the value production chain to become more of a knowledge-based economy. As more electronics production has departed in favour of investment in China, Singapore has experienced a hollowing out of its manufacturing industries. In response, Singapore has sought to foster more of its own innovations and technology rather than to import ready-made technologies through the foreign multinational corporations. The amount of research and development conducted in Singapore has increased substantially during the 1990s, although much of this research and development is taking place within the multinational corporations (Blomström, Kokko & Sjöholm 2002, p.48).

An important element of this change to high-end research and development is the need to develop a workforce with high-level research skills. Singapore's younger generations are highly qualified, including high standards in school maths and science (TIMSS) and tertiary attainment higher than the United Kingdom. Singapore has a high output of engineers (5% of cohort graduate compared with 2% in the United Kingdom) (Brown, Green & Lauder 2001, p.34). However, Singapore has a large proportion of its older workforce without full secondary education (60%). Only 10% of the workforce have intermediate qualifications as their highest qualification. Also, only a small elite is qualified at postgraduate levels (Brown, Green & Lauder 2001, p.34).

It has been claimed that Singapore's competitiveness has been derived mostly from factors other than high skills, such as its strategic location, and a relatively low-cost, disciplined, English-speaking workforce. Singapore has also benefited from having a competent bureaucracy and planning, social order and political stability, and good infrastructure. It also has a pro-business environment that is based on sound financial policies and services (Brown, Green & Lauder 2001, p.35). The need to foster high-level skills as a development strategy has become a major priority of the government.

Singapore is a good example of a concerted state-led strategy to set up a knowledge-based economy that is aiming to achieve a 'quantum jump into the global league'.[4] This is being done by investing in biomedical and engineering-based research institutes, and by providing scholarships for the acquisition of university-based high level research skills.

However, skills deficits that have been identified by the government include a lack of creative engineers, senior managers and low skills operatives in manufacturing and in services, a lack of creative professionals in advertising, media and banking services (Brown, Green & Lauder 2001, p.40, see also Government of Singapore 2003). There is also said to be a lack of entrepreneurs and risk-takers (Brown, Green & Lauder 2001, p.40).

Singapore's focus on innovation

Singapore's economic development since independence in 1965 has been remarkable, with an average annual economic growth rate of around 8%. By the late 1990s, Singapore's real per capita income level matched that of most European Union countries.

[4] Senior Minister Lee Kuan Yew, International Trade in a Digital Economy: Thriving With Change: New roles in international trade at the International Trade Award Ceremony, Ministry of Trade and Industry, Singapore.

Initially benefiting from an inflow of technology from abroad, Singapore has in recent years invested substantial resources to increase indigenous technology development. Singapore has relied to a great extent on large inflows of foreign multinational corporations rather than on indigenous companies. For instance, about 75% of Singapore's manufacturing output and 80% of exports are from foreign multinational corporations (Blomström, Kokko & Sjöholm 2002, p.34).

After an economic recession in 1985–86, which was the first time Singapore experienced negative growth rates since 1964, the government decided to upgrade its production and start producing goods and services of higher value-added that would allow for relative high wage levels. The upgrading took place on three different levels:

- ✧ a focus on improving the technological content of manufacturing production in Singapore;
- ✧ labour intensive parts of the production chain were outsourced to Malaysia (Johor) and Indonesia (Batam) and keeping more skill and capital intensive parts of the production chain in Singapore; and
- ✧ a deliberate effort was made to strengthen the service sector (Blomström, Kokko & Sjöholm 2002, p.39).

Knowledge-based economy

Since the early 1990s, the government has been trying to transform the economy into 'a knowledge-based economy' (see table 5). In manufacturing, the composition of its manufacturing exports went through a rapid technological transition between 1980 and 2000. The share of high and mid-high technology exports increased from 38% of total exports in 1980 to 84% in 2000. Average manufacturing productivity growth accelerated from 5.5% per annum in 1986–90 to 7.2% per annum in the 1991–95 period. High productivity growth was sustained at an average of 7.8% per annum from 1996 to 2000. This could be attributed to the higher level of capital investments and total factor productivity as the manufacturing base became more technology intensive (Government of Singapore 2002, p.64).

Singapore's research and development expenditure, expressed as a percentage of the gross domestic product, has risen steadily from 0.9% to 1.9% between 1990 and 2000 (Government of Singapore 2002, p.60). This suggests that Singapore's manufacturing base has continued to move up the value-chain to more high-tech and knowledge-intensive products.

However, in terms of outputs from the research and development process, Singapore's patents record is weak. While it has improved steadily over the last decade, from 25 United States patents in 1990 to 304 patents in 2001, the country's performance is still weak by international standards. Singapore registered 74 new United States patents per million population in 2001, whereas Canada and Taiwan had 131 and 294 patents, respectively. The United States ranked first with some 350 United States patents per million population (Government of Singapore 2002, p.61).

However, a recent study has shown that all core technology in Singapore was still transferred from the United States. The study shows that research and development in Singapore is more engineering rather than science based and is conducted by relatively low skilled personnel (Amsden, Tschang & Goto 2001, p.43).

In order to make the economy less reliant on a small number of key sectors such as electronics, a government committee has recommended a greater focus on areas such as the high value-added activities in photonics, nanotechnology, alternative fuels and performance materials. Greater emphasis on these areas, however, would require Singapore to broaden and deepen its knowledge capabilities (Amsden, Tschang & Goto 2001, p.67).

In the process of upgrading its manufacturing base, Singapore has become specialised in a few industries. For instance, electronics rose from contributing 18% of manufacturing value-added in 1983 to a height of 48% in 2000. However, this has also made the economy vulnerable to sectoral cyclical swings.

Table 5: Knowledge-based industries in Singapore

Knowledge-based	Non-knowledge-based
Communication/port services	Services
Finance services	Construction
Business services	Utilities
Education	Wholesale and retail trade
Healthcare	Transport
Publishing, printing, reproduction of recorded media	Other services
Refined petroleum products	Manufacturing
Chemicals and chemical products	Food, beverages and tobacco
Machinery and equipment	Textiles and textile manufactures
Electrical machinery and apparatus	Wearing apparel except footwear
Electronic products and components	Leather, leather products and footwear
Medical, precision and optical	Wood and wood products
Instruments, watches and clock	Paper and paper products
Transport equipment	Rubber and plastic products
	Non-metallic mineral products
	Basic metals
	Fabricated metal products excluding machinery and apparatus
	Other manufacturing industries

Note: This classification of knowledge-based industries and non-knowledge-based industries is based on that used in the OECD Science, Technology and Industry Outlook 2000.

Source: Government of Singapore 2002, annex A

Singapore's education and skill profile

Knowledge workers constituted 36% of the labour force in Singapore in 2000, compared with 47% in the United States, 36% in Japan and 18% in Korea. On this measure, Singapore is almost comparable with the developed economies (Amsden, Tschang & Goto 2001, p.65). The proportion of Singapore's workforce with at least secondary education has improved steadily from 51% in 1990 to 63% in 1999 and 66% in 2001. Singapore is approaching the OECD average of 70% (Amsden, Tschang & Goto 2001, p.64). The proportion of the Singapore workforce with university education has also increased steadily from 6% in 1990 to 15% in 1999 and 17% in 2001. But Singapore still lags significantly behind developed countries such as the United States and Japan (Amsden, Tschang & Goto 2001, p.64).

Singapore's qualification distribution for its total population is polarised at one end with a small elite of highly qualified persons and at the other end, a significant number of citizens at low qualification levels. However, for the 25–29 age cohort, the proportion with high-level qualifications has greatly increased. This highly polarised pattern is different to other countries. In the United Kingdom and the United States, the pattern is one of substantial high skills elites, a minority qualified at intermediate levels and a long tail of under-qualified. The pattern for Germany, Korea and Japan, on the other hand, is one of wide skills distribution with the majority at intermediate skills level, substantial skilled elites and a small tail of under-qualified (Brown, Green & Lauder 2001).

Singapore's approach to skill formation has been described as a 'Developmental High Skills Model' (Brown, Green & Lauder 2001, p.23). This refers to a highly educated bureaucracy but with a polarised skills distribution in the workforce as a whole. Technical skills and values are promoted by the government. The economy is strong in relation to infrastructure, location, pro-business environment, labour discipline and cost. However, it has been competitive mostly in medium technology production and service industries based on intermediate skills.

There are strong governmental attempts to make Singapore an educational hub in the region, both by expanding the activities of domestic universities and by attracting foreign educational institutions. The goal is to attract ten world-class educational institutions to set up branches in Singapore by the year 2008, primarily by offering various subsidies and financial incentives. Several prestigious United States universities have already located in Singapore, including Wharton, Chicago Business School, Johns Hopkins, and the Massachusetts Institute of Technology (MIT). The modes of entry vary substantially, but most institutes establish themselves in Singapore either on a small scale (Chicago) or in collaboration with a Singaporean counterpart (Wharton, Massachusetts Institute of Technology, Johns Hopkins) (Blomström, Kokko & Sjöholm 2002, p.43).

Post-secondary VET provision

Singapore has sought to upgrade its technical training substantially over the last two decades and has been successful in doing so. Singapore in 2002 graduated 72% of its young people with a post-secondary qualification. A fifth (20.3%) graduated from the National University of Singapore or the Nanyang Technological University. Over a third (35%) graduated from the polytechnics and 16.2% graduated from the Institute of Technical Education (Singapore Ministry of Education 2003).

The Nanyang Technological University (NTU) was initially established in 1981 but was reconstituted in 1991. As the Nanyang Technological Institute (NTI), it admitted its first batch of 582 engineering students in July 1982. Other courses followed: Accountancy (1987), Business, Computer Engineering (1989), Materials Engineering, Arts with Diploma in Education, Science with Diploma in Education (1991), Communication Studies (1993) and Biological Sciences (2002). In 1991, the Nanyang Technological Institute was renamed Nanyang Technological University, with the authority to award its own degrees. Degrees awarded by the Nanyang Technological University are recognised by the relevant professional institutions both locally and internationally.

> NTU aims at becoming a university with general academic excellence and niches of international eminence. Its mission is to train leaders, professionals and entrepreneurs for Singapore and the region and to advance research and development in both the academic and professional disciplines. (Nanyang Technological University 2004)

A key element of the engineering degree at Nanyang Technological University for 20 years has been the six-month industrial placement as part of the formal requirements for the degree. The industrial placement is offered mainly in semester 2 of the third year. A new focus in the placement from 2003 is to put more emphasis on achieving designated learning outcomes. These refer to a range of possible academic, professional, and personal outcomes (Ng & Loh-Goh 2003, pp.3–4). Each student during the first two weeks of the placement is to develop a work plan outlining specific self-directed learning objectives. Students are to be supervised by a site supervisor—preferably an engineer—and an academic supervisor. Assessment is through scrutiny of a logbook, an oral interview as well as a final report (Ng & Loh-Goh 2003, pp.5–7).

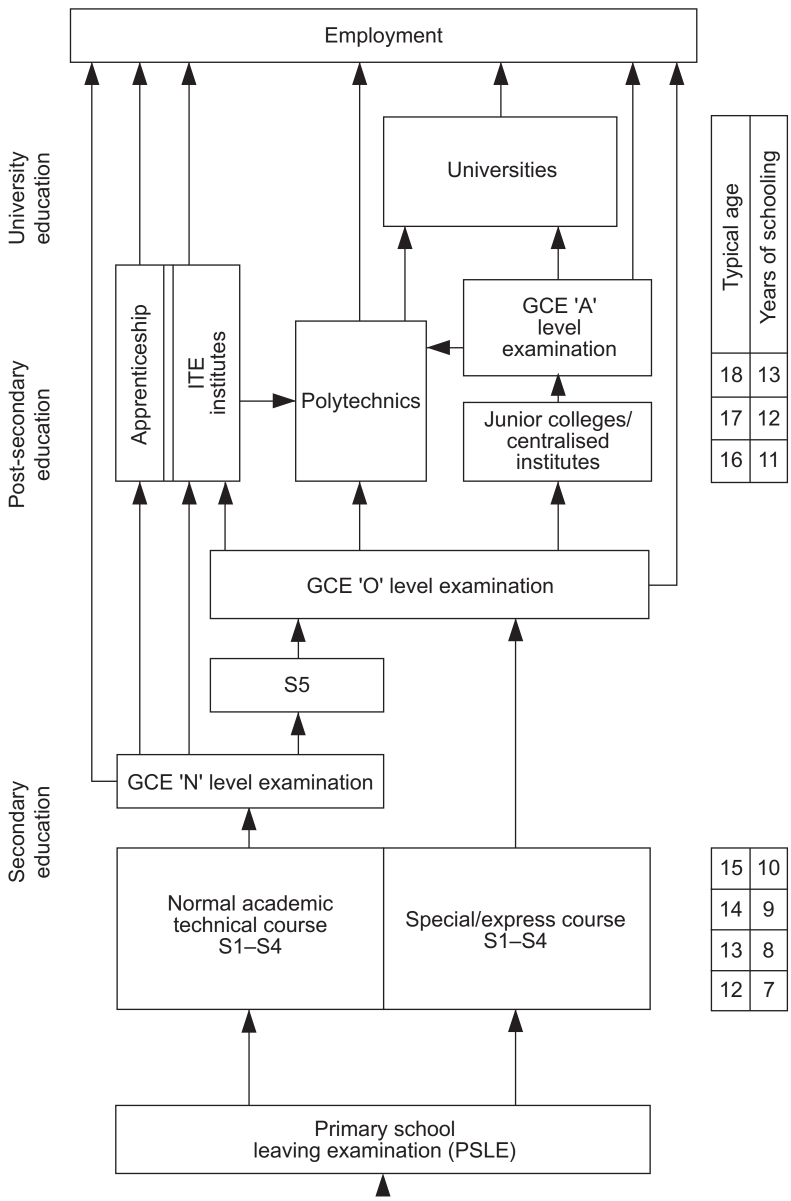
In order to respond better to the demands of a knowledge economy as distinct from an economy based on manufacturing, the Nanyang Technological University has changed its curriculum structure. The new structure reduces the number of core modules in favour of more cross-disciplinary studies. A feature of the new structures from mid 2003 is to encourage students to design their own course by allowing them to pursue more their own interests. New minor programs have been introduced in entrepreneurship, environmental management, education studies and communication studies.

Singapore has five polytechnics, established from the early 1990s. The polytechnics provide training for 'middle-level professionals to support the technological and economic development of Singapore'. Polytechnic graduates are said to be valued as 'practice-oriented and knowledgeable middle-level professionals, much sought after by industry' (<http://www.moe.gov.sg/corporate/post_secondary.htm#poly> viewed 25 November 2004). In 2002, there were 54 689 students studying at the five polytechnics, with 35% of the relevant age cohort graduating from a polytechnic (Singapore Ministry of Education 2003).

Another provider of vocational education and training is the Institute of Technical Education (ITE), established in 1991. The institute took over the role and functions of the Vocational and Industrial Training Board of Singapore and is therefore the national authority for the setting of skills standards and the certification of skills in Singapore. As a post-secondary technical institution, its primary role is to ensure that its graduates have the technical knowledge and skills that are relevant to industry. The institute in 2002 had 17 468 students with 16% of the relevant age cohort graduated from the Institute of Technical Education in 2002 (Singapore Ministry of Education 2003).

The secondary school system incorporates a technical stream to Year 10 level that prepares students for study at the Institute of Technical Education or for apprenticeships (see figure 1). The curriculum focuses on proficiency in English and mathematics. An option exists for students from this stream to continue on to tertiary study as well.

Figure 1: The secondary and post-secondary education system in Singapore



Source: Singapore Ministry of Education 2003

Areas for further policy development

Three particular areas related to the knowledge-based economy have been highlighted for greater policy emphasis. In relation to a national innovation system, greater linkages between different elements in the system are needed (Government of Singapore 2002, p.71). The government's Agency for Science, Technology and Research is fostering closer linkages between public sector research and development and industry clusters. It is also promoting the creation, ownership and exploitation of intellectual capital at its research institutes. Exploit Technologies Pty Ltd is a company set up to centrally manage and commercialise intellectual property created by the research institutes. Recent progress includes an increase in collaborative research and development projects with industry (Government of Singapore 2002, p.71).

It is also recognised that Singapore needs entrepreneurs to create new business models based on the new discoveries and to challenge existing firms to innovate. A government committee has proposed a comprehensive set of initiatives for nurturing entrepreneurship. These include allowing for greater creativity in the education system, attracting global entrepreneurial executives to Singapore as 'mentors', development of the venture capital market as well as making the legal environment more conducive for new start-ups (Government of Singapore 2002, p.71).

Also acknowledged is the need to further upgrade Singapore's workforce. Proposed initiatives include a three-tiered system of universities to provide a broader tertiary education base as well as cater to specialised niches. Also recommended is the setting up of a core of quality commercial schools for on-the-job upgrading. Attracting multinational corporations to set up regional training facilities in Singapore is an established strategy that is seen as encouraging a greater dissemination of organisational and technological knowledge (Government of Singapore 2002, p.71).

The future

As noted above, many companies, mostly in the manufacturing sector, have moved to lower cost countries such as China and Malaysia. The number of jobs lost in 2002 reached a 17-year high of 39 500. Some 81 500 Singaporeans were unemployed in December 2002, with some 10 000 of these being graduates (Ng & Loh-Goh 2003, p.12). Graduates are struggling to find jobs, even with degrees from reputable overseas universities.

Despite the government's efforts to develop and promote continual education and training of workers, the high unemployment rate is expected to persist. The duration of unemployment is also expected to lengthen. The median period of a worker being out of a job has more than doubled—from 5.3 weeks in 1992 to 13.9 weeks in 2002 (Ng & Loh-Goh 2003, p.12).

Another factor affecting the employment situation in Singapore is the move to hi-tech industries such as biomedical sciences. This means that job losses in traditional manufacturing industries far outstrips any employment gains at these new industries, leading to the so-called structural employment problem (Ng & Loh-Goh 2003, p.12).

Singapore will continue to be under pressure to make innovation work, not least because of the lack of alternatives to sustaining a high wage economy.

Appendix 3

List of interviewees on Australia's national innovation system and the implications for vocational education and training

Mr Neil Nyholm	Project manager	Industry TechLink	Carlton
Mr David Hanna	CEO	Innovation Economy Advisory Board State Government of Victoria	Melbourne
Mr Tim Sullivan	Manager, industry marketing	Dept of Innovation, Industry and Regional Development	Melbourne
Dr Ian Marsh	Research director	Committee for the Economic Development of Australia (CEDA)	Canberra
Mr Justin Hill	Manager, innovation awareness innovation strategy	Department of Industry Tourism and Resources	Canberra
Mr Matt Gredley	Innovation access	Department of Industry Tourism and Resources	Canberra
Ms Kath Billing & Donna Reid	Australian Network of Practice Firms	Canberra Institute of Technology	Canberra
Mr Warwick Howland	Project Officer, Centre for New Manufacturing	Swinburne University of Technology	Melbourne
Ms Tess Julian	Director	Ratio Pty Ltd <http://www.ratio.net.au/>	Sydney
Mr John Cawley	Manager, Centre for New Manufacturing	Swinburne University of Technology	Melbourne
Mr Mark Jacobs	Manager, innovation	Queensland Department of State Development and Innovation	Brisbane
Mr Ross Brodie	Manager, innovation awareness	Queensland Department of State Development and Innovation	Brisbane
Mr Greg Chalker	Industry Liaison Agent, precision engineering	Australian Manufacturing Technology Institute Ltd	Melbourne
Mr Michael Magelakis	Industry Liaison Officer, biotechnology	Australian Industry Group	Melbourne
Mr Tony Mellors	Industry Liaison Agent, general manufacturing	Victorian Chamber of Commerce and Industry	Melbourne

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