Dimensions of innovation: Some historical perspectives on vocational education and training and innovation in Australia – A discussion paper

Richard Pickersgill
Charles Sturt University

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Level 11, 33 King William Street, Adelaide SA 5000
PO Box 8288 Station Arcade, Adelaide SA 5000, Australia
ph +61 8 8230 8400, fax +61 8 8212 3436
email ncver@ncver.edu.au
<http://www.ncver.edu.au>

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Key messages

This discussion paper considers the development of a uniquely Australian system of innovation and its relation to the vocational education and training (VET) system. It asserts that the Australian system of innovation fits the pattern of incremental innovation and diffusion of technical knowledge.

- Creating knowledge is a *necessary* condition for innovation to occur; however, the creation of knowledge is not a *sufficient* condition for innovation to occur. In practice, innovation comes from complex interactions between many individuals, organisations and environmental factors rather than being a straight line from new knowledge to a new product. These complex interactions are the result of the particular historical experiences which shape individual national systems of innovation.
- The Australian system of innovation fits the pattern of gradual innovation and diffusion of technical knowledge. Most innovation occurs as a result of incremental changes to production processes or services. It is not primarily the result of radical new breakthroughs in basic science or technology.
- To respond to challenges of geography and climate, Australia depended on innovative local solutions to local problems. With the growth of an Australian-born population, the skills supplied by migration were increasingly supplemented by the skills developed by an emerging technical education system at semi-skilled, trade, certificate and diploma levels.
- A key characteristic of Australian developments in technical education and its relationship with industrial, agricultural and extractive industries that distinguishes Australia from Britain was the formative roles of the states. Industrial law, through apprenticeships and industry, rather than enterprise-based awards, provided a de facto national system of occupation-based definitions of formal skill.
- A skilled workforce is a key pathway by which diffusion of knowledge occurs and the development of the skilled workforce is, in general, the domain of the VET institutions in Australia.

Executive summary

This paper considers the development of a uniquely Australian system of innovation and its relation to the vocational education and training (VET) system from a different and more long-term historical perspective than that by which innovation has usually been discussed in contemporary Australian and international policy debates. It is argued that the basis for a unique Australian innovation system was laid down between the late nineteenth century and the period of post-Second World War reconstruction. Arrangements prior to the formation of the technical and further education (TAFE) system in the mid-1970s are therefore considered.

In practice, innovation comes from 'complex interactions between many individuals, organisations and environmental factors' rather than being a 'linear trajectory from new knowledge to new product' (European Commission 2001, 1.5). The Business Council of Australia recognised this in 1992 when it rejected as too 'narrow and misleading' the:

> … conventional wisdom … that innovation equals invention plus commercialisation … Innovation is not science. Nor is it technology or the ownership of invention.
>
> (Carnegie et al. 1993, p.3)

As the European Commission further notes: 'From this perspective the development of "human resources" is critical, first for the creation of new knowledge (primarily basic science) and second, for the diffusion of knowledge throughout society' (European Commission 2000, p.29). A skilled workforce is a key pathway by which diffusion occurs and the development of this skilled workforce is, in general, the domain of VET institutions.

The European settlement of Australia and the development of Australian society occurred as part of the eighteenth century period known as 'The Enlightenment', and with Australian society absorbing key political and social lessons from the American and French Revolutions. Early Australian society participated in the general European and North American practice of the nineteenth century of applying science to technology. Moreover, early Australian governors were often amateur scientists, and a network of philosophical and learned societies became part of the colonial social fabric from the 1830s onwards.

Imported steam engines were used as early as 1813. By 1836 they were not only being modified by resident craftsmen for new marine and industrial uses, but local manufacturing had also commenced. The small-scale but thriving local industrial activities, which developed to supply the small but dispersed local population and agricultural export industries, expanded with the demands of the gold rushes of the 1850s.

The expansion of capital-intensive agriculture and the growth of extractive industries in all colonies after the gold rushes increased the need for technically innovative solutions. Rather than a derivative colonial science and technology, it is more accurate to see Australian developments in the nineteenth and twentieth centuries as part of a dynamic process occurring *within* mainstream western science and technology. In other words, innovation and technological development were *absorbed*, and lessons *adapted* within the constraints of a limited population and markets in colonial and federated Australia; they did not have to be *adopted* from 'outside'.

The development of Australian technical education from the 1880s (although constrained by a small population, and fragmented labour, product and capital markets) reflected the fact that the colonies, and later the Commonwealth, were part of a common process in western societies. The libraries of the various colonial learned societies (in particular, their technical journals), the schools of arts and the mechanics institutes reflect knowledge and engagement with the latest scientific and technological developments in Britain and North America. Of particular interest is colonial knowledge of developments on the continent, where science and technology were being applied to the new chemical and biology-based industries. Australian colonies were active in participating in the various international exhibitions in the latter part of the nineteenth century, as well as promoting them in Sydney and Melbourne.

A key characteristic of Australian developments in technical education and the development of industrial and agricultural infrastructure that distinguishes Australia from Britain was the formative role of the state. The state invested heavily in essential capital infrastructure, and in the training of the skilled operatives who built it. In addition, industrial law, through apprenticeships and industry-based awards, provided a de facto national system of occupation-based definitions of formal skill. As a result, Australian practice in technical education tended to resemble processes on the continent (as a result of state intervention or encouragement, such as that in Bismarckian Germany), rather more than it did the locally based education system of the British metropolis. Britain in fact only began to approach a national system of technical training in the 1970s with the passage of the *Manpower Services Act*. In Australia, although the states delivered the technical training (compulsory in the case of most apprenticeships), the broad standards were set in legally binding federal industrial awards which were mirrored at the state level, with specific skills determined by the need for skill recognition within regionally dispersed occupational labour markets.

From the early years of Federation the technical education system in all states reflected this legally supported occupational structure. In a sense, the formal adoption of a national training system in the late 1990s was an outcome of over a hundred years of informal practice. The associated shift from state to federal influence and control in VET reflects similar changes to federal–state relations in other areas, which followed as a direct result of state transfer to the Commonwealth of a range of taxation measures during the Second World War.

Australia's colonial heritage, its reliance on resource development, and its dependence on and integration with the world economy make it an interesting case study of emerging globalisation. To respond to challenges of geography and climate, Australia depended on innovative local solutions to local problems and relied on the development and diffusion of skills provided by the technical education system at semi-skilled, trade, certificate and diploma levels, complemented by a program of planned skilled migration.

The Australian system of innovation fits the pattern of incremental innovation and diffusion of technical knowledge. Historically, from colonial times to the advent of the present national system, the technical education and training institutions, for all their historically specific characteristics, industry critics and state differences, have functioned to support this process.

Dimensions of innovation: Some historical perspectives on VET and innovation in Australia

Introduction

The purpose of this paper is to contribute to the discussion of the dimensions of innovation in Australia, particularly the role of technical and vocational education in Australian innovation. It considers the development of the unique Australian system of innovation, and its relation to the current vocational education and training (VET) system. The perspective adopted is more long-term and historical than has usually been the case in contemporary Australian debates. Contemporary discussion, particularly since the release of the Australian Government's paper, *Backing Australia's ability* (2001), has tended to focus on technological innovations, and in particular, on the relationship between basic science and its application to innovation. Discussion has tended to assume that relationships are direct and linear. This can be seen for example in discussions which measure innovation through surveys of capital or investment intensity, such as international league scales of research and development (for example, Dawkins 2001). These measures generally reflect standardised international approaches to data collection typified by the Organisation of Economic Co-operation and Development's *Frascati manual* (OECD 2002a). While not denying that there is a necessary link, this paper suggests that the relationship is more complex, a fact acknowledged by the Organisation of Economic Co-operation and Development (OECD) in the more recent Oslo data collection measures (OECD 2002b), which have reintroduced more holistic concepts of human resources development. The traditional human resource aspects of innovation and development theories which were integral to the Keynesian post-war programs until the Organization of the Petroleum Exporting Countries (OPEC) oil crisis of the 1970s (see Kelly 2000) have again become more prominent in the most recent European Union discussions (European Commission 2000, 2001). These matters are briefly considered in recent research funded by the National Centre for Vocational Education Research (NCVER) (Toner et al. 2004), although the technical data collection methodologies and criteria, the assumptions that underpin them and the caveats to consider have been canvassed in more detail by the Australian Bureau of Statistics (ABS 2002).

In general, this paper suggests that these more recent measures and yardsticks encompass a broader understanding of the nature of innovation, and of the inputs required. In practice, innovation comes from 'complex interactions between many individuals, organisations and environmental factors' rather than a 'linear trajectory from new knowledge to new product' (European Commission 2001, 1.5). 'From this perspective the development of "human resources" is critical, first for the creation of new knowledge (primarily basic science) and second for the diffusion of knowledge throughout society' (European Commission 2000, p.29).

This approach is particularly relevant to the development of small, but industrially sophisticated economies such as Australia. As the Business Council of Australia remarked in the early 1990s, most innovation, particularly in Australian industry, is incremental and process-oriented rather than measured by the appearance of new, radically different products. The Business Council of Australia at that time therefore rejected as too 'narrow and misleading' the:

> … conventional wisdom … that innovation equals invention plus commercialisation … Innovation is not science. Nor is it technology or the ownership of invention.
>
> (Carnegie et al. 1993, p.3)

The development of this skilled workforce is, in general, the domain of VET institutions. Historically in Australia the role of state-funded VET institutions in the form of technical colleges, technical and agricultural institutes and, from 1975, a national technical and further education (TAFE) system, played a crucial role in the development of a skilled and adaptive workforce.

Theories of development and the Australian experience

Whereas recent debate has tended to focus on the technological and scientific aspects of innovation, longer-term theoretical perspectives have attempted to situate innovation within the broader transition to mercantile and capitalist economies around the North Atlantic from around the fifteenth century.

Classical examples of large-scale historical description and analysis include Marxian class analyses of the transition from feudal to capitalist modes of production, and Wallerstein's (1974, 1980) discussion of the origins of an essentially capitalist economy in the crises in agriculture in late feudal period. Another example is Polanyi's *The great transformation* (1975) which detailed the institutional supports and development of self-regulating market economies, defined as the 'innovation which gave rise to a specific civilization' (p. 3) in the context of a broader analysis (written as a refugee from 1930s central European fascism) of the collapse of nineteenth-century certainty and the major political and social changes of the twentieth century. Other historically based explanations for innovative transformation of the modern world include Joseph Schumpeter's (1934) early description of entrepreneurial activity and the dynamic 'creative destruction' of markets and later investigation of the impact of large-scale research and development activity (Schumpeter 1942) in large firms, and 'linear stages' of development, of whom Gerschenkron (1962) is the most prominent. Rostow's *Stages of economic growth* (1971) significantly subtitled *as a non-communist manifesto,* posited four stages—'preconditions', 'take-off', and 'drive to maturity', leading to the contemporary developed world as 'the age of mass consumption'—as essential sequences of development. This process was supported by Newtonian science and subsequent derivative technology. Rostow speculated further on what we would now term a post-industrial society, although the development debate that the book provoked was little concerned with this aspect of his work. Significantly, all these authors did most of their original research and writing prior to the Second World War. Post-war discussions tended to occur in the context of the break-up of the colonial empires and be directed by questions of how best to assist development in the emergent Third World economies.

The development of the Third World, or in more contemporary terms, the 'newly emerging industrial economies' has a rather different history from that of industrial societies. It is concerned with issues of ownership of technology, information, and the transfer of institutions from advanced industrial societies to nation states with existing and developed political structures, although these political arrangements did not necessarily reflect the capital security, the education and training infrastructure or legal frameworks generally considered necessary to support capitalist agricultural and industrial expansion. This was the focus of intense debates in the post-war period about the causes of and solutions to 'under/overdevelopment' and the 'North–South divide'. The approach to development followed by a range of post-war United Nations development commissions and commentators from the early 1950s through to the late 1970s (for example, Sir Arthur Lewis, Harbison Myers, Gunnar Hrydal, the Pearson and Brandt Commissions) reflected predominantly 'institutionalist' or 'substantivist' assumptions (Polyani 1975). The period has been concisely summarised from a sociological–historical perspective by Goldthorpe (1996).

These particular post-war activities and general questions of ongoing and sustainable development were linked by their macro-level approach to sectoral development and a broad conception of human resource development (HRD) as a holistic and socially situated process. These macro-level explanations have, to a considerable extent, been replaced in the last decades of the twentieth with a more micro-, firm-level understanding of human resource development (Kelly 1992). Alfred Chandler's influential (1977) *The visible hand* certainly located major and revolutionary changes in

United States industry in the nineteenth and twentieth centuries in new and innovative approaches of management inside large bureaucratically organised firms, but the perspective was broadly historical and the identified transformations economy-wide. Theories of development and innovation which remain situated at the level of the firm, for example, most contemporary managerial approaches to human resource development which emphasise firm-level skill and development needs over economy wide industry and occupational development have, from the perspective of this paper, little explanatory power, and provide little guidance for policy.

The basic argument of this paper is that Australian economic and industrial development occurred as an integral part of the general western expansion of science and technology. Whatever the reasons for the take-off of science and technology in Western Europe following the social and scientific advances of the early modern period, Australia was colonised as part of this process of capitalist expansion, and as such, Australian development does not require a separate theoretical explanation. Australian innovation and development occurred within the scientific and social changes of European societies from the end of the eighteenth century, when European settlements were established through to the present day. What is typical of development in Australia is the way local technological adjustments were developed to local industry and agriculture in response to particular constraints of climate, raw materials and a relatively small population. This development occurred within a common European scientific and technological culture. This was applied to new physical conditions; it did not have to be adopted from outside. A European colony of settlement was primarily a European society; it was not the Empire of India or French Indo-China.

It is easily forgotten that the population of Australia at the beginning of the twentieth century was only just over three million. At the beginning of the First World War it was only around four million, of whom 60 000 prime-age males died or were incapacitated between 1914 and 1918. To put this in perspective, the population of the continent at the beginning of the twentieth century, when the political, legal, social and technological institutions that still underpin twenty-first century Australia were either already existent or were, like Federation, in the process of finalisation, was significantly less than that of greater Sydney or Melbourne today. In a very real sense, after the first couple of decades of European settlement, Australia has always been a ‘modern’ state, albeit sparsely populated and economically dependent on metropolitan and North American trade links.

Implication for skill development

No detailed knowledge of development theory is required to notice obvious implications for domestic capital formation, transport costs and the limits of local demand for products and services. Recalling Adam Smith’s dictum that the division of labour is limited by the extent of the market suggests that there would be a demand for general occupation-based and transferable skills rather than narrow job-specific skills. In other words, skill formation in Australia would be directed towards occupational labour markets rather than the internal labour markets in single large firms typical of European, and particularly North American experience.

General theories of innovation and development have all been written from the centre, and often from a nationally based perspective of industrial development—from Adam Smith in discussions of eighteenth-century mercantilism; Marx’s combination of technological and social forces; Schumpeter’s creative destruction and entrepreneurship (and later large-scale research and development centres in major firms (for example, Schumpeter 1934; cf. 1942); Gerschenkron’s 1962 linear stages; Rostow’s (1971) ‘non-marxist manifesto’ of sequential development stages; and Chandler’s (1977) managerial revolution in large North American firms. In general, there has also been a focus on the most visible aspect of developing industrial society—large-scale industries—and the theories have reflected those national experiences.

That there is a correlation between economic development and the expansion of science and technology and innovation seems clear, even if the particular processes are debateable. This suggests that general theories of innovation and development should not be applied uncritically to Australia at the national level. If Australian development is seen as part of a broader expansion of technologically sophisticated capitalist economies, with specific developments constrained by particular local characteristics, questions of innovation and development are best explained empirically, rather than theoretically. Insofar as historical experience can provide a guide to future policy, the lesson is that policy development, although informed by theory, needs to be based on the actual empirical situation. An appreciation of what is in fact the present case, rather than what we might think ought to be the case, is a necessary if not sufficient base for policy.

Before Kangan: The foundation of VET

This discussion therefore considers arrangements prior to the formation of the TAFE system in the mid-1970s. There are two main reasons for this. The first and most important is that, as this discussion argues, the unique structural and institutional developments which formed (and continue to form) the basis of the Australian national innovation system occurred between the late colonial and post-war reconstruction periods. Fundamentally, this involved the adaptation of western science and technology into a developing economy characterised by low population, dispersion of natural resources, and limited internal product and capital markets. In response, sophisticated patterns of import substitution and industrial production were developed to support the agricultural and extractive export industries. The small internal market meant that production runs were small, and economies of scale limited and local capital formation constrained. This was countered by direct capital investments of the colonial states in major capital infrastructure, often also substituting for private investment in productive enterprise, what Butlin (1962) termed 'colonial socialism'. This gave subsequent Australian Governments a far more direct and active role in Australian economic development than was the case in Britain.

In education and technical training, this process continued after Federation, primarily at state level. Private investments in education and training have been minimal in Australia, at least until the last quarter of the twentieth century, while federal government involvement in technical education commenced as part of the war economy, only becoming significant in technical education (unlike universities and schools) from the mid-1980s.

The second, and pragmatic reason for the focus on this period is that the institutional history and formation of a national TAFE system, and its subsequent development have been very well analysed in Gillian Goozee's (2001) *Development of TAFE in Australia*. Furthermore, conventional discussions of innovation in the contemporary national context are well served by a range of NCVER (for example, Ferrier, Trood & Whittingham 2003) and other publications (for example, Marceau & Manley 2001). A critique of some of the policy assumptions in relation to VET is found in Pickersgill and Walsh (2003).

In general, the current explicit linkage of 'innovation' with future economic prosperity can be interpreted, in short-term perspective, as a continuation in public policy statements of the 1980s about perceived lack of competitiveness of Australian industry in the face of globalisation of product markets. The thrust of this paper is that a longer-term perspective can be equally valuable.

Australia and the 'low skills' debate

The idea that Australia was a 'low skills economy' gained credibility in the award-restructuring period of the 1980s, most explicitly in the publication, *Australia reconstructed* (Australian Council of Trade Unions–Trade Development Committee 1987). This view has underpinned much of public policy in vocational education and training since. The view was derived from contemporary European OECD, International Labour Organisation and United Nations Educational, Scientific and Cultural Organisation publications reflecting 'productivist' debates following the OPEC oil crisis. These discussed the different trajectories that economies might take towards a 'high skill' future characterised by investments in training or to the stagnation of 'low skill equilibria' predicted for the United Kingdom by industrial relations critics (Keep & Mayhew 1999; Pickersgill 2001a, 2001b). This debate provided the rationale for award restructuring, skill-based career paths and for the negotiations between the state governments and the Commonwealth Government which led to the national training system with the establishment of the Australian National Training Authority (ANTA). A comprehensive national system was, however, really only practically implemented with, from 1997, the widespread availability of training packages. Even here the new national system has only had major impact at intermediate skill levels.

However, concerns about 'skill', and its relationship to production are by no means a recent phenomenon. In 1987, following the overseas mission to investigate skill formation practices in Europe, the report, *Australia reconstructed,* expressed this relationship when it stated that:

> Evidence suggests that Australia is not producing the right skills as well as not producing enough skilled people. This evidence includes:
>
> - the sharp decline in, and very low levels of, exports of technology based product
> - the failure to develop commercially a number of products discovered or developed domestically
> - the persistent shortages of higher-level and specialist skills in engineering, science and computing, and
> - the narrow focus of the skills acquired by many Australian workers.
>
> (Australian Council of Trade Unions–Trade Development Committee 1987, p.xiii)

The issues raised here, particularly the first three points, prefigure those of the current 'innovation' debate. However, a report resulting from a much earlier overseas mission similarly noted industry needs and solutions.

> What is really required is, (a) definite recognition of the economic value of a sound system of technical education …
>
> … In Europe technical schools were founded *in anticipation* of requirements, and have practically been the means of creating industries. Here the method is *to wait for a demand,* for some special form of instruction, and then to provide it imperfectly.
>
> … One cannot study the Technical Schools of Germany … and fail to recognise that there is a belief in the national value of all forms of education that is if not wholly wanting in us, is at least sadly deficient in comparison.
>
> … Germany's provision for higher, *technical,* secondary and primary education expresses, in a vivid and practical way her belief that expenditure on the education of a people pays, and is the necessary foundation for great national success …
>
> (New South Wales Government 1905, pp.19, 186–7; emphasis in original)

Similar reports, frequently with similar findings, have been common. In 1879 Arthur Liversage, as New South Wales representative at the Paris Exhibition, had reported back to parliament on the need to develop a technical education system. While the 1903–04 New South Wales Commissioners were writing their extensive report (noted above), similar processes were in train in Victoria (Cobb 2000; Rushbrook 1995). During the 1930s state education departments participated in educational research funded by the United States Carnegie Institute in the 1930s, while after the Second World War, a 1947 New South Wales report on engineering certificates delivered by Sydney Technical College, commissioned as part of the establishment of the proposed Institute of Technology (now the University of New South Wales) found that the Australian certificates were equivalent to degrees offered at Edinburgh, London and the Massachusetts Institute of Technology. The Commonwealth Government also became involved in this period, primarily through expansion of the university sector under the Menzies Government (for example, Murray Commission of 1957) but significantly in relation to skill development and recognition in the 1969 Tregillis report (Department of Labour and National Service 1970).

Much of the contemporary debate over the importance of innovation tends to be subsumed by reaction to recent developments following from the Australian Government report, *Backing Australia's ability* (2001), and it is easy to forget that, during the 1970s and through the 1980s, a range of reports and initiatives abounded which were specifically intended to improve 'innovation' (see overviews in Birch & Rystrand 1988; Australian Academy of Technological Sciences and Engineering 1988; Australian Science, Technology and Engineering Council, 1979; Carnegie et al. 1993). Contemporary state technical education systems responded to these initiatives; the proposal for a new national TAFE system (which was also to incorporate a broader adult and further education role) was also a response to these developments (Australian Committee on Technical and Further Education 1974).

Thus, early reports and policy proposals, while not always explicitly justifying expansion of technical education and training in terms of innovation, invariably justified expansion in terms of supporting technological development, both in what was considered to be immediately required, and also importantly, what were perceived to be future requirements. In the technical education sector these needs were pragmatically identified as skilled workers appropriate to the needs of Australian industry. The training in broad occupation-based skills reflected the type of innovation which characterised the innovation needs and practice of Australian industry, which was accurately summarised by the Business Council of Australia as primarily involving 'process' rather than radical product innovation (Carnegie et al. 1993, introduction)

In addition to skill formation narrowly understood, the technical education system contributed substantially to another fundamental and underlying basis of national innovation systems, that is, a general and non-content-specific increase in general education, stable social structures and technological 'literacy'. From the late colonial period through to the 1960s, the technical education system, not colleges of advanced education or the universities, was the road to formal skill enhancement and opportunity for the majority of the population. For most of the last one hundred years, the technical education system, whether it took the form of technical colleges or technical schools, was the first choice for further education for both young people entering skilled occupations, and for adults extending their educational or skills base.

Australia and the world

A common view of recent history portrays Australia as a derivative society which, on the strength of agricultural and mineral exports in the nineteenth century, rode to early prosperity 'on the sheep's back' supported by a system of national protection and imperial preference. The result was that major adjustments were necessary from the mid-1980s to enable Australian industry to meet the challenges of globalisation and international competition. To respond to the challenges of more open product markets, a range of structural reforms was seen as necessary to free up the labour market and to increase the stock of skills in the population. From these challenges the national training system was developed. While there is some truth in the rationales of this broad sketch of received opinion, this understanding misses critical aspects of Australian development.

The European settlement of Australia and the development of Australian society occurred after the eighteenth century 'Enlightenment', and absorbed key political and social lessons from the American and French Revolutions, and participated in the general increase in the application of science to technology of the European and North American nineteenth century. Rather than a derivative colonial science and technology, it is more accurate to see Australian developments in the nineteenth and twentieth centuries as part of a dynamic process occurring within mainstream western science and technology. In other words, innovation and technological development were absorbed and lessons *adapted* within the constraints of limited population and markets in colonial and federated Australia; but they did not have to be *adopted* from 'outside'. This is a fundamentally different process from technology transfer and diffusion, terms applied to innovation and development in the Third World and the newly industrialising economies.

In her discussion of the development and application of science and technology in Australia, Ann Moyal has persuasively argued that the majority of the early inventors were trained in Britain, and that, as a result, in the early Australian colonies:

> … there was little official impulse for the training of that important army that T.H. Huxley had called 'the foot soldiers of Science'. The 1880's saw the beginning of educational change.
>
> (Moyal 1986, p.171)

While broadly true, this statement does need some qualification. Mechanics institutes and schools of arts had developed extensively from the 1840s (Goozee 2001, esp. chapter 2; Cobb 1983, 2000) rising to around a thousand by the 1890s. These did form the 'organisational core' (Todd 1995, p.29) of later formal technical education, particularly in Victoria (Murray-Smith 1987). Moyal's point however raises two issues, which are easy to gloss over.

The characteristics of the small colonial population, around three million at that time, depended largely on the characteristics of its migrants. For most of Australian history this has involved an excess of skilled and semi-skilled over unskilled migrants (see table 1). Although, by the late nineteenth century, the numbers of Australian-born were greater than those born overseas, it was not until the first decade of the twentieth century that this cohort reached maturity and assumed political, social and commercial predominance. Imported skills were therefore crucial.

A second point involves the nature of the science and technology applied to agricultural and industrial production. As noted earlier, Australia was settled in the first phase of the Industrial Revolution when mechanical and civil engineering was the focus of industrial development, and Britain and steam power reigned supreme. This was the province of the 'artisan engineer' rather than the research scientist. Informal and tacit skills and knowledge embedded in individuals and located in artisan practice, rather than resulting from formal research and development, underpinned technological change. It wasn't really until the development of the new chemical and biological industries on the continent, particularly in Germany, in the late nineteenth century that basic and applied science became prominent in industrial production and Britain was challenged for industrial supremacy. The educational developments in Australia of technical education in the 1880s (although constrained by a small population, and fragmented labour, product and capital markets) indicated that the colonies, and later the Commonwealth, were part of a common process in western societies. In fact, Australian practice tended to resemble that occurring on the continent (as a result of state intervention or encouragement, such as that in Bismarckian Germany) rather more than it did the locally based education system of the British metropolis.

The distinctive nature of the Australian experience, compared with that of Britain, can also be disguised by the use of common terms. For example, in the context of a discussion about the historical role of apprenticeship, Goozee cites Hermann et al. on the general point that:

> … in Australia further education systems and their legal and educational arrangements, not surprisingly have tended to replicate their British counterparts.
>
> (Hermann et al. 1976, p.27 cited in Goozee 2001, p.11)

Again, this is superficially accurate. A similarity in occupational titles and a common legal framework provide many examples of apparently similar practice. Yet this view also misses significant adaptations to and developments in response to local conditions.

It is true, for example, that apprenticeships followed the British occupational pattern. However, in the early twentieth century the apprenticeship system was institutionalised within the unique Australian (and New Zealand) system of industrial awards in a form quite different from that in Britain. The closest the Britain came to a national system of training was following the *Manpower Services Act* of 1967. However, in Australia evening apprentice training had been included in awards in the first decade of the twentieth century, and from the 1920s most states included mandatory day release for indentured apprentices. This compulsory system of off-the-job training, unknown in the United Kingdom, provided an impetus for the ongoing development of technical college systems in the various states and formalised broad-based occupational classifications that developed around the needs of the small size, and hence low production runs of most private Australian firms (for example, Gospel 1994). In a similar fashion, the extension of transport, utilities and civil infrastructure required in the late nineteenth century through to the First World War produced a demand for technician and diploma-level personnel, a demand that the small and exclusive universities could not satisfy, but which the major technical colleges of Sydney and Melbourne and the School of Mines and Industry in Adelaide had been established to accommodate. Again, unlike Britain, but more in line with German experience, all these processes were either underwritten or coordinated by the state.

Australian industrial development and technical education: From colonies to federation

The most recent Australian debates have, to a great extent, mirrored overseas discussions, particularly those emanating from the OECD and the International Labour Organisation. Dating from the early 1990s a series of reports and programs had been initiated in the context of perceived threats from Japan and the newly industrialising economies to traditional European pre-eminence in basic science and technology. The recent emphasis on 'innovation' in Australian discussions from the late 1990s have been summarised in the Commonwealth Government's five-year action plan *Backing Australia's ability*. This stated that:

> … innovation-developing skills, generating new ideas through research, and turning them into commercial success is key to Australia's future prosperity.
>
> (Commonwealth of Australia 2001, p.7)

It is noticeable that the emphasis in *Backing Australia's ability* is on an interpretation of the innovation process as primarily involving radical innovation, based on research and development programs in the pure and applied sciences. In general the plan reflects a fairly conventional (for example, see Schumpeter 1911; cf. 1942) view of the relationship between basic science and technology and the development and marketing of innovative products and services. That is, it assumes national economic progress and competitiveness to be (largely) dependent on new technology developed from basic science in order to create innovative products or processes. This general view implies significant research and development investment by both the public and private sectors, and assumes the existence of extensive educational, scientific and technological institutional arrangements and linkages to underpin research and development investment (Pickersgill & Walsh 2003).

However, as a number of commentators from the VET sector have noted, the government's action plan has little to say about the potential contributions of VET, nor the role that VET currently plays in developing skills in the workforce and the broader community. As Fitzgerald (2001) has stated, VET is 'the key unfinished business in the federal government's series of Innovation policies'. In many ways it also misses a number of unique factors that contribute to the Australian national innovation system.

Colonial science and technology

In the Australian colonial context, the application of this mechanical and civil engineering technology was therefore rarely dependent on the importation of technological artefacts. In shipbuilding for example, all the necessary skills were available amongst the shipwrights of the First and Second Fleets, and many of the natural materials such as timber were at hand. Later migration provided more a quantitative rather than qualitative increase in the skills base. Early limits to the permitted tonnage of locally built vessels were imposed by an East India Company monopoly. Since the limits were not an indication of a lack of local skills and knowledge of shipbuilding in Australia, they were soon abolished. In 1813 a skilled artisan had to be brought to the colony to assemble the first imported steam engine. By 1836 steam engines were being built in Sydney for both manufacturing and marine use and imported engines modified locally for new applications. The latest metallurgical principles were applied in the earliest examples of smelting copper and iron in the 1840s and applied in the development of locally produced agricultural equipment, including the cogs and gears for wind, water, animal and later steam-powered grain mills (Linge 1979, pp.24–46; Birmingham & Jeans 1983).

By the end of the gold rushes of the 1850s a pattern of broad dry land agriculture had been firmly established. Various colonial land acts passed in the 1860s certainly involved political conflict between class and regional interests, but they also reflected the reality that early imperial visions of small-scale farming communities based on an idealised European model were not viable in Australian conditions. Capital-intensive, not labour-intensive pastoral and agricultural practices developed under the constraints of soil and climate. The agricultural expansion in wool, grain and animal products and later sugar, provided regional markets for a range of agricultural machinery that was substantially supplied by local, frequently regional manufacturers. As Butlin (1962) has shown, manufacturing was increasingly important in local capital formation as the century progressed. This expansion of industry also facilitated, through a highly mobile labour force, the diffusion throughout the colonies of what were frequently informally acquired skills.

The distillation of spirits and the growth of the brewing industry also produced a small group of artisans experienced in what we would now describe as industrial chemistry. Small-scale and 'low tech' from our perspective, brewing became a significant industrial activity. Lack of refrigeration, and the vagaries of inland transport spread this technology to regional centres. While brewing, fermenting and forms of distillation used in the preparation of alcohol raise images of the early rum trade, it should not be forgotten that it was from these processes that major breakthroughs in the understanding of bacterial processes were being made in Europe by, amongst others, Pasteur in France and Koch in Germany. At the turn of the century it was the application of this brewing technology, combined with industrial chemistry, metallurgy and the skills of a locally trained carpenter EJ Lyster that led to the development of the Potter–Delprat floatation process for metal extraction at Broken Hill, later adopted worldwide (Cull 1993; Blainey 1971, 1993).

Fermentation and the practical and theoretical knowledge and skills involved were further developed within the technical colleges, institutes and medical schools of the universities. They provided a technical base for a range of biological production techniques, notably in animal vaccination, so that, in the nineteenth century, an Australian anthrax vaccine developed at Narrandera in rural New South Wales was demonstrably more effective than one produced by the Pasteur Institute (Todd 1995). By the early twentieth century the new Commonwealth Serum Laboratories (Brogan 1990) could draw on both good scientists and adaptable technicians.

Cultural underpinnings

A printing press arrived with the First Fleet and the first issue of the official *Sydney Gazette* in 1804 contained an article on the prospects of viticulture, translated from the French for the occasion. Plantings in the Hunter followed shortly afterwards. The first learned society in the colony was the Philosophical Society of Australasia, established in 1821, which in 1866 became the Royal Society of New South Wales. Each new colony, whether it separated from the original colony of New South Wales like Tasmania (1825), Victoria (1851) and Queensland (1859), or was settled separately like South Australia (1836) or Western Australia (1831), developed similar societies or clubs. These societies, whose journals provided wide coverage of international developments in the natural sciences and technology, as well as detailed reports of colonial investigations, provided a focus for colonial debates on education and training.

The politically well-connected members of these societies formed a network connecting the older mechanics institutes, schools of arts, new universities and emerging technical colleges and agricultural institutes. The geologist Archibald Liversage, for example, who was Secretary to the New South Wales Royal Society for ten years, promoted the study of geology and mineralogy in schools. As a professor at the University of Sydney, and through his 1879 report on technical education undertaken while acting as the New South Wales representative at the Paris International Exhibition, he was instrumental in setting up formal technical education at Sydney Technical College and the associated New South Wales Museum of Technology. The establishment of the

Melbourne Workingman's College in 1887 (now the Royal Melbourne Institute of Technology University [Murray-Smith & Dare 1987]) and the South Australian School of Mines and Industry (the educator of BHP's Essington Lewis), and now the site of the University of South Australia, involved similar social networks linking prominent individuals and families (such as the Ormonds and Bonythons) with government and industry to develop technical education.

A slice through scientific publications in two symbolic years in Australian history, 1888 and 1901, shows that colonial society was abreast of international developments. The presidential address in the 1888 centenary edition of the *Journal of the Royal Society of New South Wales* was explicit in drawing readers' attention to local and international, scientific and technological developments and their potential application to industrial expansion. Also significant were the ten pages that noted recent additions to the society's library. These consisted of papers and journals from Britain, France, Germany, Italy and the United States. A similar involvement with the international scene is apparent in other colonial societies' proceedings. The mixture of reviews of the natural and applied sciences and advocacy of systematic technical and scientific education to be funded by the colonial state continued the theme that the New South Wales society's secretary, Archibald Liversage had pushed over ten years earlier when he had been instrumental in setting up the New South Wales Technical Education Board.

The colonial situation contrasted with that of the metropolis. In the previous year (1887) TH Huxley had argued in the British journal *Nature* for the extension of technical training in Manchester. Like many others, he was influenced by the coordinated approaches to technical education and training developing on the continent. However, in the United Kingdom, local administrations continued to set the standards in both school and technical education, unlike the systems on the continent or, from a far smaller population base, those in the Australian colonies. Indeed, the United Kingdom had to wait until the 1960s for the Manpower Services Commission 'before attaining the nearest thing to a national system the country had known' (Gospel 1994).

The contrast between the United Kingdom and the Australian colonial experience can be illustrated at another important symbolic date—Federation in 1901. In its January 1901 issue the scientific journal *Nature* expressed grave concern about the case of Regina v. Cockerton. This case, extensively covered, appealed against an action of a London school board which had disallowed expenditure for materials and equipment for the teaching of art and science. Deploring the ad hoc decisions of local administrations and in the hope that the matter would proceed to appeal to the Privy Council, the editors of *Nature* concluded:

> But whatever may be the present state of the law, one thing the case makes transparently clear, and that is the chaotic state of English education. (*Nature* 1901, vol.63, p.242)

The editors of *Nature* were to be disappointed. In contrast, by the end of the colonial period, the state of Australian technical education may be described as underfunded, but not chaotic. While there were differences amongst the colonies, these were fewer than the similarities.

Colonial divergence

The Australian colonies had established free and secular education, at least to primary level by the 1880s. Universities had been established in Sydney (1850), Melbourne (1853), South Australia (1874), Tasmania (1890), and in the early twentieth century in Queensland (1909) and Western Australia (1910). Notwithstanding their sandstone buildings and architectural references, these universities were modelled not on Oxford or Cambridge, but on the new University of London, which like continental Europe, and in particular Germany, emphasised the study of the natural and applied sciences and technology. Chairs were established in the basic sciences and medicine, which became the focus for research on human health at Melbourne, and animal husbandry and disease prevention at Sydney. An early graduate in engineering at Melbourne University in 1866 was WC Kernot who became the first Australian-born professor of engineering in 1883 (Moyal 1986). Although primarily focused on undergraduate teaching until after the Second World War, doctoral candidates were accepted in science at Melbourne as early as 1887.

At the close of the nineteenth century, colonial states supported the extension of free, secular and compulsory education to the primary level, and the extension of technical colleges and institutes beyond the capital cities and into strategic regional areas. Unlike Britain (and the United States) where education remained primarily a responsibility of local or municipal authorities, the emerging Australian system was at all levels, from primary school to university, distinguished by its reliance on direct financial and administrative support from the state.

Goozee notes the received view that there has not been much research or writing about the development of technical education compared with the school sector, and cites Hermann et. al to the effect that imperial connections were reflected in local institutions with Australian practices tending to replicate their British counterparts (Hermann et al. 1976 cited in Goozee 2001, p.11). Implicit in this view is that 'replication' involves a time lapse. While this view contains elements of truth, it is by no means a complete picture. As noted above, free, secular and universal primary education had been established early in Australia, primarily due to the powerful role played by the secular state. However, secondary education lagged and was almost exclusively the domain of the private church schools until the early twentieth century.

However, this was balanced in part by the major growth of technical education colleges and institutes in all of the colonies. Primarily through part-time evening courses, these substituted for a secondary technical system. Schools of agriculture were established at Roseworthy (South Australia) in 1884, Dookie (Victoria) in 1885, Hawkesbury (New South Wales) in 1888 and Gatton (Queensland) in 1898. The first institutes and schools of mines were established in Ballarat (Victoria) in 1870, Bendigo (Victoria) in 1873, Gawler (South Australia) in 1888 and Zeehan (Tasmania) in 1893. Thus, while technical education within the school system had to wait until the expansion of state secondary education in the twentieth century, a strong network of state-funded technical training institutions, providing large components of what we would now term VET, was in existence by the close of the colonial system.

There were significant differences between the colonies, and post-Federation states. As historian Stephen Murray-Smith notes with respect to Victoria:

> … the Victorian Schools of Mines were in many ways a special phenomenon: the form in which they arose was not to be found in other colonies, for they were a product of a vigorous provincial economic and cultural life not to be found elsewhere. (Murray-Smith 1987, p.13)

As a description of Victorian development, this is a reasonable statement. However, the development of the Victorian schools of mines reflected the needs of deep quartz vein mining in the Ballarat (1870) and Bendigo (1873) regions. The inclusion of mechanical engineering programs used the existing infrastructure to respond to agricultural developments, particularly the extension of wheat farming and mechanical harvesting. As such, it was a response to specific local industry conditions. The development of the South Australian School of Mines and Industry, located in Adelaide, was a similar response, although the mining processes, sites, ores and supporting infrastructure were more dispersed. Similarly, in New South Wales, Queensland and Tasmania, mining (from Mount Lyell to Broken Hill and Mount Morgan and Mt Isa), extractive, agricultural and industrial developments were far more regionalised. Statewide coordination made sense, and the systems in those states developed along different paths from that of Victoria, the effects of which (centralisation versus regionalisation of VET) are still with us.

In education and training, the direct involvement of the state set the stage for post-Federation development. But the process was not simply an imposition of state authority. Representative government and a range of important individuals, such as Peter Board in New South Wales and Frank Tate in Victoria, all left the imprint of their individual personalities. Colonial bureaucrats and officials were also well aware of the latest 'progressive' educational theorists in North America, as well as continental systems of technical education, particularly those of Germany, even if they frequently did not have the resources to fully implement their ideal schemes. In school education, textbooks tended to be sourced from the Irish National system, rather than English local authorities. In the technical education system, while standards and certification such as those provided by the London City and Guilds were widely used, newer industrial processes from Europe and North America entered the curriculum, particularly in the various branches of engineering. In general, the approach of the technical education authorities mirrored the approach adopted in local industry. While local industry reproduced occupational titles derived from the United Kingdom, it developed its technological capacity based on the most appropriate North American or European models. This was evident in the growth of the steel industry in Newcastle, which in the 1920s was one of the most modern and productive in the world (Blainey 1971). Financial capital was generally sought from London. However, intellectual capital and technological expertise were more widely appreciated, sought and applied. What is really characteristic of the Australian system is the investment by the state in the transfer of technical education infrastructure to regions to support the development of the extractive and primary industries that formed the export part of the economy.

Invention and innovation in Australia: Some examples

Invention has played a large role in Australian popular culture, with some leading inventors and scientific figures such as William Farrer (1845–1906) and David Unaipon (1872–1967), celebrated on banknotes and in social studies curricula. The stump-jump plough (1876), the combine harvester (1885) and 'Federation wheat' were significant in agriculture. Lawrence Hargraves's (1850–1915) experiments with flight in 1894, the Potter–Delprat flotation process for the extraction of zinc (1904), Anthony Mitchell's invention of the thrust bearing (1905), the original development of commercial refrigeration by compression in Geelong by James Harrison in 1850 and its successful application to meat exports from Sydney in 1879, the first production line 'ute', a Ford in 1937, and the humble rotary mower (1952–03) and Hills hoist (1948) are among well-known technical or industrial examples (Cull 1993).

More scientifically advanced inventions or innovations include the Commonwealth Scientific and Industrial Research Organisation's role in the development of the atomic mass spectrometer (1954), the Interscan aircraft landing system (1991), heart pacemaker (1929), gene shearing for genetic engineering (1987) and the bionic ear (1978). Recent green-friendly inventions include the development of Synroc for atomic waste disposal (1978) and the laser grooved solar cell which continues to be developed at the University of New South Wales (Cull 1993; Moyal 1986, 1987; Blainey 1993). However, the preceding list does not cover all innovations and major industrial process technologies assisted by the Commonwealth Scientific and Industrial Research Organisation and technical staff from the state technological museums and major technical colleges (Schedvin 1984; Mellor 1958).

The capacity to translate invention into production in either innovative products or processes is not, however, simply a matter of inventiveness, or even the availability of suitably motivated and cashed-up venture capitalists. The extent of product, labour and capital markets and the existence of appropriate social and technical infrastructure are crucial. Notwithstanding constraints imposed by population size, a small domestic market and the 'tyranny of distance', the process of product and process innovation in Australia demonstrates the integration of Australian industry within the world scientific and technological community, supported by high levels of technical competence and adaptability in the domestic workforce.

Imported and locally developed skills

Until the direct involvement of the colonial state, first in primary and then in technical education in the 1870s, skill formation and transmission occurred informally on the job, and skill diffusion through mobility in a tight skilled labour market. As figure 1 indicates, skilled migration has always been a major contributor to the labour force. Although definitions of skilled occupations differ across time, and it is possible that self-reporting of skills by migrants may have inflated the data for the skilled occupations reported in figure 1 (see Linge 1979, appendix, for a technical discussion), the overall excess of skilled and semi-skilled migration over unskilled has been evident for 120 years.

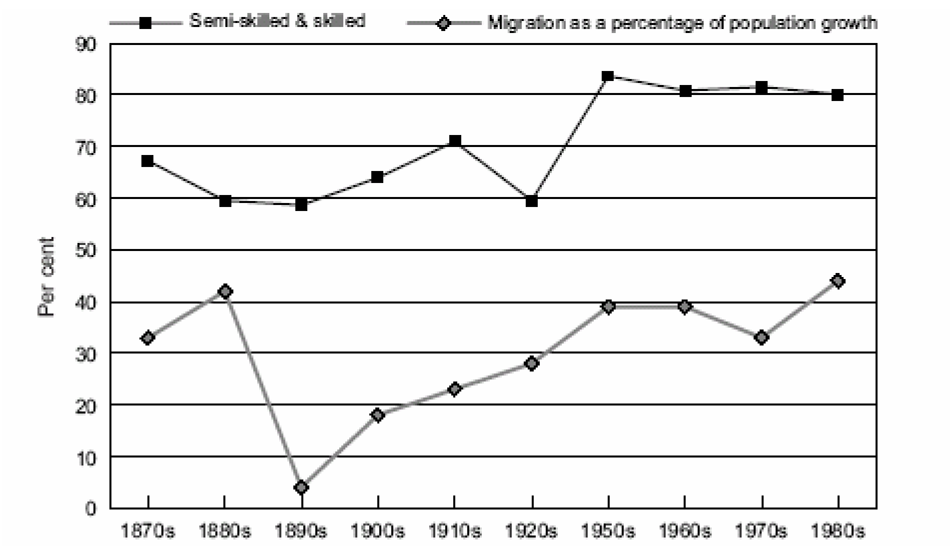
Table 1: Contribution of migration to skills and population growth—1860s to 1970s (percentages)

	1870s	1880s	1890s	1900s	1910s	1920s	1950s	1960s	1970s	1980s
Skilled	21.60	20.70	29.63	30.65	30.30	29.08	31.89	32.98	40.30	49.00
Semi-skilled upper	4.40	5.20	6.88	7.63	4.53	13.97	29.24	29.60	32.40	23.52
Semi-skilled lower	41.20	33.60	22.10	25.66	36.10	16.46	22.52	18.24	8.85	7.57
Unskilled	32.80	41.95	40.19	35.89	28.95	40.54	16.38	19.20	18.54	19.85
Av. Year increase ('000s)	26.80	28.54	10.70	13.33	40.27	27.14	59.87	63.02	48.65	40.75
Per cent of population growth	33.00	42.00	4.00	18.00	23.00	28.00	39.00	39.00	33.00	44.00

Source: Adapted from Withers (1989)

The significance of migration has often been stated, but can be clearly seen in the simplified graph presented in figure 1. Apart from the depression years of the 1890s, and again in the depressed 1930s, when in any case migration was low, skilled migration has exceeded unskilled migration and has remained roughly proportional to overall population increase.

Figure 1: Skilled migration to Australia and total migration as a percentage of population growth



Source: Table 1

Local skill development

From around the 1840s onwards, mechanics institutes and schools of arts began to play a role in diffusing skills. Murray-Smith (1987), for example, locates the origins of technical and further education at least partially in the system of institutes. Although they were rarely organised along coherent discipline lines, important institutions, particularly in Victoria, such as the Ballarat School of Mines, did develop from local mechanics institutes. On the whole, the offerings of the institutes and schools were like the curate's egg, good in parts, but no substitute for the more formal and structured programs that developed from the 1870s with the establishment of a formal system of state-funded institutes of agriculture, mining and technology. Nonetheless, Todd's assessment of their value is realistic.

> … the cultural infrastructure (of science and technology) comprised organisations often regarded as ancillary … but able to draw on a broader base of social support. The mechanics' institutes formed the backbone of this infrastructure with their object of the diffusion of Science and other useful knowledge … By the late nineteenth century there were about 1000 organisations in the Australian colonies. (Todd 1995, p.29)

The mechanics' institutes, schools of arts, schools of design and schools of mines also provided an 'organisational core on which technical education was moulded as industrial developments forced governments to extend their educational responsibilities in the latter part of the century' (Todd 1995, pp.27–8).

If artisans were the 'foot soldiers' of science and technology—as described by TH Huxley—then the technical colleges and institutes, the schools of mines and industry and the agricultural colleges were the source of the even more critical non-commissioned officers of industry. The universities provided a small but significant research capacity, particularly in the medical and agricultural sciences, with a steady stream of graduates from the 1860s onwards. However, entry to university depended on matriculation which, with no state high schools in the nineteenth century, depended on a church or private school education (private wealth or the occasional scholarship). It was the more numerous technicians, upper-level artisans and certificated engineers of the technical colleges and institutes who formed the skilled nucleus for the development of public utilities and industries in the late nineteenth and early twentieth centuries. Services in the capital cities and regional centres and the emergence of chemical and electrical industries relied heavily on graduates of the technical colleges of Melbourne, Sydney, Brisbane and Adelaide.

This process was complemented by unique Australian institutional developments in the apprenticeship system. Colonial apprenticeship followed the English model of on-the-job training delivered (if at all) by the employer, and struggled to survive. While retaining the skills divisions associated with British occupational models, the Australian system diverged from the English training model. With Federation, the Commonwealth's industrial powers were used as part of a wage-setting mechanism, to define through awards, the minimum skill descriptions for key occupations. State industrial law generally followed federal leads. In practice this meant that, in the twentieth century, the Australian apprenticeship system adopted a Germanic rather than British approach, although within different legal and institutional structures. The Australian apprenticeship system increasingly included mandatory formal off-the-job apprentice training to be delivered by a technical college system, which constitutionally was a state not a federal responsibility.

Technical college courses were directed to the needs of an intercolonial occupational labour market and the developing industries which supported the substantial public investments in infrastructure, such as water, gas, electricity and civil construction, and some private construction. However, the technical colleges, particularly the large colleges and systems, were not restricted to 'trade' or 'engineering' subjects and were remarkably cosmopolitan in their courses. For example, the 1898 calendar of Sydney Technical College listed courses on mechanical and civil drafting, chemical and electrical engineering, higher-level certificates in the construction, printing and mechanical trades, and courses in French and Indian cuisine. There was also a range of business and accounting subjects and certificates, the students of which were predominately the daughters of the middle classes. In a display of mutual recognition that would not be repeated for almost a hundred years, satisfactory completion of the plumbing trade certificate at Sydney Technical College was sufficient for recognition by the relevant statutory authorities in all other Australasian colonies, including New Zealand (Sydney Technical College 1898).

Although the technical colleges and institutes in conjunction with the museums of science and technology undertook applied industrial research at an equivalent level to the less numerous universities, forms of instruction and the status of employment differed. In the technical education system, part-time study was common and frequently undertaken at night. Students were usually employed and, also unlike the situation in the university system, a relatively small core of full-time staff was supplemented by part-time instructors and lecturers, frequently technical college graduates themselves, recruited from local industry. This exchange of skilled and qualified personnel between technical colleges and institutes, large public sector utilities, and both large and small employers, created an institutional framework within which technological innovations, generally process-oriented, could be diffused. In the process, late colonial investment in education and training took on a pattern still familiar today. Investment in skill formation (or human capital) was primarily a government activity, which in contemporary terms, could be regarded as a 'public good'. This was supplemented by far smaller individual private investment through student fees and foregone earnings during training. Investment by the private sector was limited, although representatives of private firms were both active and vocal in college committees and course affairs.

Diffusion

The recent accounts of major structural changes in the Australian economy following the oil crisis of the 1970s and the supposed imperatives of globalisation in the 1990s may perhaps more realistically be interpreted as an acceleration of longer-term structural trends commencing in the late 1890s and continuing throughout the twentieth century. As figure 2 indicates, the cross-over period occurred in the late 1960s and 1970s, reflecting a general shift in OECD economies from a manufacturing to service base.

Figure 2: Changes in distribution of production and white-collar employment in Australia, 1911–81 (percentages)

Note: 'Production' includes estimates for all manufacturing, agriculture, civil and private construction; 'white collar' includes all sales, managerial and clerical occupations and professions.

Source: Table 2

While productivity continued to increase in commodity production and in manufacturing, employment in the sectors declined. Certainly manufacturing and construction combined still accounted for around 30% of the labour force from Federation to the 1980s; however, the growth of a white-collar workforce at the expense of agriculture and mining occurred early and reflected a changed social structure in which administrative and clerical occupations began to increase in the capital cities and regional centres (see table 2) Significantly for future development, all sectors were serviced by a range of technical education and training institutions that ranged from operative to technician to professional levels.

Table 2: Changing structure of Australian industry—employment 1911–81 (percentages)

	1911	1921	1933	1947	1961	1971	1981
Upper professional	1.7	1.7	1.8	1.4	2.8	2.6	4.3
Graziers	1.7	1.6	2.8	2.3	2.3	1.5	1.5
Lower professional	3.2	3.5	3.9	4.5	5.9	8.3	10.3
Managerial	5.0	3.7	4.5	5.9	7.1	7.2	5.8
Shop proprietors	1.3	1.7	2.8	-	1.2	0.7	0.7
Farmers	11.8	11.3	7.6	11.4	4.6	3.4	2.8
Clerical	4.1	6.6	9.9	13.7	15.6	19.5	20.7
Armed services	0.5	0.5	0.5	1.6	1.5	1.7	1.6
Craftsmen	17.3	17.0	12.2	15.9	16.4	15.0	14.1
Shop assistants	6.3	5.9	4.6	7.0	5.0	5.3	5.9
Operatives	7.5	8.8	8.4	10.0	11.2	10.7	8.5
Drivers	5.2	5.4	5.1	5.5	5.0	4.4	4.0
Service workers	11.4	11.1	11.3	7.6	7.6	8.3	9.6
Miners	4.8	2.5	2.2	1.2	0.8	0.7	0.6
Farm workers	10.4	8.7	10.0	-	3.9	2.6	1.7
Labourers	7.6	9.7	12.2	9.9	9.1	7.8	7.2
Totals	**98.1**	**99.7**	**99.8**	**97.9**	**100.0**	**99.7**	**99.3**

Source: Adapted from Withers (1989)

War and reconstruction to the present

The experience of the Pacific War demonstrated the depth to which technical and scientific skills had become embedded in Australian industry and the industrial workforce. In particular, it showed the strategic significance to the country and to industry of the technical education system, and the depth of skills of its professional and technical staff.

The economy was redirected, not just to increase munitions, but also to expand industrial employment and increase output through more effective chemical, electrical, mechanical and civil engineering processes. In this, the state technical colleges and their staff were critical. The contribution of the technical education system was not limited to training. Colleges and their staff were also directly involved with production, and the largest metropolitan and regional colleges contributed to total output by converting some premises to manufacturing facilities.

However, the key contribution was the role of the main colleges in supplying production tooling to external industry (see Mellor 1958; Blainey 1971). In a production environment 'the tools that make the tools' are critical. High levels of theoretical and practical applied knowledge are required. During the Second World War it was not merely existing industries or industrial processes that were integrated with the technical colleges and technical college staff. Whole new processes and industries, such as the optical industry, were developed or greatly expanded. By the early 1940s Australian industry was (with the exception of some specialised areas which relied on rare earths) virtually self-sufficient at design and production levels.

This wartime success should not just be seen as an issue for nationalistic self-congratulation. What is important is why and how it was achieved. The argument in this report is that it was made possible because it grew directly out of the real structure of Australian industry and industry's relationship with the technical education institutions. Import substitution, market constraints, broad-based skills, familiarity with modern technology and production processes, and a need to adapt to local conditions, together meant that innovation in Australian industry generally occurred through the extension and modification of existing technologies to fit new purposes. This typically relies on 'trade' and 'para-professional' level engagement with production, rather than research and development departments. It is this level that the Australian technical education system had developed to serve. The significance of this sector for Australian industry is indicated in table 3, based on a longitudinal survey of the workforce conducted by the Australian National University in the 1970s, just prior to the development of the TAFE system.

By dividing the 1971 workforce into age cohorts it was possible to identify the source of formal qualifications. Although the skill level breakdown is somewhat crude, the table shows the relative importance of qualifications at trade and technician level obtained through the various state 'tech' systems, compared with tertiary qualifications (including teaching certificates and the like).

Table 3: Source of qualifications in the Australian workforce—1930–60 (percentages)

Qualification	**Years**			
	pre-1929	1929–38	1939–48	1949–57
Trade level	31	38	41	46
Technical level	12	12	15	17
Tertiary (non-degree)	0	5	7	8
Tertiary (degree)	0	3	2	3
	n=201	n=413	n=514	n=556

Source: Adapted from Hatton and Chapman (1989, p.131)

It is also interesting to note the increase of 'tertiary non-degree' qualifications, which were primarily the areas targeted by the first post-Second World War expansion of colleges and institutes of advanced education. The table indicates that, despite the Great Depression, a fairly effective, if underfunded technical education system provided a skill base able to support the rapid industrial expansion during the Second World War, and the post-war 'boom' that followed.

Evidence to support this analysis was also provided during the planning for a proposed institute of technology in New South Wales (now the University of New South Wales) in Sydney during 1947–49. A report commissioned to compare the education and training provided to engineers by Sydney Technical College found that, in terms of content, the course for certificate engineers at the technical college was equivalent to those of London University, Edinburgh and the Massachusetts Institute of Technology, and of generally longer duration. Importantly, the technical college courses also included modern production-engineering subjects, based on North American practice, which British universities did not really adopt until much later. It should be noted that the standards for certificate engineers in other states, also taught in the technical education system, were similar to those of Sydney Technical College. They had to be. Notwithstanding state differences amongst the departments of education, the colleges were all supplying the same occupations, engaged with the same organisations and professional associations, and therefore developed curriculum directed at the same needs.

The immediate post-Second World War period saw significant Commonwealth funds allocated to retraining returned service personnel in both the technical education sector and the universities. However, by the beginning of the 1950s, the policy emphasis at state and federal levels had shifted to higher education. Many of the upper-level courses in the technical colleges were transferred to existing and emerging higher education institutions. Post-war migration, particularly skilled migration, supplied both new labour and stimulated Keynesian demand. Technical education became somewhat of a poor relation to other education sectors. New South Wales and Victoria in particular took different paths, with New South Wales developing a separate Department of Technical Education after 1949 and a Department of Education responsible (especially from the 1960s) for a comprehensive high school system. Victoria by contrast, expanded and developed a technical high school system which was later incorporated into TAFE.

Kangan to the present

From the 1970s successive Commonwealth Governments moved towards the establishment of a national training system. In 1973 the new Whitlam Government established the Australian Committee on Technical and Further Education chaired by Myer Kangan. Its report, *TAFE in Australia* (Australian Committee on Technical and Further Education 1974), also called the Kangan report, is generally considered a 'milestone of great and enduring significance ushering in the modern era of TAFE in Australia, defining TAFE as an alternative sector of education and delineating the general role for the current VET sector in Australia' (Kearns & Hall 1995).

The Kangan report set the agenda for change and the Technical Education Commission was established under the *Technical and Further Education Act* of 1975. The Fraser Government came to power in 1976, and the next 15 years were characterised by growth in TAFE systems, development of national policies and structures, and ongoing tension between the Commonwealth and states over policies, processes and funding (Goozee 1993). There were also important changes in the TAFE student profile, improvements in student financial assistance, and the targeting of educational programs towards disadvantaged groups.

The Hawke Labor Government's concern with structural reform of the economy, and in particular, the issue of unemployment, led to the appointment in late 1983, of the Committee of Inquiry into Labour Market Programs, chaired by Peter Kirby. The committee's report, released in 1985, made 86 recommendations, the most important of which was to develop a system of traineeships which would combine broad-based vocational education and training in an institution with work in a related occupation.

In the early 1990s, the Finn report, *Young people's participation in post-compulsory education and training* highlighted the tension between general education (assumed to be a broad range of transferable skills) and vocational training (assumed to be a very narrow range of competencies). The major theme of the report was that both industry and individual needs were leading to a convergence of general and vocational education. In addition, Prime Minister Paul Keating's 1992 economic statement (One Nation) included a proposal for the Commonwealth to fully fund TAFE. It recognised that, compared with schools and universities, the TAFE system was under-resourced, and growth was required to assist Australia to become more economically competitive. Conflict arose between the Commonwealth and the states and territories, and between states, over the funding of TAFE. However, it was agreed to jointly fund the national training system through the establishment of the Australian National Training Authority, with the Commonwealth supplying growth funding for 1993.

Along with changes in all sectors of education in the late 1980s, for TAFE there was the development of a training market, the move towards competency-based training and the push towards more specific skills formation rather than broad vocational education and training. As Goozee (2001) notes 'the coining of the of the term "skills formation" to replace TAFE and training gave a strong indication of the new directions which were to be taken in applying economic rationalism to vocational education and training', a process somewhat at odds with previous expressed beliefs about the convergence of general and vocational education.

As part of a newly created VET sector, TAFE needed to secure its share of Commonwealth funds and to market itself in an increasingly competitive environment. At the same time the Commonwealth Government was committed to reducing unemployment and encouraging a commitment to training by business and industry. These and other factors contributed to what became known as the Australian Training Reform Agenda. In 1995 the Australian Government established the National Employment and Training Taskforce (NETTFORCE) to assist in marketing new traineeships, and a structured approval process for new traineeship packages with all states and territories. The first national training packages were endorsed in 1997 and the packages cover the competency standards, qualification rules and assessment guidelines for an industry, although some, such as business services, are cross-industry (Smith & Keating 2003).

In 1993 the endorsement of the Australian Qualifications Framework was a major step towards a nationally consistent system of qualifications and awards. The framework, incorporating 12 levels of qualifications, was introduced in 1995. Finally, the Australian Quality Training Framework was introduced in 2002 with the intention of again improving the quality of VET delivery. This framework contains standards which establish rules about how registered training organisations are to operate in order to gain and maintain registration, as well as standards for state accreditation authorities.

Conclusion

Australia's colonial heritage, its reliance on resource development, its dependence on and integration with the world economy from the earliest days of settlement, and its social and industrial adaptation to unique local conditions makes it an especially interesting historical example of the need to locate policy development within a realistic assessment of the actual context, rather than the desirable context. One of the questions asked of history is 'what can we learn from it'? In reply, one of the most distinguished of twentieth-century historians, Eric Hobsbawn, has wryly noted that:

> Unfortunately, one of the things historical experience has also taught historians is that nobody ever seems to learn from it. (Hobsbawm 1997, p.47)

What can be learnt, or at least hoped for, is that decisions made with regard to real, rather than ideal situations, tend to have more beneficial outcomes than decisions and policies based on ideal, but unrealistic outcomes, a particularly relevant issue when models are transferred without regard to the actual structural and institutional conditions.

The last decade has seen significant changes to the administrative and funding arrangements of the formal VET system. However, an emphasis on change and difference at a system level can mask ongoing continuities in industry itself. Notwithstanding the major structural changes in the Australian economy that have accelerated since the late 1970s, the Australian innovation system still primarily depends on process rather than radical innovation. Capacity has expanded, new production processes and products introduced, and new markets for manufactured goods and tertiary services have developed. But the essential characteristics of an economy constrained by a relatively small domestic market have not significantly changed. This is not to denigrate Australian industry. As the Business Council of Australia remarked in the early 1990s, most innovation in all advanced economies is of this type. It rejected as too 'narrow and misleading' the:

> … conventional wisdom … that innovation equals invention plus commercialisation … Innovation is not science. Nor is it technology or the ownership of invention.
> (Carnegie et al. 1993, p.3)

In practice, innovation comes from 'complex interactions between many individuals, organisations and environmental factors' rather than being a straight line from new knowledge to new products (European Commission 2001, 1.5). In this context, as we have seen, human resource development is essential for both the creation and diffusion of knowledge. A skilled workforce is a key pathway by which diffusion occurs, and the development of this skilled workforce is, in general, the domain of VET institutions. This involves far more than a rationalisation of VET credentialling mechanisms.

The Australian system of innovation fits the pattern of incremental innovation and diffusion of technical knowledge. Historically, from colonial times to the advent of the present national system, the technical education and training institutions, for all their historically specific characteristics, industry critics and state differences have functioned to support this process. To respond to challenges of geography and climate, Australia depended on innovative local solutions to local problems and relied heavily on the skills supplied by the technical education system at semi-skilled, trade, certificate and diploma levels. Where constraints on the application of these skills occurred, it was generally a result of industrial and work organisation issues in large hierarchically organised workplaces. Inability to apply skills for organisational reasons is not a failure of the training system to supply those skills.

Contemporary society is the product of historical process and Australia has, since European settlement, been 'tethered to the world' (Lawson 1898). The particular challenges of the twenty-first century are not likely to be met by reproducing training and industry models drawn from an idealised past (or for that matter an idealised future). However, the lesson that history can provide is that technical and other forms of education in Australia developed in response to real, not idealised conditions. There seems little reason to suppose that the response to future needs, and the best policy base from which to judge that response, should be any different.

References and notes

Sources for VET and innovation

A sketch and literature review of development across 200 years must rely on secondary sources; however, as Goozee (2001) notes, readers in search of general history of technical and vocational education are, with the exception of Murray-Smith (1987), based on his earlier thesis, not particularly well served, although Jolly and Swenson (2001) provide interesting oral history accounts of technical schooling in South Australia. There are a number of general histories of education, for example, Austin (1975), Barcan (1965, 1980), Austin and Selleck (1975) and state education or specialist histories (Goodman 1968; Mitchell 1973) that include general references to technical education. Crane and Walker (1957) and Selleck (1982) are biographical studies of the influential educationalists, Peter Board (New South Wales) and Frank Tate (Victoria). Interesting unpublished theses on technical education and TAFE are those of Goozee and her history of post-Kangan TAFE (1993, 2001), Rushbrook (1995) on post-war Victorian technical training and Shields (1990) on the development of craft skills and apprenticeship. Examples of celebratory centenary histories include the Victorian Department of Education (1973), Murray-Smith and Dare (1987) on the evolution of the Royal Melbourne Institute of Technology and Neil (1991) on Sydney Technical College. Joan Cobb (1983) wrote an important in-house history of the New South Wales system to 1949, which fortunately is now available in an edited form (Cobb 2000) and provides a useful contrast to the majority of accounts written from a Victorian perspective.

That technical education, particularly its relation to industrial development, has not been subject to more detailed historical scrutiny by educationalists is somewhat surprising. At Federation, for example, there were only three state high schools in Australia, all in New South Wales. At the period that same state had over 30 technical colleges serving both youth and older workers, and from the 1870s all colonies had introduced a range of technical institutes, schools of mines and industry, agricultural colleges, technological museums, and universities with chairs and departments in the natural and applied sciences.

An appreciation of the importance of skill formation to economic development is however to be found in a range of materials falling under the generic title of economic history. GJR Linges's superb and detailed *Industrial awakening* (1979) charts the development and geographical dispersal of colonial industry. Subsequent industrial and economic development is well covered by a number of economic historians associated with the Research School for the Social Sciences at the Australian National University (for example, Butlin 1962; Schedvin 1984; Withers 1989). Accessible general histories of science and technology (Moyal 1984, 1986; Todd 1995) complement a number of company or industry histories, of which the works of Blainey (for example, 1971, 1978, 1993) all contain discussions of innovations, technology and 'technical education', although rarely directly linked. Academic journals such as *Australian Economic History Review*, *Prometheus*, *Labour History* and the *Journal of Industrial Relations* are more productive sources than strictly educational journals, although *Melbourne Studies in the History of Education* and the *History of Education Review* contain VET-related material amongst their more general school education emphasis.

Industry-based professional journals such as the *Personnel Practice Bulletin* and publications by the Institute of Engineers (for example, Lloyd 1968, 1984) address skill formation, albeit at times with a professional slant. Most colonies also had royal societies whose members were involved in the early formation of educational institutions from (at least) the 1870s. Their published proceedings chart the development of the natural sciences and technology, and like their British counterparts, such as the London Society's Journal *Nature,* contain scattered but significant references to the importance of education in general, and technical and scientific education in particular. Members of these societies played significant roles in the development of the respective colonial, and later state technical education systems, and their involvement may be conveniently traced through the *Australian Dictionary of Biography*.

References

ABS (Australian Bureau of Statistics) 2002, *Measuring a knowledge-based economy: An Australian framework,* discussion paper, ABS, Canberra.

Austin, A 1975, *Australian education, 1788–1900: Church, state and public education in colonial Australia 1961*, 3rd edn, Pitman, Melbourne.

Austin, A & Selleck, R 1975, *The Australian government school: 1830–1914*, Pitman, Melbourne.

Australian Academy of Technological Sciences and Engineering 1988, *Technology in Australia, 1788–1988: A condensed history of Australian technological innovation and adaptation during the first two hundred years,* AATSE, Melbourne.

Australian Council of Trade Unions & Trade Development Committee 1987, *Australia reconstructed, ACTU/TDC mission to Western Europe: A report by the mission members to the ACTU and the TDC*, AGPS, Canberra.

Australian Committee on Technical and Further Education 1974, *TAFE in Australia: Report on the needs in technical and further education, volume 1*, (Kangan report), ACOTAFE, Canberra.

Australian Dictionary of Biography 1966+, Melbourne University Press, Melbourne.

Australian Science, Technology and Engineering Council 1979, *Annual reports*, ASTEC, Canberra.

Barcan, A 1965, *A short history of education in NSW*, Martindale Press, Sydney.

——1980, *A history of Australian education*, Oxford University Press, Melbourne.

Birch, A & Rystrand, L (eds) 1988, *The nature and role of innovation in the economy: Report of the 1988 review of science, technology and engineering in Australia*, Institution of Engineers for National Science and Technology Analysis, Canberra.

Birmingham, J & Jeans, D 1983, *Industrial archaeology in Australia: Rural industry*, Heinemann, Melbourne.

Blainey, G 1971, *The steel master: A life of Essington Lewis*, Melbourne University Press, Melbourne.

——1954, *The peaks of Lyell,* 4th edn, Melbourne University Press, Melbourne.

——1993, *The rush that never ended: The history of Australian mining*, Melbourne University Press, Melbourne.

Brogan, A 1990, *Committed to saving lives: A history of the Commonwealth Serum Laboratories*, Hyland House, Melbourne.

Butlin, N 1962, *Australian domestic product investment and foreign borrowings: 1861–1938/9*, Cambridge University Press, Cambridge.

Butlin, N, Barnard, A & Pincus, J 1982, *Government and capitalism: Public and private choice in twentieth century Australia*, Allen & Unwin, Sydney.

Carnegie, R, Butlin, M, Barratt, P, Turnbull, A, Webber, I 1993, *Managing the innovating enterprise: Australian companies competing with the world's best*, Business Council of Australia, Melbourne.

Chandler, A 1977, *The visible hand: The managerial revolution in American business*, Belknap Press, Cambridge, MA.

Cobb, J 1983, 'A technical education' (typescript), NSW Department of TAFE, Sydney.

——2000 *Sweet road to progress: The history of state technical education in New South Wales to 1949*, NSW Department of Education and Training, Sydney.

Commonwealth of Australia 2001, *Backing Australia's ability: An innovation action plan for the future*, January, Commonwealth Government, Canberra.

Crane, A & Walker, W 1957, *Peter Board: His contribution to the development of education in New South Wales*, ACER research series, no.71, Australian Council for Educational Research, Melbourne.

Cull, R 1993, *Inventive Australians*, Longman Cheshire, Melbourne.

Davison et al. (eds) 1998, *The Oxford dictionary of Australian history*, Oxford University Press, Melbourne.

Dawkins, P 2001, *Annual R & D and intellectual property scoreboard*, Melbourne Institute in conjunction with IP Australia and IBIS World, cited in *The Australian*, Higher Education Supplement, 2 February.

Department of Labour and National Service 1970, *The training of skilled workers in Europe: Report of Australian Tripartite Mission to study methods of training skilled workers in Europe, 1968–69,* Commonwealth Government Printing Office, Canberra.

European Commission 2000, *Communication from the Commission to the Council of the European Parliament: Innovation in a knowledge driven economy*, viewed 20 January 2001, <http://www.europa.eu.int/eur-lex/en/com/cnc/2000/com2000_0567en01.pdf>.

European Commission 2001, 'Opinion of the Economic and Social Committee on the "Communication from the economy"', *EU: Official Journal of the European Commission*, 17 September.
Ferrier, F, Trood, C & Whittingham, K 2003, *Going boldly into the future: A VET journey into the national innovation system*, NCVER, Adelaide.
Finn, B (chair) 1991, *Young people's participation in post-compulsory education and training* (the Finn Review), AGPS, Canberra.
Fitzgerald, V 2001, 'Time to build the knowledge economy', *Australian Financial Review,* 16 March, p.59.
Gerschenkron, A 1962, *Economic backwardness in historical perspective,* Belknap Press, Cambridge, MA.
——1968 *Continuity in history, and other essays,* Belknap Press, Cambridge, MA.
Goodman, R 1968, *Secondary education in Queensland: 1860–1960*, ANU Press, Canberra.
Goldthorpe, J 1996, *The sociology of post-colonial societies*, Cambridge University Press, Cambridge.
Goozee, G 1993, *The development of TAFE in Australia* , NCVER, Adelaide.
——2001, *The development of TAFE in Australia,* 2nd revised edn, NCVER, Adelaide.
Gospel, H 1994, 'The survival of apprenticeship training: A British, American and Australian comparison, *British Journal of Industrial Relations*, vol.32, no.4, pp.505–22.
Hatton, R & Chapman, B 1989, 'Human resources in the nineteenth and twentieth centuries', in *Australia's greatest assets: Human resources in the nineteenth and twentieth centuries,* eds David Pope and Lee J Alston, Federation Press*,* Sydney, pp.123–35.
Hobsbawm, E 1997, *On history*, Weidenfeld and Nicolson, London.
International Labour Organisation 2002, *Learning and training for work in the Knowledge Society*, ILO, Geneva.
Jolly, E & Swenson, A 2001, *A broader vision: Voices of vocational education in twentieth century South Australia,* Michael Deves Publishing, Adelaide.
Kearns, P & Hall, W (eds) 1995, *Kangan: 20 years on*: *A commemoration: TAFE 1974–1994*, NCVER, Adelaide.
Keep, E & Mayhew, K 1999, 'The assessment: Knowledge, skills and competitiveness', *Oxford Review of Economic Policy*, vol.15, no.1, pp.1–15.
Kelly, D 2000, 'Human resource development', *14th Australian Industrial Relations Academics of Australia and New Zealand Conference*, February 2000, Newcastle.
Kelly, P 1992, *The end of certainty: The story of the 1980s*, Allen & Unwin, Sydney.
Kirby, P (chair) 1985, *Report of the Committee of Enquiry into Labour Market Programs*, AGPS, Canberra.
Lawson, H 1898, 'When the world was wide', in *Collected verse of Henry Lawson*, edited with introduction and notes by C Roderick, vol.1, 1885–1900, Angus and Robertson, repr. 1967, Sydney.
Linge, G 1979, *Industrial awakening: A geography of Australian manufacturing 1788–1890*, ANU, Canberra.
Lloyd, B 1968, *The education of professional engineers in Australia,* Association of Professional Engineers, Melbourne.
——1984, *TAFE and the technical workforce in engineering: A personal account of educational workforce and terminology issues 1957–1983*, occasional paper no.5, TAFE National Centre for Research and Development, Adelaide.
Marceau, J & Manley, K 2001, 'Australia's system of innovation', in *Business, work and community*, eds G Dow and R Parker, Oxford University Press, Melbourne, pp.81–100.
Marx, K 1976, *Capital, vol.1: A critique of political economy*, [first published 1867], translated Ben Fowkes, Penguin and New Left Books, London.
Mellor, D 1958, *The role of science and industry*, Australian War Memorial, Canberra.
Mitchell, B 1973, *Teachers, education and politics: A history of public school teachers in NSW*, University of Queensland Press, St Lucia.
Moyal, A 1984, *Clear across Australia: A history of telecommunications*, Nelson, Melbourne.
——1986, *A bright and savage land: Scientists in colonial Australia*, Collins, Sydney.
——1987 'Invention and innovation in Australia: The historian's lens', *Prometheus*, vol.5, no.1, pp.92–118
Murray-Smith, S 1987, *Behind the mask: Technical education yesterday and today*, Footscray Institute of Technology, Footscray, Victoria.
Murray-Smith, S & Dare, A 1987, *The Tech: A centenary history of the Royal Melbourne Institute of Technology*, Hyland House Publishing, Melbourne.
Nature 1905, vol.63, p.242, London, Macmillan.
Neil, N 1991, *Technically and further: Sydney Technical College: 1891–1990,* Hale and Iremonger, Sydney.
New South Wales Government 1905, *Report of the Commissioners on Agricultural Commercial, Industrial and Other Forms of Technical Education* (Knibbs Turner Report), NSW Government Printer, Sydney.
OECD (Organisation for Economic Co-operation and Development) 2002a, *Frascati manual: Proposed standards for surveys on research and experimental development* (first edition 1963), OECD, Paris.
——2002b *Oslo manual: The measurement of scientific and technological activities: Proposed guidelines for collecting and interpreting technological innovation data* (first edition 1996), OECD, Paris.
Pickersgill, R, 2001a, 'Skill formation in Australia beyond 2000: "Flexibility" and vocational education and training policy', *International Journal of Employment Studies*, vol.9, no.1, pp.121–39.
——2001b, 'VET and innovation: Some conceptual issues', paper presented to the 10th Annual VET Researchers Conference, Deakin University, Geelong, July.

Pickersgill, R & Walsh, M 2003, 'Innovation and vocational education training policy in Australia', *Australian Vocational Education Review,* vol.10, no.1, Griffith University, Nathan, Queensland.

Polanyi, K 1975, *The great transformation* (first published 1944) Octagon Books, New York.

Rostow, W 1971, *The stages of economic growth: A non-communist manifesto*, 2nd edn, Cambridge University Press, Cambridge.

Rushbrook, P 1995, 'Straws in the wind: The construction of technical education in Victoria, 1945–1985', unpublished PhD thesis, Monash University, Melbourne.

Schedvin, B 1984, *Shaping science and industry*, Australian National University Press, Canberra.

Shields, J 1992, 'Skill reclaimed', unpublished PhD thesis, University of Sydney.

Schumpeter, J 1934, *The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle,* Harvard University Press, Cambridge, MA (originally published in German in 1911).

——1942, *Capitalism, socialism and democracy*, Harper and Row, New York.

Selleck, R 1982, *Frank Tate: A biography*, Melbourne University Press, Melbourne.

Smith, E & Keating, J 2003, *From training reform to training packages*, Social Science Press, Tuggerah, New South Wales.

Sydney Technical College 1898, *1898 Calender*, NSW Government Printer, Sydney.

Todd, J 1995, *Colonial technology: Science and the transfer of technology to Australia*, Cambridge University Press, Cambridge.

Toner, P, Marceau, J, Hall, R & Considine, G 2004, *Innovation agents: Vocational education and training skills in Australian industries and firms*, NCVER, Adelaide.

Victorian Department of Education 1973, *Vision and realisation: A centenary history of education in Victoria*, Melbourne.

Wallerstein, I 1974, *The modern world-system: Capitalist agriculture and the origins of the European world-economy in the sixteenth century,* Academic Press, NY.

——1980, *The modern world system II: Mercantilism and the consolidation of the European world-economy, 1600–1750,* Academic Press, NY.

Withers, G 1989, 'The immigration contribution to human capital formation', in *Australia's greatest assets: Human resources in the nineteenth and twentieth centuries*, eds D Pope and L Alston, Federation Press, Sydney pp.53–71.

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National Centre for Vocational Education Research Ltd

Level 11, 33 King William Street
Adelaide SA 5000

PO Box 8288 Station Arcade
South Australia 5000

Phone +61 8 8230 8400
Fax +61 8 8212 3436
Email ncver@ncver.edu.au

www.ncver.edu.au