2002

The organisation of knowledge: optimising the role of universities in a Western Australian 'knowledge hub'

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Publication Details

Turpin, T, Marceau, J, Garrett-Jones, SE, Appleyard, R & Marinova, D, The organisation of knowledge: optimising the role of universities in a Western Australian 'knowledge hub', Perth, Western Australia, Technology and Industry Advisory Council (TIAC), 2002.

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Abstract
A feature of globally competitive knowledge-based economies is that governments, universities and industry work together in these economies to create regional ‘knowledge hubs’. A knowledge hub is essentially a “region” with an ensemble of knowledgeintensive organisations located in both public and private sectors. Knowledge hubs have three major functions: to generate knowledge; to transfer and apply knowledge; and to transmit knowledge to others in the community through education and training. The present study was commissioned by TIAC with a view to developing options to optimise the role of WA’s universities in supporting a WA Knowledge Hub. Universities have an important part to play in all three functions of a knowledge hub. However, the present study has identified some structural weaknesses that inhibit the optimal contribution of the State’s universities. The analysis and recommendations developed in this report are based on: recent national, State and WA regional data sets; a review of international experiences in developing knowledge-based development strategies; and a series of interviews with key WA ‘stakeholders’.

Keywords
organisation, universities, role, optimising, hub, australian, knowledge, western

Disciplines
Business | Social and Behavioral Sciences

Publication Details
Turpin, T, Marceau, J, Garrett-Jones, SE, Appleyard, R & Marinova, D, The organisation of knowledge: optimising the role of universities in a Western Australian 'knowledge hub', Perth, Western Australia, Technology and Industry Advisory Council (TIAC), 2002.

The Organisation of Knowledge:

Optimising the Role of Universities

in a Western Australian

‘Knowledge Hub’

June 2002

Western Australian
TECHNOLOGY & INDUSTRY
ADVISORY COUNCIL

WESTERN AUSTRALIAN
TECHNOLOGY & INDUSTRY ADVISORY COUNCIL

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June 2002

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Foreword

The Western Australian Technology and Industry Advisory Council (TIAC) has been developing a set of studies with the theme entitled "Towards a Western Australian Knowledge Economy".

These studies have explored the opportunities available to the State to develop appropriate policy and programmes which will increase the "knowledge component" of the Western Australian economy and, as a result, the level of high skilled, high wage employment in the state.

In the development of this report titled "The Organisation of Knowledge Optimising the Role of Universities in a Western Australian Knowledge Hub", TIAC has explored the opportunities available to the State to develop a "Western Australian Knowledge Hub" by encouraging the Universities towards greater participation in a Western Australian Knowledge Economy.

I would like to thank Professor Tim Turpin and his project team for their research and support in the development of this report.

John Thompson
Chairman, TIAC

Executive Summary

A feature of globally competitive knowledge-based economies is that governments, universities and industry work together in these economies to create regional 'knowledge hubs'. A knowledge hub is essentially a "region" with an ensemble of knowledge-intensive organisations located in both public and private sectors. Knowledge hubs have three major functions: to *generate* knowledge; to *transfer and apply* knowledge; and to *transmit* knowledge to others in the community through education and training. The present study was commissioned by TIAC with a view to developing options to optimise the role of WA's universities in supporting a WA Knowledge Hub.

Universities have an important part to play in all three functions of a knowledge hub. However, the present study has identified some structural weaknesses that inhibit the optimal contribution of the State's universities. The analysis and recommendations developed in this report are based on: recent national, State and WA regional data sets; a review of international experiences in developing knowledge-based development strategies; and a series of interviews with key WA 'stakeholders'.

1. Summary of Issues

(i) International Experiences

International experiences illustrate the importance of institutional diversity and collaboration between universities in providing a strong knowledge base for a well functioning knowledge hub.

- The formative role of universities in strengthening knowledge capacity has not been a function of their size. On the contrary, in many cases quite small universities have been able to maximise their contribution by collaborating in just a few key strategic areas (See Chapter 3).
- In the more dynamic knowledge hubs institutional specialisations and strengths have been maintained and provide key platforms for supporting "regional" industrial and economic development. *The case of Georgia Institute of Technology in the US and its sustained strategy of engineering excellence (Chapter 3) illustrates the benefit of maintaining and building on research excellence in key strategic areas for state development.*
- In almost all cases, some form of agency or authority has been instrumental in promoting partnerships. Two-way partnerships between universities and industry are important but collaboration across a whole range of institutions and organisations is necessary for a well functioning knowledge hub. *The case of Alberta Province in Canada, comparable to WA in many ways, provides a good example of how industry policy has served to provide a catalyst for building closer collaboration between universities, industry and other knowledge intensive sectors (Chapter 3).*

- In most cases collaboration in graduate training and research rather than in undergraduate teaching programs provides the platform for developing international knowledge hubs. If these areas are functioning effectively undergraduate programs tend to follow.
- In many of the overseas cases, universities have had to undergo considerable organisational change. This has been necessary to enable them to adapt to new and challenging industrial and social demands. This has required building more flexibility into the ways knowledge generation, transfer and transmission are managed.

(ii) The Challenge for Universities in a WA Knowledge Hub

Until 1996, WA appears to have been well placed to become a national knowledge hub. It had a higher level of general expenditure on R&D per person than the national average. More significantly, it had a higher level of business expenditure on R&D than every other State, except Victoria. Further, in WA the proportion of business sector investment in R&D increased rapidly through the early 1990s, from just over 33 per cent in 1989 to 57.8% in 1996-7, higher than all other States.

Since 1996, however, the situation in WA, has changed dramatically. The State has now entered a new and less favourable period in knowledge development with a considerable downturn in business sector R&D investment.

The low proportion of engineering and science students engaged in postgraduate studies in WA is a cause for considerable concern. In 2000 only 3.3 per cent of the State's postgraduate students were enrolled in engineering and only 14% in science. If WA is to become an internationally recognized knowledge hub, this imbalance across the disciplines will need to change.

> **The five WA universities (4 public and 1 private) represent considerable institutional diversity and have developed quite different student and research profiles. However, while they are clearly performing a valuable role in the development of WA's knowledge base, there is an urgent need to overcome some structural weaknesses that are presently inhibiting their role in a WA Knowledge Hub (See Chapter 2).**

Universities have performed a critical role in consolidating the economic base in knowledge hubs in other parts of the world. WA must draw on the capacity of all five universities in the State to contribute to the economic base of a WA Knowledge Hub.

(iii) Challenges for the Generation of Knowledge

- By international comparisons the level of research investment taking place in Western Australian universities is modest.
- Universities in WA are winning less than their proportional share of national competitive grants.
- While combining resources would bring some economies of scale, having fewer but larger universities will not overcome the inherent structural financial constraints.
- The WA business R&D environment is heavily concentrated in the mining sector. This presents a challenge because fluctuations in business fortunes in the sector leave on-going investments in university knowledge generation volatile and uncertain.

Because of the comparatively small size of the WA knowledge-economy a WA Knowledge Hub is only likely to achieve world class recognition in a small number of specialized areas.

(iv) Challenges for the Transfer of Knowledge

In WA there is a disjunction between R&D investments at universities and those in other sectors - business, Commonwealth research agencies and State government agencies. This is not necessarily a problem because the sectors each perform quite different roles in a knowledge hub. However, functional complementarities between the knowledge generation activities are essential. It is the linkages between the institutions rather than what takes place within each element that is the key to a well functioning knowledge hub.

- Unlike other regions around the world (as well as in some other Australian States) government in WA plays only a minor role in steering collaboration toward State strategic goals.
- In contrast to knowledge hubs elsewhere, the links between universities and other institutions in WA are rather loosely structured, fragile and under-funded.
- Many innovative and valuable examples of collaboration can be found in the WA university system but each is driven almost entirely by a small number of key individuals and, with only a few exceptions, have not generated the critical mass necessary to sustain a globally competitive knowledge hub.
- Research carried out at WA State research institutions represents a small proportion of the overall WA R&D effort (12 per cent) and this is spread across a number of agencies. There is a need to find ways to enable these investments to contribute to a State based critical mass in strategic key areas.
- WA universities contribute to national Cooperative Research Centres and are engaged in partnerships with industry and institutions with funding through national research schemes. However, their share in these programs is below that of most other States.
- One of the key factors in knowledge transfer is the capacity of individuals to work across institutional boundaries. By overseas comparisons, WA academic staff are not particularly mobile. *In order to maximise the role of*

the State's universities there is a need to increase the flow of highly trained personnel between universities and other sectors.

(v) Challenges for the Transmission of Knowledge

- The number of WA students enrolled in university education appears to have reached a plateau.
- While Australian enrolments continue to grow, enrolments in WA actually decreased between 1999 and 2000.
- The number of postgraduate students in WA since 1989 has grown at only half the national rate.
- Other studies around the world have shown how much industry relies on the role of universities for training highly specialised personnel.
- In WA there are worrying trends in the pattern of student enrolments, particularly at postgraduate levels and in science and engineering.
- In some areas of postgraduate study, small numbers of students are isolated from colleagues and academic staff because of institutional boundaries, in spite of the fact that they are working on similar problems. *There is a need, therefore, to find ways to build greater critical mass in key areas and link them to research and development across all universities and institutions in the knowledge hub.*

(vi) Challenges for Regional WA

Regional issues raise some specific challenges for WA. Numbers of university students from the regions have been decreasing. This is in spite of an increasing proportion of 15-19 year olds living in the regions and the fact that all WA universities have some form of regional presence.

Given the presence of all five universities in some parts of regional WA, and the diversity of training available, there is a need to generate closer cooperation between universities as well as between universities and the TAFE sector at the regional level.

2 Recommendations:

Effective policies for promoting knowledge based development call for a new paradigm that emphasises Western Australia as a region built around institutional collaboration within a state structure but linked to national and transnational knowledge systems.

(i) It is recommended that the State develop a Western Australian Knowledge Hub and give consideration to:

(a) Developing critical mass concentrated around specific fields of knowledge across institutional boundaries. (Section 4.2)

(b) Establishing the drivers for change. (Section 4.3)

(c) Establishing a consolidated regional emphasis. (Section 4.4)

(d) Extending an International Presence. (Section 4.5

(e) Monitoring Progress. (Section 4.6)

(ii) It is recommended that the recently established Ministerial Education Exports Advisory Committee be given responsibility for the development of a Western Australian Knowledge Hub.

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1. TOWARD A WESTERN AUSTRALIAN KNOWLEDGE HUB

1.1 Background

The Western Australian Technology and Industry Advisory Council (TIAC) commissioned the present study to advise on ways to optimise the role of the State's universities in developing a Western Australian Knowledge Hub. Following a range of recently commissioned studies TIAC has observed that, in order to meet global innovation challenges, key cities around the world are becoming 'knowledge hubs' with attendant clusters of education, training and research organisations developing strong linkages to industry, technology parks, incubators and other private sector R&D infrastructure.

Universities perform a pivotal role in the development and support of knowledge hubs. However, developing a 'knowledge hub' is not simply a matter of increasing participation rates in higher education. Opportunities for employment in knowledge-intensive industries and a knowledge intensive environment that *attracts* and retains not only knowledge workers already living in the State but also those from overseas are important segments of the hubs. The question that has driven this study is how can the State's universities best contribute to the creation of such an environment?

Specific terms of reference for the project included:

- Determining the extent to which the State's universities cooperate and coordinate their operations so as to maximise the State's investment and strengths in the provision of skills and knowledge;
- Identifying the factors that influence regional Western Australians when considering tertiary education and the extent to which these preferences are met by the State's universities;
- Proposing options available to the State Government for increasing the participation of regional Western Australians in a Knowledge Hub through the State's university sector.
- Establishing a consolidated 'stakeholder view' of the opportunities and constraints that exist in regard to achieving a world class Western Australian Knowledge Hub through the university sector;
- Identifying structural factors that facilitate or inhibit the role of the State's universities in the development of a Western Australian Knowledge Hub that can achieve global recognition.

The present study has drawn on local and international experiences to guide state government in developing policy options to maximise cooperation and coordination among universities so as to optimise the state's investment and strengths in the provision of skills and knowledge.

Interviews were held with key stakeholders in WA through August, October and December 2001 and February 2002. In parallel with these interviews the project team collected and analysed national and state data sets to identify the current state of knowledge intensity and investment in the State. The analysis and proposed strategy for WA presented in this report also draws extensively on international case studies, many of which are presented, in summary form, in this report.

1.2 What is a Knowledge Hub?

It is now widely recognised that global competitiveness is dependent on the capacity of economies to acquire knowledge capital and to apply new knowledge through a highly trained and specialised workforce. The term 'knowledge-based' or 'learning economy' emerged to describe those economies in which the production, distribution and use of knowledge are the main drivers of growth, wealth creation and employment across all industrial sectors. The concept of a knowledge-based economy has sometimes been used to make a contrast between so called 'new' economies based on new technologies, from 'old' economies based on long established products and process.

However, a knowledge-based economy is not simply one that emphasises new technologies or even new knowledge. A knowledge-based economy is one in which *all* sectors are knowledge intensive, are responsive to new ideas and technological change, are innovative, and employ highly skilled personnel engaged in on-going learning. In short, knowledge and skills have to be useable and used in the production of all manner of goods and services.[1]

As knowledge-economies have become more global they have become more independent of national institutions and processes. This is because knowledge is produced, transferred and diffused through organisational networks that are only partly dependent on proximity. Some analysts have used the term 'organisational proximity' to refer to the capacity to share knowledge and interactive learning among firms and other knowledge-intensive institutions.

However, spatial proximity is only one aspect of organisational proximity. The growing sophistication of information and communication technologies has opened the way for the growth of knowledge networks 'based upon spatially dispersed' interaction.[2] It is the combination of proximity and spatially dispersed interaction that characterises the development of 'knowledge hubs' in various parts of the world.

A knowledge hub is essentially an ensemble of knowledge-intensive organisations located in both public and private sectors. Some are research-intensive knowledge producers, such as research institutes or universities. Others are demanding knowledge users, including firms but also service providers such as hospitals. The knowledge-users provide a focus for knowledge-generation, transmission and diffusion. Producers and users are closely connected and, while spatial proximity is important, they do not have to be physically co-located. The experiences and economic impact of knowledge hubs such as the Silicon Valley and the North Carolina Research Triangle emphasise the integrated role of human resources, public agencies and firms in generating and applying international and local knowledge.

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1 OECD, *Cities and Regions in the New Learning Economy,* OECD, Paris 2001, p. 11.
2 OECD *ibid,* p. 21.

Knowledge hubs have three major functions: to generate knowledge; to transfer and apply knowledge; and to transmit knowledge to others in the community through education and training. Knowledge hubs generate new basic knowledge of relevance to many industries, both old and new. The impact of this knowledge is not necessarily direct, nor immediate. But it is influential. In addition, they also generate applied knowledge that is directly and immediately relevant to local industries. Secondly, knowledge hubs capture (and participate in creating) knowledge generated elsewhere, nationally or internationally, and develop this further to meet specific local needs. Thus national or international knowledge is translated, applied or transferred into locally useful knowledge for supporting existing industries, generating new industries, informing public policies and meeting other kinds of community needs such as health, urban planning, environmental control, education, and aged care. The transmission function of a knowledge hub takes place through educational institutions such as universities and schools but also through life-long learning processes that involve firms, community based institutions and a variety of government agencies and services including hospitals, clinics and professional associations.

1.3 The Role of Universities in Knowledge Hubs

Universities have an important role to play in all three major functions of a knowledge hub. However, there needs to be an interdependent relationship between universities and the other sectors that contribute to the hub. While it can be observed that knowledge hubs are 'almost always "anchored" by a great research university, producing high quality graduates and leading edge technology, the converse is assuredly not true.'[3] Not all great universities are surrounded by a booming economy. Thus the role of universities in supporting the development of a knowledge hub can be usefully understood by considering their role in deepening knowledge intensity across different sectors, industries and the broader community through the generation, transfer and transmission of knowledge. Essential to this role are the international, national and local domains through which knowledge is *captured* and *used*. This interactive and integrated process through which a knowledge hub functions is illustrated in Figure 1.1.

In considering the role of particular universities it is useful to bear in mind that present university forms and organisation are historically contingent, and not based on necessity. This means that they need to be rethought every so often as circumstances change. For example, in the nineteenth century universities grew in western countries during an explicitly nation-building era. Universities grew as other elements of their societies grew – cities, wealth, and scientific discoveries. But they grew differently in different countries. In France, for example, in the nineteenth century for several decades they became little more than places for polite public discussion. In their place the *Grandes Ecoles*, elite technical teaching institutions, were created to take the state's aims forward. The importance of that distinction still colours the higher education landscape in France today. In Australia, universities were modeled on the Scottish system mixed with some elements of that of the US. Whilst European universities are built on quite different models. Since, in Europe, students who

[3] Louis, G. Tornatzky, Denis O. Gray, and Paul G. Waugaman, *Making the Fture: Universities, Their States and the Knowledge Economy,* Southern Growth Policies Board, Raleigh, 2001, p. 3.

complete secondary education are guaranteed a place by law and are supported by a series of social measures as long as they are students, universities are flooded with young people who mostly drop in and out and in again over many years.

The point of these examples is to emphasise that knowledge generation and transmission can take many forms. One needs to recognise that there is no one best way in which to organize them. Everything can and should be rethought as the social context and role of universities change. The essential thing is to rethink broadly. Just amalgamating universities in places where there are thought to be 'too many' or as others have reported 'too few' may be to not think broadly enough. A critical ingredient for a successful knowledge hub therefore concerns the ways that universities cooperate among themselves and with other institutions to generate, transfer and transmit knowledge and the way they organise themselves internally to achieve this.

Recent work on clusters of business activity and the relationship between such clusters and 'knowledge hubs' centred on public sector research organisations has indicated that these relationships are a good deal more complex than was suggested by initial observers. Early studies often assumed a straightforward relationship such that more research and closer links between local industry and researchers were always 'better'.

Recent studies have shown that universities and similar public sector research institutions differ in their relationships with user organisations both in relation to the *type* of new knowledge concerned in the transfer and to the *mechanisms* of such transfer. Both relationships and knowledge transfer are critically affected by the level of sophistication of the receiving companies. It now seems that universities generating leading edge research have a very broad 'footprint' in terms of the organizations interested in receiving the knowledge generated. This means that sophisticated companies located very far away in geographical terms may well be the most interested in 'breakthrough' research in basic sciences whereas less caring companies, located closer to the source of knowledge, are unable to see value. This is because, for example, breakthrough research information can be readily absorbed by the high level R&D personnel, working in the science-intensive firms, even though they are further away spatially and/or by the product development teams in that segment of industry which may be located in many places. In other words, personnel in some firms may be 'symbolically closer' to the knowledge generators than others located geographically nearby. A good example of this is the close relationship between the mining industry in WA and the University of Queensland.

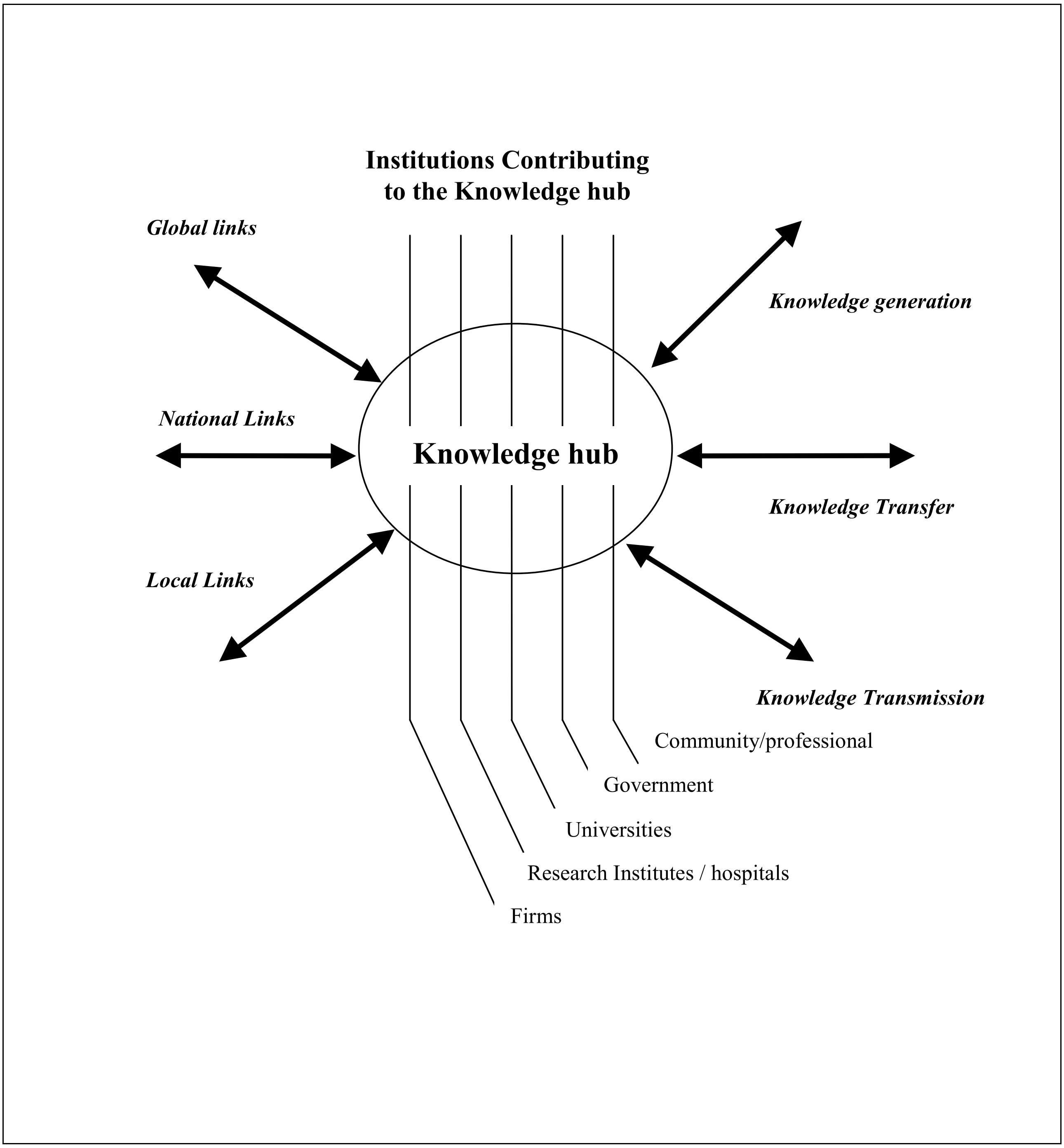
In some cases, this research-intensive relationship may encourage receiving firms to relocate their operations to be nearer to particular universities generating the new knowledge but in most cases the knowledge received needs to be matched with and incorporated into high level information generated in other research organizations located elsewhere again. Provided that the firms' 'receptors' are well tuned to research activities in a given set of organisations there is no reason for them to co-locate in any given area. This means that high-level internationally leading edge areas of research in given universities may be of great value to leading firms in certain industries *wherever* they may be located. Thus, while such work may seldom directly encourage firms to co-locate with research leaders, it may, via a more circuitous route, also contribute to the upgrading of firms in the researchers' area - for instance, suppliers to the distant receiving firms must upgrade their capacity to incorporate the new knowledge in order to maintain their market position.

In this upgrading process they may engage with other, often more local, knowledge-generating institutions whose research is more applied and can be used to test new products or equipment as part of a more general upgrading process. In these circumstances enterprises may be linked to knowledge-generating institutions in ways which involve short term or formal spot contracting arrangements. These arrangements may be with individual companies or the research may be jointly commissioned and received by 'clubs' of enterprises with a more or less collective interest in the outcomes of research experimentation or testing. In this kind of arena in particular knowledge acquisition is not free; indeed, it can be extremely costly in financial terms, both for the direct contracting arrangements and through the need on the part of some firms to employ new or more highly skilled R&D or other personnel and extra equipment.

In this sense, the creation of a 'knowledge hub' has many dimensions, which mean that spatial proximity to the sources of new knowledge does not *automatically* encourage firms to take advantage of what is on offer, nor does distance necessarily deter them.

As the institutions in a knowledge hub develop and mature the challenge is to maximize local benefit for local stakeholders, Universities, through collaborative partnerships, are becoming more international and are involved in activities quite different from their role 20 or 30 years ago. There is thus a challenge to ensure that universities remain knowledge diffusers or transmitters as well as knowledge producers. Different universities in a region may perform these roles in different combinations and in different ways. Each can be very valuable. The international experiences discussed in Chapter three of this report provides some interesting and creative examples to illustrate how this diversity can be harnessed and integrated into a state knowledge hub.

Figure 1.1 The Interactive Nature of a Knowledge Hub



2. THE STATE OF THE STATE: STRENGTHS AND WEAKNESSES OF UNIVERSITIES IN CONTRIBUTING TO A WESTERN AUSTRALIA KNOWLEDGE HUB.

2.1 Industry investments in Knowledge and Innovation

Many areas in different countries have developed some of the characteristics of a knowledge hub in that they have created and used high technology or new scientific knowledge. This has often involved both firms and higher education institutions in a degree of specialization. Internationally and nationally there is usually considerable variation in this knowledge generating capacity by "region".

One useful measure of "regional capacity" to generate new knowledge is the level of R&D expenditure carried out by business and other R&D performing sectors located in that region. The ABS collects data on R&D expenditure in Australia by State and by sectoral location in which the R&D is carried out. More detailed data are also available for field of research, socio-economic objective and, in the case of business sector, by industry classification (ANZSIC).

At the national level there has been a steady increase in the level of higher education expenditure on R&D. In contrast, there has been a steady decline in the level of Commonwealth expenditure in other forums. In the business sector there was a rapid rise through the early 1990s followed by a marked decline after 1995 (see Figure 2.1).

International evidence shows that in most OECD countries, investments in knowledge actually increased through the 1990s. Consequently Australia's knowledge investment performance in international comparative terms has weakened. In 1985 Australia's R&D investment was 85 per cent of the level recorded in the U.S. By 1998, the Australian level of investment was only 70.5 per cent of the U.S. level.[4]

A more detailed analysis of the Australian data shows that the business sector decline is mainly due to declining R&D investments in the mining sector. For 1996-7 the mining sector invested $545 million in R&D, second only to electronic and electrical equipment. This represented over 13 per cent of all business sector investment. By 2000 national business R&D expenditure in this sector had fallen to $272 million, 6.7 per cent of all business sector investment.

Western Australia (WA) has been a major contributor to national development in the mining and minerals sector and it is not surprising that the national trend noted above is reflected in the WA data. Data for the year 2000 shows a continuing trend toward lower business sector R&D investment in WA (see Figure 2.2).

The period leading up to 1996 suggests that WA was well placed to become a national knowledge hub. It had a higher level of gross expenditure on R&D (GERD) per capita than the national average, second only to the ACT and Victoria. But, more

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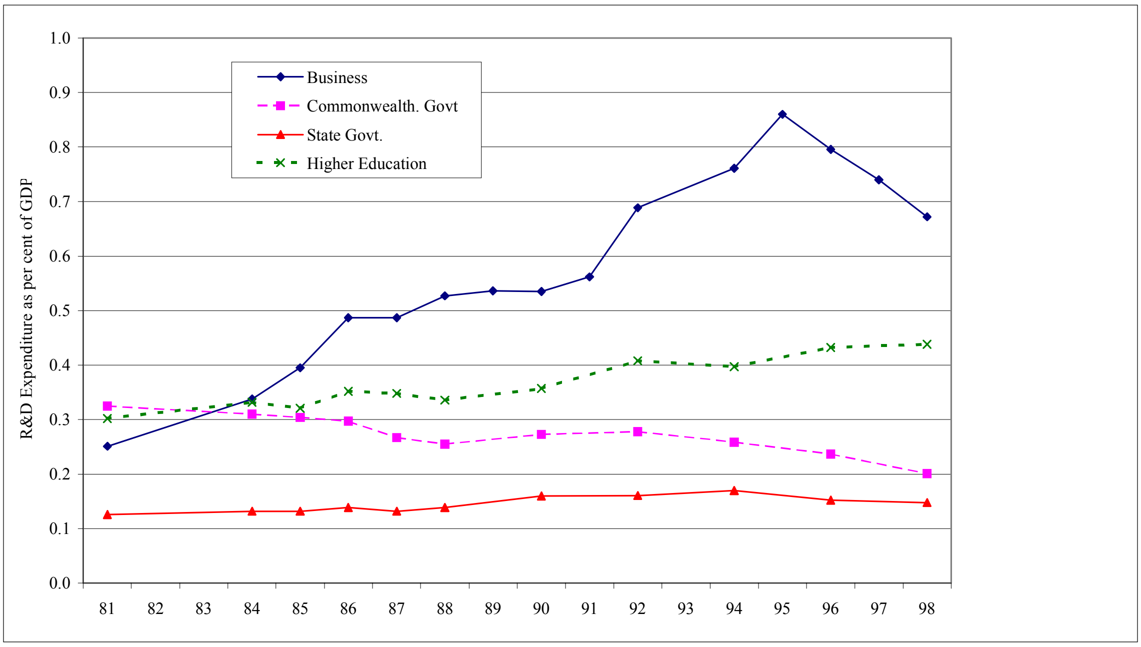
4 M. Consadine, S. Marginson, P. Sheehan and M. Kumnick, *The Comparative Performance of Australia as a Knowledge Nation,* Chifley Research Institute, April, 2001, p. 2..

significantly, it had a higher level of business expenditure on R&D (BERD) than every other State except Victoria (see Figure 2.3). Further, in Western Australia the proportion of business sector investment in R&D increased rapidly through the early 1990s, from just over 33 per cent in 1989 to 57.8% in 1996-7, equal to the Victorian business sector performance and higher than all other States.

After 1996, however, the situation in WA changed dramatically. The data suggest that since 1996-7 the State has entered a new and less favourable period in knowledge development with a considerable downturn in business sector R&D investment.

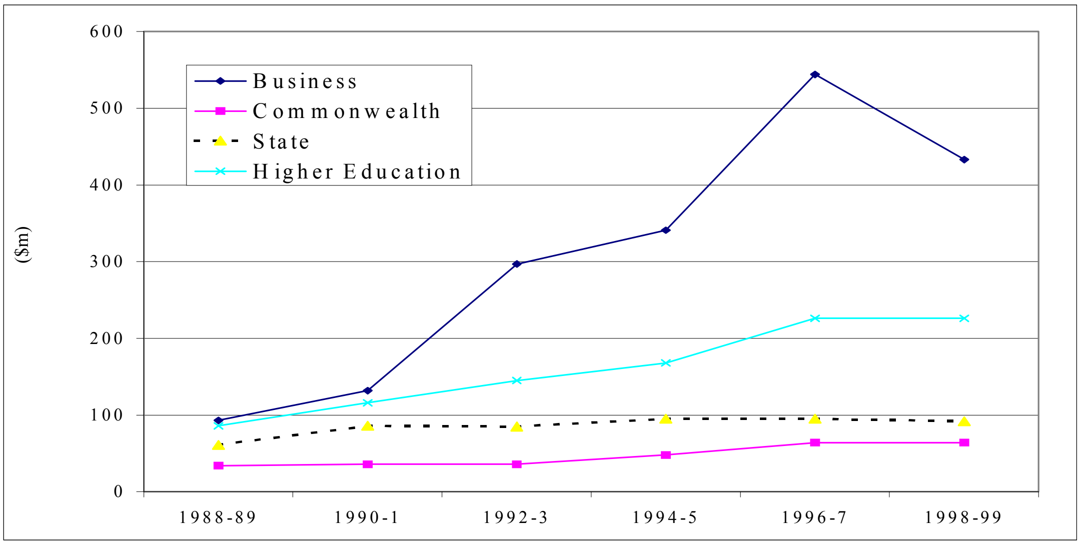
This downturn is also seen in the results of Australian national innovation surveys. The results of these surveys show a marked decline in Australian innovation between 1994 and 1997. However, for WA the decline has been even more pronounced than elsewhere in Australia (see Table 2.1). While the proportion of Australian firms undertaking technological innovation fell from 32 to 26 per cent between 1994 and 1997, the proportion of WA firms fell from 39 to 24 per cent. We focus in more detail below on the period from 1996 to the present.

Figure 2.1 R&D expenditure (by sector of performance) in the business, government and higher education sectors, Australia, 1981-82 to 1998-99



Source: Garrett-Jones and Liu, 2002.

Figure 2.2 R&D Expenditure by Sector: WA, 1988-1999



Source: ABS, R&D expenditure data. Tables prepared for the Centre for Research Policy, 2001

Table 2.1 Percentage of Businesses in WA Undertaking Technological Innovation by Industry

Industry subdivision	*1994(b) WA*	*1994(b) Aust*	*1997(a) WA*	*1997(a) Aust*
Food, beverages & tobacco	57.5	33.5	*33.4	36.3
Textiles, clothing, footwear & leather	*35.9	28.2	*13.9	15.4
Wood & paper products	**4.6	14.3	2.7	15.7
Printing, publishing & recorded media	*47.4	32.3	**33.9	25.6
Petroleum, coal, chemical & assoc. products	*37.2	44.6	35.3	42.1
Non-metallic mineral products	*37.1	35.2	*18.3	35.5
Metal products	*38.3	30.9	*6.9	21.1
Machinery & equipment	43.8	40.3	32.9	35.3
Other manufacturing	34.0	30.5	*31.1	20.9
Total manufacturing	*39.4*	*32.2*	*23.8*	*26.0*

* indicates a standard error >= 25%
** indicates a standard error>= 50%
(a) reference period 1/7/94 to 30/6/97
(b) reference period 1/7/91 to 30/6/94

Source: ABS, *Innovation Surveys* special tables prepared for AEGIS, 2001

Business sector R&D in WA has long been concentrated in mining and metal production. Significantly, these areas were the major contributors to the recent fall in R&D investment. Thus, for example, between 1996 and 97 the proportion of mining R&D expenditure dropped from 42 to 30.7 per cent. It recovered to record 49.3 per cent in 1998-9 but then dropped again to only 29.2 per cent in 1999-2000. The other major R&D performing sectors - metals and electrical show similar volatility (see

Table A1 in Appendix One). Property and business services R&D remained comparatively stable. However, there were some growth areas such as motor vehicles and other transport, industrial machinery, and from a lower base, scientific research, and photographic and scientific equipment. This latter group suggests some areas that might be explored more closely in the context of the other R&D investing sectors.

Generating a knowledge hub is not simply about getting the business sector to invest more resources in concentrated areas of industrial R&D. Rather, it concerns building globally competitive niche areas and developing an international reputation for excellence within them. *While R&D is a major factor in producing new knowledge, a well functioning knowledge hub requires a strong university sector to complement these investments by transferring the knowledge to students. It is these sorts of complementary functions that create a highly skilled environment for transferring knowledge between the university sector and business.*

2.2 The Western Australian University System

2.2.1 The Universities

There are five universities in Western Australia. The oldest, the University of Western Australia (UWA), was established in 1913 and served the State as the only university until 1975.

Tertiary programs available in Western Australia prior to the formation of UWA were offered through technically and professionally oriented institutions such as the Perth Technical College (PTC), which opened in 1900, the WA School of Mines, which opened in 1902, and the WA College of Education (dating back to 1902). These earlier institutions provided the institutional foundations for the present day system of five universities.

In 1966 the PTC was incorporated into the Western Australian Institute of Technology (WAIT) and located at a new site a few kilometres south of the city centre. In 1969 three other WA institutions merged with WAIT: the WA School of Mines, the Muresk Agricultural College (formed in 1926) and the Schools of Physiotherapy and Occupational Therapy (formed in the 1950s).

In 1970, planning commenced to establish WA's second university. State legislation to establish the university was passed in 1973 and 1975 became the university's inaugural year. These two universities formed WA's top tier of what became known as the binary divide in higher education. UWA and Murdoch offered both undergraduate and postgraduate degrees and were funded for both teaching and research. The second tier of the system, comprising the Institutes of Technology and Colleges of Advanced Education, offered undergraduate degrees only and received public funding for teaching but not for research.

The Dawkins reforms of the late 1980s, ended the national binary divide and created a 'unified national system of higher education. At that time all Australian universities were encouraged to amalgamate with other institutions in new areas, where appropriate, to achieve a level of critical mass (at that time assumed to be around

8000 EFTS - equivalent full-time students). In 1987 there were 19 universities in Australia and 47 colleges of advanced education. By the early 1990s, following a spate of amalgamations, there were 32 universities and three colleges of advanced education. In WA two 'new' universities emerged, Curtin University of Technology in 1986 and Edith Cowan University in 1991. Pressure for amalgamations involving Murdoch University emerged through the 1980s and again in the 1990s but were rejected on the basis that they were not viable and not in the long term interests of the State.

The State's fifth university, the University of Notre Dame, a small private university, was founded in 1990. These five universities, four public and one private, serve to provide WA with undergraduate and postgraduate degree courses, a range of professional diplomas and certificates, and considerable capacity for research and development in many fields.

2.2.2 University Governance

Under the Unified National System of Higher Education universities are funded under the Federal Higher Education Act. Block grants are allocated for teaching and research on the basis of national formulae which take into account the comparative numbers of full-time equivalent students enrolled over recent years and institutions' comparative success in attracting competitive research funds, numbers of research student completions and the numbers of publications produced. Universities are also required to report centrally through research and research training management plans and through on-going quality and audit assessments.

However, all universities, with the exception of the Australian National University, operate under their own Acts passed by State Legislation. In Western Australia, the Acts specify governance arrangements for each institution and set out the balance of representation on each university's Senate. Governments in WA have tended to take a non-interventionist approach to university governance and there is no single State authority with overall responsibility for university policy. This stands in contrast to the situation in Victoria and Queensland. Victoria, for example, is currently reviewing existing governance arrangements for all Victorian universities. Queensland has a long track record of effective intervention, utilising a range of incentives.

Western Australian government has some incentives in place to support the concentration and development of research infrastructure. The Centres of Excellence program, for example, provides grants intended to lever additional Commonwealth funds through programs such as the Cooperative Research Centres. On occasions the government has sought to generate concentrations in strategic teaching areas, such as engineering and business studies, through institutional cooperation across universities and business schools, but these efforts have had mixed success. As one of our respondents put it: 'there are examples where collaboration across institutions have occurred but these are generally weakly developed and depend on personalities for sustainability'.[5]

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5 Interview October 24th, 2002.

2.2.3 Student Enrolments

WA accounted for 9.4 per cent of the Australian university student population in 2000 with a total of 66,654 students enrolled across the five institutions[6]. While WA university enrolments have increased by 6.5% over the past five years, they have not increased as rapidly as they have in NSW and Queensland (see Table 2.2). Consequently, through the past five years WA's share of the national student population has fallen from 9.7 per cent in 1996 to 9.4 per cent in 2000. However, the overall increase in student enrolments is primarily due to the rapid rise in overseas enrolments. In WA overseas students account for 15 per cent of all students, compared to 13.7 per cent nationally (Table 2.3).

The five WA universities reflect quite different enrollment profiles. Curtin University is the largest institution with 21,614 students. Edith Cowan is a similar size with 19,091 students. The University of Notre Dame carries the smallest number of students (1,407 enrolled in 2001). The University of Western Australia enrolled 13,479 and Murdoch 10,863.

Table 2.2 Total Enrolled Australian University Students by State, 1996-2000

Year	*NSW*	*VIC*	*QLD*	*WA**	*SA*	*TAS*	*NT*	*ACT*	*Multi-State*	*Total*	*WA as % of Total*
1996	195,240	175,038	108,175	61,354	47,919	12,761	4,976	19,993	8,638	634,094	9.7
1997	204,524	179,030	114,641	65,209	48,535	12,840	4,678	20,020	9,350	658,827	9.9
1998	210,618	182,154	117,919	65,657	48,041	12,628	4,689	19,941	10,206	671,853	9.8
1999	216,997	183,882	121,537	67,367	49,037	13,108	4,707	19,871	9,761	686,267	9.8
2000	223,459	185,978	125,185	65,321	49,027	12,778	4,496	19,528	9,713	695,485	9.4
% change	14.5	6.3	15.7	6.5	2.3	0.1	-9.6	-2.3	12.4	9.7	

* Note: See Footnote 6, below.
Source: DEST, 'Students 2000 – selected higher education statistics database.

2.2.4 Overseas Student Enrolments

Progressive deregulation in the Australian university sector through the 1990s (as well as deregulation overseas) has enabled WA universities to contribute to the WA economy through the international marketing of higher education. Australian institutions captured a considerable component of the overseas student market. Overseas student enrolments grew from 25,000 in 1990 to 96,000 in 2000. By 2000, nearly 14% of all Australian higher education students were overseas students. WA universities have enrolled a considerable proportion of these students (10.4 per cent of all international students in Australia). This suggests WA universities are well linked internationally. However, the significant growth in numbers in WA over the past

[6] The official DEST data for WA do not include the total number of students enrolled at Notre Dame University. The total number of students enrolled at Notre Dame have been revised and reflected in Table Three. The total number of students shown in Table Two are based on the data provided by DEST.

decade has not matched the significant growth at the national level.[7] The majority of overseas students studying in WA were enrolled at Curtin (43.8%) and Edith Cowan (21.8%).

Table 2.3 Australian and Overseas Student Enrolments, WA and Australia: 2000

Enrollment Location	*Australian students*	*Overseas students*	*All students*	*% overseas students of all students at location*	*% of all WA Students*	*% of all WA overseas students*	*% of all WA Australian students*
UWA	11,955	1,524	13,479	11.3	20.3	15.3	21.2
Curtin	17,355	4,259	21,614	19.7	32.5	42.8	30.7
Murdoch	9,042	1,821	10,863	16.8	16.3	18.3	16.0
Edith Cowan	16,965	2,126	19,091	11.1	28.7	21.4	30.0
Notre Dame	1,196	211	1,407	15.0	2.1	2.1	2.1
Total WA	***56,513***	***9,941***	***66,454***	***15.0***	***100.0***	***100.0***	***100.0***
Total Aust.	599,878	95,607	695,485	13.7			

Source: DEST, 'Students 2000 – selected higher education statistics data base supplemented with data provided by individual institutions.

2.2.5 Indigenous Students

Western Australian universities also enroll a high proportion of indigenous students. Just over 20% of all Australian indigenous students enrolled in universities are enrolled in WA. Edith Cowan and Curtin enroll the highest proportions of this group of students. Of the 1,474 Aboriginal students in WA 52 per cent are at Edith Cowan and 28 per cent at Curtin.

2.2.6 Enrolments from the WA Regions

The number of university undergraduate commencements from regional WA in 2001 shows a general decline on 1996. As proportions of the regional population (regional students per 1000 regional population) commencements have declined from a peak in 1997 of 4.17 per 1000 regional population (2,124 students) to a low of 3.57 (1,838 students) in 2001 (see Table 2.4 and Appendix 2). This fall in WA regional university enrolments stand in contrast to general increases in the resident population aged 15 - 19 years in the regions. The regional population in this age cohort between 1996 to 2000 rose by 14 per cent. In Peel, the one region that shows a general growth trend between 1996 and 2000, the 15-19 years age cohort increased by over 27 percent. However, it should be noted that Peel is essentially an outer urban region of Perth and consequently is not representative of the rural regions of WA.

The regional resident population in the 20-24 age group has, in contrast, declined between 1996 and 2000 (-0.8 per cent). But in two regions, the Mid-West and the Pilbara, the 20-24 resident population has been increasing (by 18 per cent in the Mid-West and by 10 per cent in the Pilbara).

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[7] TIAC, *Export of Western Australian Education and Training: Constraints and Opportunities*, TIAC, October, 2000, Table A1.

These WA regional enrolment data show that while the regional populations from which university students are generally recruited have been growing over the past five years, enrolments at the State's universities from these regions have been decreasing. The decline in resident population in the regions for the 20-24 year age group, interpreted in the context of an increasing 15-19 years age group, suggests that typically this age group is continuing to leave the regions but few, apparently, are doing so to study at universities in WA. Another factor to take into account in interpreting the data is that in the more remote WA regions there is a high proportion of the Aboriginal population who, for a range of socio-economic reasons, have had low tertiary participation rates. It is worth noting, however, that Aboriginal university participation rates have been rising generally and cut across a wider range of study fields.[8] Some of the WA universities, Edith Cowan in particular, have been making major contributions to increasing Aboriginal university enrolments.

Table 2.4 Commencing undergraduate students by WA region, 1996-2001

WA Region	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
Gascoyne	20	22	19	13	12	13
Goldfields-Esperance	240	330	442	295	209	200
Great Southern	261	230	244	245	235	193
Kimberley	92	105	84	67	108	87
Mid West	238	258	204	319	242	240
Peel	165	175	191	238	248	213
Pilbara	109	76	70	49	56	47
South West	683	695	638	725	656	686
Wheatbelt	188	233	162	225	193	159
Total regions	*1,996*	*2,124*	*2,054*	*2,176*	*1,959*	*1,838*
Ratio per 100 regional population	4.17	4.42	4.19	4.35	3.86	3.57

Source: Data provided by institutions

2.2.7 Postgraduate Enrolments

In 2000 the total WA postgraduate student population was 10,929 students. This represents 7.7 of the total Australian postgraduate population. While the WA postgraduate student population has increased from 6,956 in 1989 to 10,938 in 2000, the State's proportion of all national postgraduate student enrolments has been in a general decline since that year (see Table 2.5). This decline becomes more serious when it is taken into account that WA has the nation's fastest growing cohort of 18–25 year olds.

[8] See Turpin, T, Iredale, R. and Crinnion, P, 'The Internationalisation of Australian Higher Education: Implications for Australia and its International 'Clients' *Minerva forthcoming*, 2002.

The decline has not been uniform across all fields of study, however. For example, business enrolments, although increasing from 1,670 in 1989 to 2,787 in 2000, fell from 13.7 per cent to 6.5 per cent of the national total over this period. Engineering remained reasonably stable, falling from 5.9 to 5 per cent over the same period. Education, architecture and veterinary science actually increased their proportion of national enrolments (see Table A2 in Appendix One).

In 2000, Curtin had the highest share of the State's postgraduate students (32.1 per cent). Edith Cowan had 25 per cent while UWA had 23.2 per cent and Murdoch had 18.7 per cent. Notre Dame carries a small proportion of the State's postgraduates, 0.5 per cent. In terms of institutional postgraduate intensity, UWA and Murdoch had the highest concentrations, with 18.9 per cent each (see Table 2.6).

Postgraduate students in WA are overwhelmingly concentrated in three fields of study: business economics, education and arts/social sciences. These three groups account for 67 per cent of all Western Australian postgraduate enrolments. This follows the national pattern in Australia but it is more pronounced in WA.

There are major differences in the fields of postgraduate education across the different WA institutions. For example, Murdoch postgraduate students are mostly concentrated in business, education and science, while Curtin's postgraduates are concentrated in business, arts/social science and health. UWA postgraduates, on the other hand, are more generally spread across sciences, education, business and arts/social sciences. Edith Cowan postgraduates are most concentrated in business, education and arts/social science (see Figure 2.3 and Table A3 in Appendix One).

Table 2.5 Postgraduate student enrolments, WA and Australia: 1989 - 2000

Year	*National p/g student enrolments*	*WA p/g student enrolments*	*% WA of national p/g enrolments*
1989	69,993	6,956	9.9
1990	78,851	7,717	9.8
1991	92,879	8,592	9.3
1992	103,471	8,959	8.7
1993	113,642	9,334	8.2
1994	116,775	9,647	8.3
1995	124,123	10,229	8.2
1996	132,500	11,075	8.4
1997	138,051	11,784	8.5
1998	137,006	11,096	8.1
1999	139,849	11,519	8.2
2000	142,508	10,938	7.7
Per cent increase	103.6 %	57.2 %	- 2.2 %

Source: DEST Student Enrollment Data

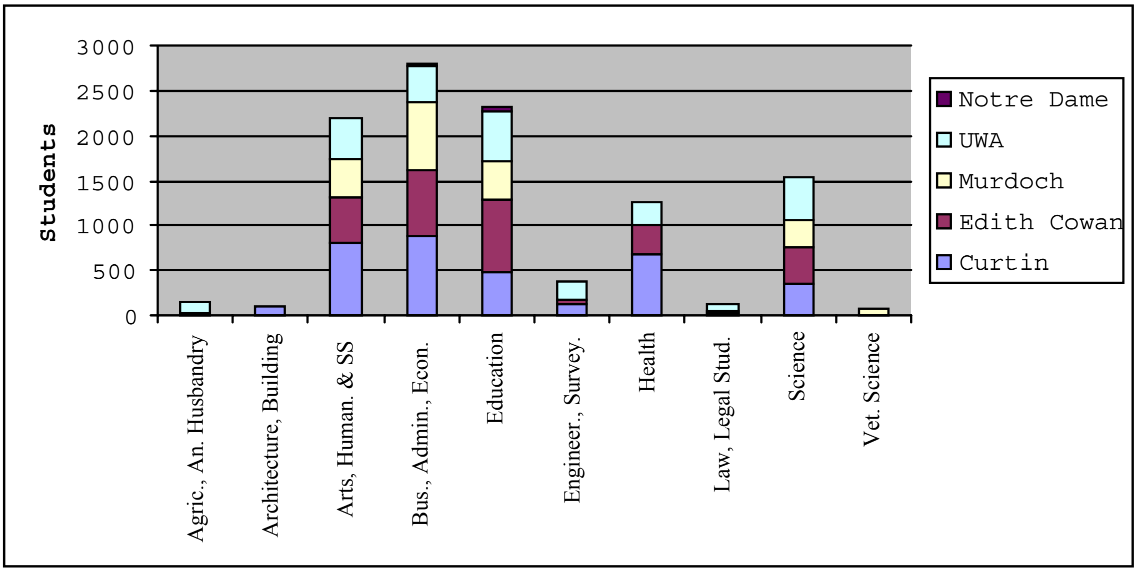
Table 2.6 WA Postgraduate Student Enrolments: 2000

Institution	*Enrolled Postgraduate Students 2000*	*% of all WA PG Students*	*% of total institutional enrolments*
UWA	2,531	23.2	18.9
Curtin	3,504	32.1	16.2
Murdoch	2,049	18.7	18.9
Edith Cowan	2,784	25.5	14.6
Notre Dame	61	0.5	4.2
Total WA	*10,929*	*100*	*16.4*
Total Australia	142,423		20.5
Per cent WA PGs of all Australian PGs		7.7	

Source: DEST, Student Statistics. Tables prepared for the Centre for Research Policy, 2001.

An investigation of the trend across fields of study shows a general convergence in the numbers enrolled across the major four institutions in the larger fields of study. However, these data also reveal some changes in institutional profiles. For example, Curtin University has shown a decline in the number of engineering postgraduate students but a marked increase in social science students (see Figures A1 to A5, Appendix 1).

Figure 2.3 Postgraduate student enrolments by field of study and institution: WA 2000



Source: DEST, Student Statistics. Tables prepared for the Centre for Research Policy, 2001.

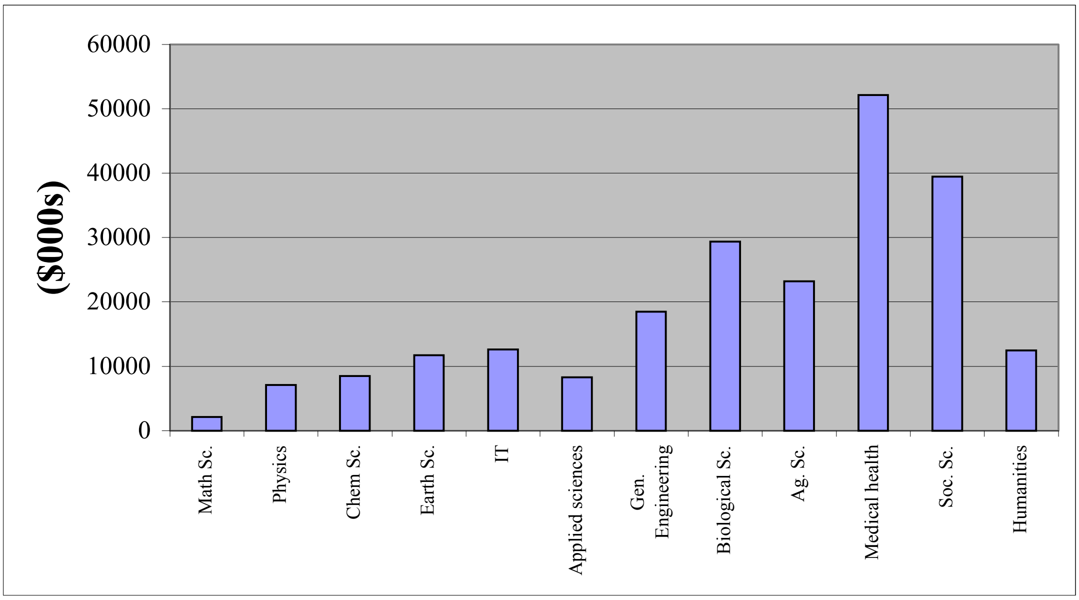
2.2.8 Knowledge Generation: Research and Development at WA Universities

R&D expenditure in WA universities in 1992 represented 8.5% of national expenditure. Through the mid 1990s this rose to nearly 10 per cent. However, the latest available data (1998) show the WA proportion to have fallen back to 8.7 per cent. This reflects a similar fall in the state's business sector R&D investment (from 11.9 per cent of national business sector R&D expenditure in 1996, to 8.5 per cent in 1999.

In 1998 expenditure on R&D at all WA universities totaled $225 million. This figure is small by international comparison (see Chapter Three below). It is also small in comparison with the figure for NSW ($809 million) and Victoria ($557 million) and slightly less than the figure for South Australia ($240 million).

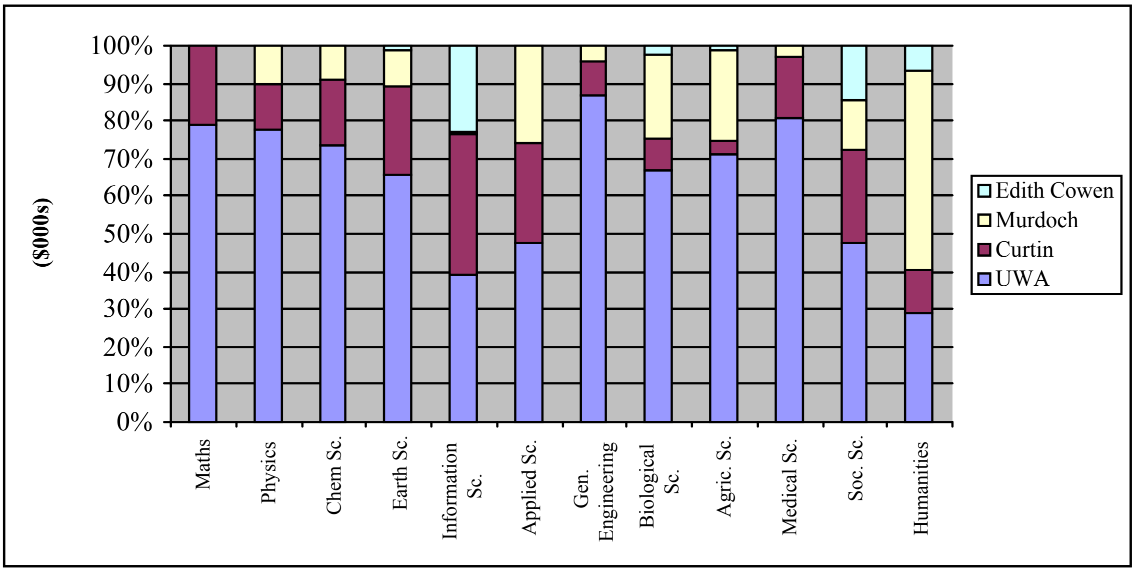
Most university R&D expenditure in WA is on medical research, followed by the social sciences, biological sciences, agricultural science, and general engineering (see Figure 2.4). The physical sciences combined (maths, physics, earth and chemical sciences) account for a figure similar to the combined expenditure in the social sciences. UWA is by far the major R&D performer, followed by Curtin, Murdoch and Edith Cowan. University R&D is funded through two broad mechanisms. It is supported through general university funds (GUF) including academic salaries or through academically separately budgeted research (ASBR). The latter is research that is funded through specifically targeted research including block research grants, external grants or research consulting. Data for the four major research-active universities for 1996 showed that UWA spent around three times the amount of the next largest R&D performer (Curtin) from both funding sources. In some fields, such as general engineering and medical science, UWA accounts for over 80 per cent of research expenditure. However, as Figure 2.5 shows, UWA accounts for considerably smaller proportions of research activity in information science and the humanities.

Figure 2.4 WA University Research Expenditure by Field of Research: 1998



Source: ABS, R&D expenditure data. Tables prepared for the Centre for Research Policy, 2001

Figure 2.5 Research Income at four WA Universities as a Proportion of Fields of Research



Source*:* *Diversity and Convergence*, Table A31, ARC, 2000 data for 1996.

These data illustrate some differences between the five WA universities. The following section provides an overview of each of the five institutions and identifies specific areas of university strength and areas where organisational collaboration might achieve better outcomes for supporting a WA Knowledge Hub.

University of Western Australia

The University of Western Australia (UWA) is the State's longest established university (created in 1913). In the Australian context, it is a medium sized, comprehensive university with around 13,000 EFT students. In 2000, 11 per cent of all UWA students were from overseas and 18.9 per cent of all students were postgraduate students. The total number of commencing undergraduates increased from 3091 in 1996 to 3,471 in 2001.

UWA has a small regional campus at Albany but all students are enrolled through the main city campus. The number of students enrolled from WA regions has increased steadily from 1996 to 2001 (from 318 to 385, currently representing 11 per cent of all students. UWA's share of WA postgraduate students from the regions remains comparatively small accounting for 6 per cent of all postgraduate students.

UWA is generally regarded as one of Australia's leading research universities and certainly the leading research university in WA. It receives approximately $67 million of external research income and expends in excess of $100 million annually. UWA claims to be internationally competitive in terms of capabilities, staff distinctions and research outcomes, particularly across sixteen key areas.

Key research strengths at UWA

Geomechanics and offshore engineering	Agriculture and natural system management	Medical science
Earth sciences	Plant and animal science	Biomechanics
Materials sciences and engineering	Classics and ancient history	Resource economics and law
Environmental engineering	English studies	Telecommunications
Crystallography and molecular science	Anthropology	
Atomic, molecular and surface physics	Psychology	

These research strengths are reflected in the institution's total research income. For example, UWA research income accounts for around 80% of all WA medical science research, 85% of all general engineering, around 80% of all mathematics and physics research, and around 70% of all agricultural science research.[9] The university has considerably lower proportions of research income in the fields of information science, applied science, and humanities.

The university places a high priority on developing strategic partnerships. A new Oral Health Centre, for example, is a joint initiative between UWA, Curtin University, the State Government and TAFE. A new industry partnership has been established with the creation of a $50 million software engineering centre with Motorola. UWA is involved with four CRCs and three Special Research Centres (SRC). UWA wins annually around 60 – 70 per cent of all ARC Discovery grants awarded to WA institutions and between 40 – 50per cent of all WA ARC Linkage grants.

In 2000 UWA received nearly $6 million in research funding from industry grants or contracts. External partners included Samsung, Corning, Woodside Oil and the Australian Rural R&D Corporations.

UWA clearly stands out as a major knowledge producer in the State. Senior university administrators pointed out to us during stakeholder meetings that the university has a unique and central role to play in developing a WA Knowledge Hub.

> 'If WA is to be a major player in the global knowledge economy it needs UWA. It also needs the involvement of the other universities. However, UWA has a special role to perform. This is because of the sheer weight of its research intensity and unique institutional strength.[10]

UWA, as it was pointed out to us, was in the same position as 'lighthouse' universities in the US Northwest and east coast that serve as anchor points for emergent knowledge hubs. In addition, the university has the highest proportion of endowment funding of any Australian university, which places it in a unique position in terms of research flexibility.

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9 These proportions are based on 1995/6 data. While the overall income by FOR has increased since 1996 the proportions for 1996 remain indicative as a general guide.

10 Stakeholder interview August 17th, 2001.

Murdoch University

As Western Australia's second university, Murdoch was established in 1975. It is currently a medium sized university with around 11,000 EFT students. In 2000, 17 per cent of all students were from overseas and 18.9 per cent of all students were postgraduate students. Murdoch aspires to be a world class university distinguished for 'excellence and teaching in research, accessibility, interdisciplinarity and international outlook.'[11]

The total number of new undergraduate enrolments has increased from 1,805 in 1996 to 2,251 in 2001. Murdoch has a regional campus at Rockingham. Although this campus is, for administrative purposes, identified as a regional campus, the majority of students at Rockingham are from the Perth metropolitan area. In 2001 the proportion of regional students commencing at the city Murdoch campus was 12 per cent. The proportion of regional students at the Rockingham campus was slightly more, 19 per cent. The proportion of commencing postgraduate students from regional WA was 12 per cent of all commencing postgraduate students in 2001.

In 2000 Murdoch's research income reached $20 million, approximately 15 per cent of the institution's total income. According to the University, around 80% of all research income is generated through its six established areas of research strength and two emerging areas of strength.

Murdoch University Established and Emerging Areas of research Strength

Established Areas of research Strength		**Emerging Areas**
Agricultural and veterinary biotechnology	Contemporary Asia	Bioinformatics and bio statistics
Hydrometallurgy	Social change and social equity	Intelligent systems and software development for process operation management
Terrestrial and aquatic ecosystem management restoration	Technologies and policies for sustainable development	

In addition to these areas of research strength, Murdoch is the only university in Western Australia with a school of veterinary science.

Murdoch hosts two CRCs: the AJ Parker Centre for Hydrometallurgy and the Australian CRC for Renewable Energy. It is also involved, as a node, in four other CRCs: the CRC for Sustainable Tourism; the CRC for Molecular Plant Breeding; Australian Sheep Industry CRC; and the CRC for Beef Quality.

In terms of FORs, the major foci of research at Murdoch are the biological sciences, agricultural science and the humanities. In previous years, Murdoch has accounted for over 50% of all WA university research income in the humanities.

[11] Research and Research Training Management Report, 2001, p. 2.

According to Murdoch 'stakeholders', mining and mineral processing remain the key areas of international strength. The university has been pursuing a strategy of building and extending clusters of collaboration around these areas.

Curtin University

Curtin University was formally established under State legislation in 1986 as Curtin University of Technology. Curtin emerged from the Western Australian Institute of Technology, which in 1980 was built around four schools: applied science and engineering, health sciences; business and administration and arts and architecture. The business school at that time was the largest in Australia.

In terms of student numbers, Curtin is the largest university in WA (22,000 students in 2000). Undergraduate commencements at Curtin have declined during the past six years, dropping from 4,269 in 1996 to 4,032 in 2001. Of all students 16.2 per cent were postgraduate students and 20 per cent of all students were from overseas. The largest number of postgraduate students at Curtin are enrolled in business studies. This is the largest concentration of postgraduate students in a major field at any of the State's universities (see Table A3 in Appendix One). Other concentrations of postgraduate studies are in arts/social sciences and health/medical studies. Compared to the other universities, a smaller proportion of the University's postgraduate students are enrolled in science (10.3 per cent).

The University's main campus is located in Bentley and other campuses are located at Kalgoorlie, Muresk, Joondalup and Shenton Park. The Graduate School of Business is located in Perth CBD. The proportion of students from the regions is currently 11 per cent, a slight increase from 1998 and 1999. Of all commencing postgraduate students in 2001 at Curtin, 11 per cent were from the regions. In previous years this has been as high as 22 per cent (1998) with 16 per cent in 1999.

The University places a strong emphasis on partnerships with industry, government and community groups, particularly in research and development. Curtin's research income is currently around $20 million. According to the university's research management plan,

> '…[Curtin's] integrated research and research training programs, combined with its capacity to partner, will become increasingly important for sustainable social, health, environmental, and economic development in Western Australia and the broader national and international community'. (Research Management Plan, 2001-2005, p. 7).

Curtin has identified five thematic areas for development based on existing areas of research strength. The five are multidisciplinary areas focused on specific socio-economic objectives rather than specific research fields. They are summarized in the following chart.

Curtin's Five Thematic Multidisciplinary Research Areas

Thematic area	Multidisciplinary focus
Resources and energy	Minerals, petroleum and alternative energy
Information technology and communication	Large scale pattern recognition, telecommunications, signal processing, e-business, communications and economics
Life sciences	Biotechnology, application of molecular biology, rational drug design, formulation chemistry, and innovative nanochemistry.
Health enhancement	Drug use, developmental health, international health, indigenous health, aged care and primary health care.
Liveable communities	Cities, technologies and culture, housing and urban research, and transport studies.

Curtin hosts three CRCs and is a partner in a further three. The University makes a strong claim of success with industry focused research and development, citing commercial 'spin-offs' or collaborative enterprises such as, Atmosphere Networks Inc. and Tinnitech Pty Ltd. The University plans to develop 'incubator facilities' to foster new technology development in partnership with other universities, the CSIRO and industry partners.

The largest share of research income at Curtin has been in the medical sciences, followed by social sciences and earth science. However, in terms of proportion of all fields of research in WA it is most prominent in information science, applied science and mathematics.

Edith Cowan University

Edith Cowan University is the second largest and the second newest in WA. It gained full university status in 1991 but has a history as a tertiary teaching college dating back to 1902. In 2000, the University had just under 20,000 students enrolled across the five main campuses and in four 'center/annexes' in regional areas. The University is in the process of transferring its main campus location from Churchlands to Joondalup. Of all students enrolled in 2001, 14.6 per cent were postgraduates and 11 per cent were from overseas. The University is distinctive in that it has the highest number of indigenous students of all WA universities - 767 students in 2000 - representing 52 per cent of all Aborigines enrolled at WA universities.

After a peak in undergraduate commencements in 1997 (5565) new commencements have declined to 4501 in 2001. The overall proportion of students from the regions has remained fairly steady at around 17 per cent, most located at the Bunbury campus.

Edith Cowan has the second largest proportion of postgraduate students of WA universities - 25.5 per cent - accounting for 14.6 per cent of the institution's current enrolments. The major field of study concentration is in education, 28.8 per cent of all postgraduates enrolled in that field. The second largest group is enrolled in business studies.

The University's strategic plan has sought to expand its traditional teacher education role to focus more broadly on supporting service industries and the professions. As the university notes in its 2001 research management plan: 'ECU will commit itself to helping underpin Australia's development as the most innovative and competitive service economy in our region'.[12] Major areas of development in recent years have included business studies, nursing, communications and information technology and the performing arts. A graduate school was introduced in1998 to 'manage, coordinate and deliver administrative, research training and support services for doctoral, master and honours students, perform quality assurance functions, and strengthen the research culture of the University.[13]

Like other WA universities, Edith Cowan has identified a set of existing areas of strength and foreshadowed emerging areas. These are summarized below.

Current and emerging areas of research strength at Edith Cowan University

Established areas of research strength		**Emerging areas**
Applied financial economics	Education administration	Computer and information technology
Applied linguistics	Human genetics	Corporate governance
Applied social research	Research for service professions	Dance research Human and eco system health
Cancer palliative care and family health	Very high speed microelectronic systems	Multi-media arts SME research
E-commerce		South west regional development Youth affairs

Research income at ECU is modest in national terms but has increased from under $2 million in 1995 to over $3.3 million in 1998. Consistent with the established and emerging strengths, research expenditure at ECU has concentrated primarily on the social sciences and humanities.

Notre Dame University

The University of Notre Dame, established in 1991, is the State's newest and smallest university. Its major campus is located in Fremantle and it has a regional campus at Broome. In 2001 the university had 1407 students enrolled across five colleges: Education; Health; Law; Theology; and Business. Unlike the other institutions it is a private university built around the 'Catholic higher education tradition'. This is reflected in its stated goals, which include to:

- provide, through its teaching, curriculum and pastoral care, for the holistic education of its students;

12 ECU, Research and Research Training Management Plan, 2001, p.5.
13 *Ib id.*

- provide high quality training in the professions and to maximise the employment and career prospects of its graduates; and
- develop an academic community noted for its excellence in teaching and research in major academic disciplines and the learned professions, and for its leadership in debate on issues of public importance. [14]

Notre Dame in Western Australia is affiliated with the University of Notre Dame in the United States.

One of the features of Notre Dame is its commitment to developing higher education in the Kimberley region of WA. Its Broome campus (with 120 students) emphasises, in particular, the 'appropriate' delivery of teacher and health care education to Aborigines in the Kimberley. The education program delivered in Broome was designed to train Aboriginal teachers in remote communities through a 'community-based' approach to education delivery. The University represented this as a unique example of how VET and universities could work more closely together.

While the university is small and focused primarily on undergraduate professional teaching it is in the process of developing a research profile. A Centre for Research and Postgraduate studies has recently been established in Fremantle. The Centre is responsible for registration of research students and administering research training and scholarship schemes. It also coordinates and promotes external applications for research funding. University staff note that Notre Dame is a different type of institution from the others in WA. It is beginning to develop collaborative arrangements with the other universities but as it was pointed out to us: '…these take time and are beginning to develop more strongly over time'.[15]

2.2.9 Cross-sector R&D collaboration in WA

International experiences emphasise two important features of university and industry collaboration. First, they note that universities are critical for providing well-trained graduates and institutional capacity for problem solving in areas of demand by industry. Second, they underscore the observation that universities play a comparatively minor role in developing new ideas and products. These are driven primarily by in-house activities or through collaborative interaction between suppliers or customers. Clearly universities can contribute to knowledge intensity quite broadly not only with producers, but also with their customers and their supplier.

It has often been thought that geographical closeness was critical in the transmission of knowledge generated within formal research organisations and no distinctions were made between the 'kinds' of knowledge generated or the characteristics of the receiving organisations. Thus, it has been sometimes assumed that firms located close to centres of formal knowledge generation were in most circumstances better off in the sense that they had faster and easier access to new information.

This picture is now being modified. While there has been evidence that knowledge is 'sticky', including studies which have shown that companies located within a given

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[14] Notre Dame website: 444.nd.edu.au/about/general/mission.shtml

[15] Stakeholder interview October, 2001.

distance from a university interacted more with that institution, it is now clearer that only *certain kinds* of knowledge do not travel far effectively.

A second strand of recent research relevant here has considered the relationship between spatial propinquity and 'cluster' success. There is evidence that innovative activity, as measured by patent data and the location of high tech industries, is concentrated geographically within countries. Many observers have suggested that one of the reasons for such concentration is that localisation of specific activity, which means that mutual learning proceeds faster because interaction between players is easier. In this way a 'knowledge hub' may be expected to generate similar industrial concentrations because co-location encourages higher rates of learning. Recent research, however, suggests that the process is less related to proximity than has been thought and that knowledge creation and transmission within and between clusters of economic activity proceed in more complex ways than the simple model of co-location-learning implies.

Thus, it is now recognised that, although one reason for clustering may be the attraction of a pool of especially skilled labour (in part created by a local knowledge hub's role in transmitting existing knowledge to students) or an education and research system of special relevance, the attractive power of these factors may vary considerably over the life of any given cluster of productive activities. It may also depend greatly on the characteristics of the industry concerned, the stage of development of the knowledge concerned and the institutions created by the cluster. In some cases, a certain industry cluster may become dominant in an area and develop a set of institutions (practices and 'rules of the game') which come to dominate the local arena, including the 'knowledge hub' arena. Such dominance may not be conducive to the growth of new clusters or industries and may 'crowd out' potential newcomers.

Thus, if the efforts of a knowledge hub are too closely aligned to the needs and interests of *existing* sets of local players they may prove inimical to new entrants who require investments in other areas of knowledge but find that the local research organisations do not have the personnel and other resources to devote to new areas of effort. Paradoxically, therefore, close relationships between researchers and existing clients may stifle new players and new opportunities rather than encourage them. In a practical sense, the need for critical mass in a field always needs to be balanced by the requirement for diversity of effort. This means not only striking a balance between strength through specialisation and the flexibility essential to diversity in *field* of research endeavour but also between the basic and more applied elements of the research effort in all fields.

As we have discussed, universities contribute to knowledge intensity in many different ways of which two stand out. Some universities stand out for their capacity to generate new knowledge, often in quite specific areas. Other universities stand out because of their stronger emphasis on the transfer (or diffusion) to non-university sectors of new or existing knowledge rather than being generators of new knowledge. Others contribute primarily to the direct transmission of knowledge through teaching and training. While some universities are leaders in all areas, this distinction appears a feature of all the regional 'hubs' reported in later sections of this report. This section focuses on the transfer of knowledge and in particular on the relationship between knowledge investments made in the business and university sectors and the potential for interdependence between them.

2.2.10 Sectoral R&D Investment by socio-economic objective

Data on R&D investment by sector and socio-economic objective allow for a comparison between the four performing sectors: business; Commonwealth Government; State Government; and higher education. A key issue for identifying the optimal role for the university system in supporting a WA Knowledge Hub is the extent to which university research investments, according to socio-economic objectives (SEOs), complement or even *lead* investments in other sectors. Available data provide 'snap-shots' for specific years and identify trends over time.

According to 1998-9 data, mineral resources and manufacturing stand out as the major SEOs for R&D investment for the State as a whole. However, a breakdown by sectors reveals different investment patterns. In order to contrast the relationship between R&D performance across State, business and higher education more sharply, we selected the four major SEOs (in terms of R&D expenditure) for each sector. These are shown in Table 2.7. A comparison between sectoral R&D investments among these SEOs between 1992-3 and 1998-9 is shown in Figures 2.6 to 2.8.

Three important observations can be made here. Firstly, there is a marked difference between the SEO investments across the four sectors. A positive interpretation of these differences is that each sector is contributing to the State's knowledge development in different but complementary SEOs. A more negative interpretation would be that there is minimal coordination across the sectors, with each operating in its own traditional band of interest.

A second observation is that there has been a marked change in the SEOs of R&D investment patterns in the business sector. Whereas manufacturing was by far the major focus of investment in 1992/3 there has since been a significant shift towards minerals research as well as toward the environment SEOs.[16] In the State sector, there has been a shift away from animal production and in higher education the natural sciences and health have continued to grow more rapidly than other SEOs. The Commonwealth focus has remained much the same.

A third observation is that there has been a growth in the environment SEO categories across all sectors.

A similar sectoral investment pattern is evident in the R&D data by Field of Research (FOR). Business sector investments are primarily concentrated in general engineering, applied science and information science. Higher education R&D, in contrast, is more broadly distributed across fields of research, although major concentrations are evident in medical and health sciences, social sciences, biological and agricultural sciences. The growth areas (in terms of national proportion) have been biological

[16] To some extent these data present a contrast to the business sector R&D investment by ANZSIC discussed in section 2.1 above, which showed a proportional fall in the mining subdivision. However, the SEO data (derived from the same source) perhaps reflect a shift away from mining associated with manufacturing toward increased R&D expenditure in improving extraction processes and environmental management.

sciences, which have grown consistently since 1992, general engineering and information and computer technologies. The latter two have fallen in recent years following a peak in 1996 (see Table A3 in Appendix 1). Commonwealth R&D investment has focused more on engineering and agricultural science while State investments have been predominantly directed toward agricultural science.

Table 2.7 R&D expenditure in WA by location of expenditure and selected SEOs: (1998/9)

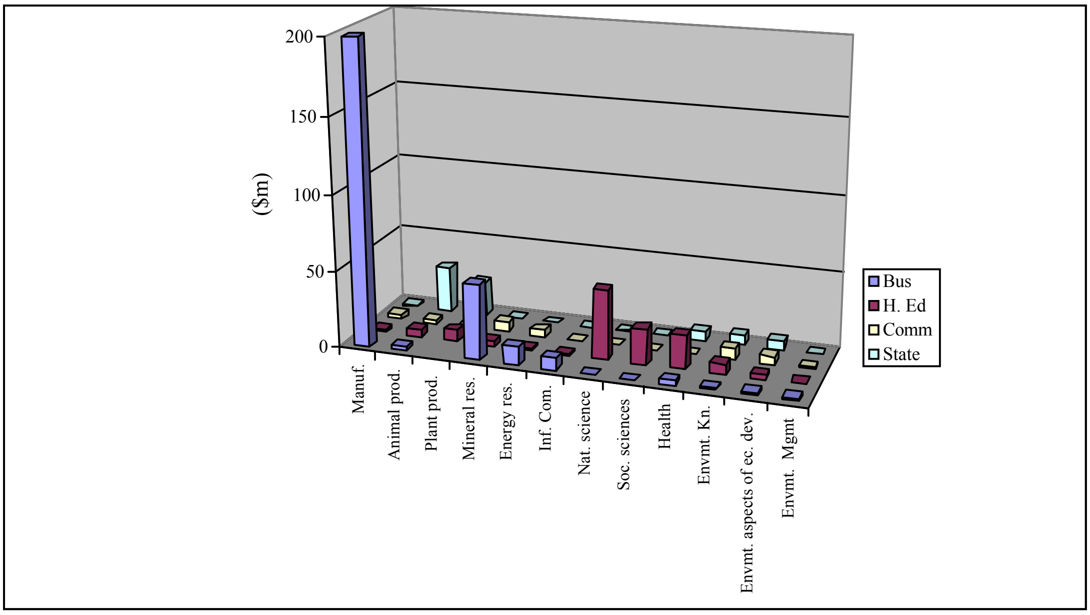
	Sector of expenditure ($million)				
Selected SEOs	*Business*	*High. Ed*	*Comm. Gvt.*	*State Gvt.*	*All sectors*
Economic Development					
Manufacturing.	128.6	4.5	4.7	4	141.8
Animal production	0	6.3	5.4	13.4	25.1
Plant production	4.7	15.5	4.2	32.5	56.9
Mineral resources (excluding energy).	201.6	8.6	10.7	0.1	221
Energy resources.	7.8	3.4	12.5	0	23.7
Inf. And Communication services	22.3	2.1	6.3	0.2	30.9
Advancement of Knowledge					
Nat. sciences, tech. And engineering	1.2	68.2	0.1	2.2	71.7
Social sciences	0	23.4	0	0.1	23.5
Society					
Health	2.3	40.6	0.4	9	52.3
Environment					
Environmental knowledge	4.1	10.9	13.1	9.2	37.3
Env. aspects of economic dev.	23.2	3.7	2.5	2.7	32.1
Env. Management	16	2.9	1.7	17.1	37.7
Total selected SEOs	*411.8*	*190.1*	*61.6*	*90.5*	*754*

Source: ABS, R&D investment data prepared by ABS, 2002.

This 'bifurcation' between the State's research performing sectors, as it has been referred to in another recent report to TIAC, has been consistent over time. A similar feature can be observed in the Australian data, although it is not so pronounced. Further, business sector R&D investment for Australia as a whole is also more evenly spread across SEOs and fields of research, with minerals and energy in a far less predominant role.

While this represents a challenge for Western Australia, we do not necessarily view the sectoral differences, as problematic *providing* there is cooperation between the sectors in producing and transferring the knowledge. Building such cooperation remains the challenge. As we argue later in this report, greater planning and steering are needed to ensure the necessary linkages and networking does occurs. In particular, optimising the role of the university sector in building a knowledge hub in Western Australia, requires that that the growth areas in higher education research and research training are consistent with the major industrial opportunities and challenges. Further, there is also a need to maximize the role of universities in generating opportunities for raising knowledge intensity in areas other than minerals and energy.

Figure 2.6 R&D Expenditure by Location and SEO, WA: 1992-3



Source: ABS R&D Expenditure, Tables produced for the Centre for Research Policy, 2002.

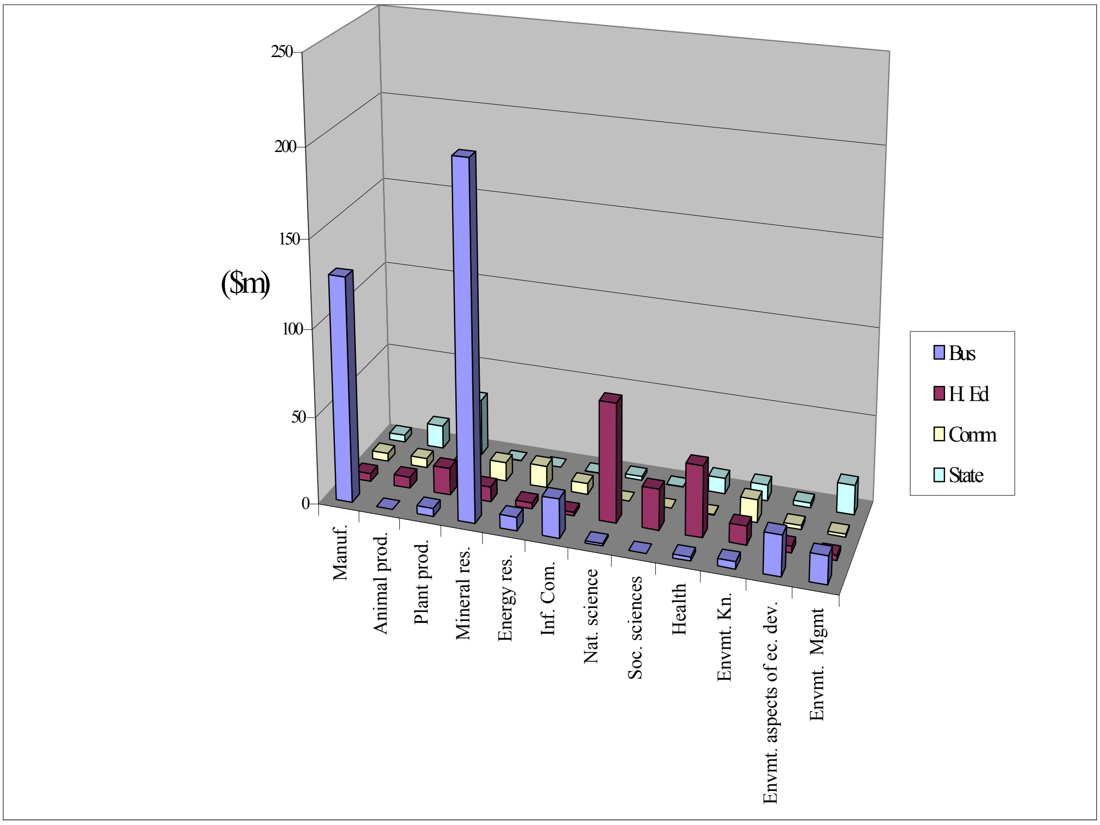
2.2.11 Participation in National Research Programs

The largest national program designed to encourage cross sector R&D collaboration is the Australian Cooperative Research Centres Program (CRCs). Six CRCs are hosted by a WA university. There are nine CRCs in which WA universities are identified as a 'core' partner. The four bigger universities in WA are all core members of at least one CRC.

Other major national research grants for centres and projects are provided by the Australian Research Council and the National Health and Medical Research Council. In 2001 the NH&MRC allocated $216.2 million nationally in new and continuing research grants. Of this, 8.7 per cent was won by Western Australian researchers. The proportion of funds to WA has been fairly consistent over the past decade.

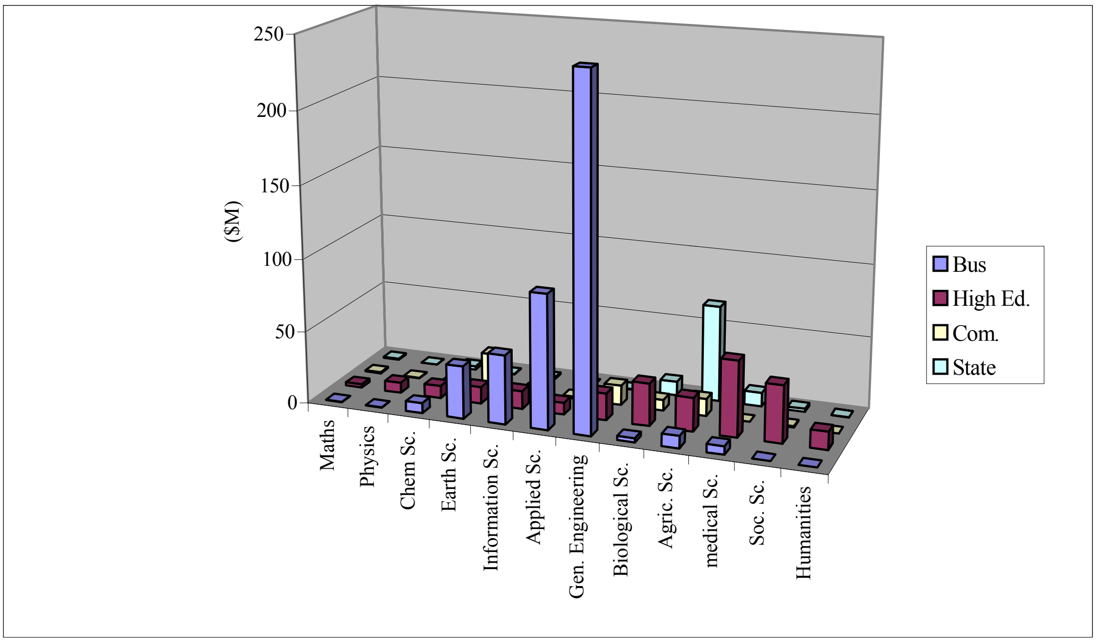
WA universities have done less well in securing ARC Discovery grants (formerly Large Grants). During the past four years, WA has won between 6.6 and 7.7 per cent of all national new grants. In 2001 the WA share was 7.1 percent.

Figure 2.7 R&D Expenditure by Location and SEO, WA: 1998-9



Source: ABS R&D Expenditure, Tables produced for the Centre for Research Policy, 2002.

Figure 2.8 R&D Expenditure by Location and FOR, WA: 1998-9



Source: ABS R&D Expenditure, Tables produced for the Centre for Research Policy, 2002.

However, WA universities have been more successful with ARC Linkage grants (formerly SPIRT grants). The number of Linkage grants obtained has risen steadily over the past four years, from 340 in 1998 to 462 in 2001. The proportion of the total number of Linkage grants won by WA universities in 2001 was 9.7 per cent of the national allocation.

WA University Involvement in the National CRC Program

CRC	Core WA University Participants
Manufacturing Maritime Engineering	 Curtin
Welded Structures	UWA
Aust. Telecommunications	Curtin
Minerals and Energy Australian Mineral Exploration Technologies	 Curtin
Landscape Evolution and Mineral Exploration	Curtin
hydrometallurgy	Murdoch Curtin
Aust. Petroleum	Curtin
Renewable Energy	Murdoch Curtin
Environment Sustainable Tourism	 Murdoch Edith Cowan
Biological Control of Vertebrate Pest Populations	UWA
Health/medical Asthma	 UWA
Agriculture and rural manufacturing Premium Wool	 UNE
Legumes and Med. Agriculture	UWA Murdoch

Source: AusIndustry, *CRC Compendium, 2000*

2.2.12 State Funded Research Programs

Alongside the national programs supporting knowledge transfer, universities and other research organisations have access to a range of WA initiatives. The Centres of Excellence, for example, provides funding for industry-focused research and development in partnership with universities, industry, CSIRO, State Government Departments, Commonwealth Agencies and Research Institutes.

Funding through the Centres of Excellence Program is essentially directed toward supporting research infrastructure with ‘ the objective of enhancing access to substantial federal funds and to promote investment in strategic research and development in industry'.[17] The funding program is therefore complementary to national initiatives such as the CRC program but is also allocated according to the potential for direct benefit to the state. All WA universities are eligible to put forward proposals in partnership with other agencies. A major objective of the program is to ensure that adequate R&D infrastructure is available and conducive to industrial R&D investment. However, funding through the program is limited and spread across a range of research areas. As one of our stakeholders pointed out:

> …the program tries to support too many activities and spread scarce resources too far - too many with too little funding. It's better to add to the strengths that are already there and *lift* that level as far as possible.[18]

A similar point was made by another stakeholder who elaborated on the need to substantially raise the overall level of State investment in R&D.

> We need to identify big problems that can't be tackled by individual institutions, but the State would need to invest sufficient for a 10 per cent R&D increase each year to bring our state to an internationally competitive level. [19]

2.3 Conclusions

The university sector in WA has grown rapidly through the past decade. Over the past five years growth in student numbers has leveled out, with the year 2000 showing the first overall drop in student numbers. The five universities represent considerable institutional diversity and have developed quite different student and research profiles.

WA's universities are clearly performing a valuable collective role in the development of Western Australia's knowledge base. However, the review presented above uncovers some structural weaknesses that work against the optimal functioning of universities in the environment required for developing a globally competitive knowledge hub. These weaknesses are summarized below under the headings of their three main institutional functions in a knowledge hub.

(1) Knowledge Generation (Research)

University investment in R&D in WA has nearly doubled since 1992. The rate of increase has been slightly higher than the national rate (56 per cent in WA compared to 54 per cent for Australia as a whole). However, the growth in WA has varied according to fields and various socio-economic objectives. In some fields, such as the biological sciences the level of investment has increased considerably while in others the increase has been more modest. In the mathematical sciences and humanities investment has actually declined. One university (UWA) stands out as by far the largest contributor to knowledge generation across almost all fields. Major contributions from other institutions represent a smaller range of fields. A challenge for supporting knowledge generation in the region generally is to ensure that

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[17] Government of Western Australia, Department of Industry and Technology, *Guidelines for R&D Support.*

[18] Stakeholder interview August, 2001.

[19] Stakeholder interview October, 2001.

university investments are maximised in key strategic areas that provide the platform for the knowledge hub.

International comparisons show that the level of research investment taking place in Western Australian universities is modest. The total State university expenditure in 2000, for example, was no more than a single research university in the US, Carnegie Mellon University, which has only 7,500 students. It is not so much the size of the university that is important, as the capacity of the knowledge hub, in total, to support leading edge research.

The capacity to fund and adequately develop university research infrastructure generally in WA represents one of the structural weaknesses. While combining resources will bring some economies of scale, having fewer but larger universities but will not overcome the inherent structural financial constraints. As many of the stakeholders in WA pointed out, it is not the capacity of institutions that is the problem but the institutional boundaries that inhibit the capacity to share resources in key areas.

> It doesn't matter how many universities there are so long as they are 'excellent' at what they do. Critical areas need to be brought together and the task is to find a way to ensure agreements can be reached and that they are sustainable.
>
> … There is only limited transfer of staff across universities and between universities and industry. A more effective knowledge hub would be one that has a high level of transfer or exchange between institutions and between sectors.
>
> …One of the weaknesses in the university sector is that there is not sufficient room to 'grow' new and promising academics.[20]

The WA business R&D environment is dominated by the mining sector. This presents both a challenge and an opportunity for the creation of knowledge. It presents an opportunity for the university sector because the mining industry provides a globally competitive platform for leading edge research and development. It provides a challenge because fluctuations in business fortunes in the sector leave on-going investments in university knowledge generation volatile and uncertain.

A further observation that can be made concerns the apparent disjunction between the research investments across the four R&D performing sectors - business, universities, Commonwealth, and State governments. In many knowledge-intensive regions, Singapore for example, there is a much closer alignment between government and business sector R&D investment.[21] We do not necessarily view this as a problem because the sectors each perform quite different roles in a knowledge hub. However, it is essential that there be functional complementarities between the knowledge generation activities taking place in each sector. Now, more than ever before, it is the linkages between the institutions in an innovation system rather than what takes place within each element that is the key.

[20] Stakeholder interviews August and October, 2001.
[21] See ASEAN1997:22.

The small size of the knowledge-economy in WA (by international comparisons) means that a WA Knowledge hub is likely to achieve world class recognition only in a small number of specialized areas.

> Australia is a small country but needs critical mass in selected areas if it is going to have an impact in world knowledge. For a single State this is even more so.[22]

The university contribution to knowledge generation is comparatively broad. In order to strengthen some critical areas it may be necessary to shift resources away from others. This is a complicated task because universities have an important role in deepening knowledge in new and emergent fields as well as in traditional fields of production and service provision. The international experiences discussed in Chapter Three suggest some mechanisms for achieving an appropriate balance between the old and the new.

A report by the Premier's Science Council has recently reviewed the activities in the State's research institutions.[23] The report emphasises the diversity among these institutions which contribute primarily to: mining and energy; conservation and natural resources; fisheries; agriculture; information technology; and health. R&D expenditure within these State research institutions, however, remains a small component of the total R&D expenditure in the State (currently around 12 per cent) and the proportion has been contracting over the past decade. There is an urgent need to ensure these small but often-important components of state R&D effort are able to draw on and contribute to key areas of an emerging WA knowledge hub.

(2) Knowledge transfer

There is evidence of a substantial level of cooperation between WA universities and other institutions. Cooperation is also a product of different types of partnership: between local universities, between local universities and WA industry partners, and with national and international partners. *However, the cooperation is often fragile and sometimes undermined by structural competitive demands.*

The differentiation and pressure for competition between universities, as they each seek to embed and expand their institutional 'niche', seem to inhibit long-term collaboration. Western Australian universities, like their counterparts in other States, operate in highly competitive environments. Knowledge transfer in a knowledge hub, on the other hand, demands collaboration and collective commitment. In contrast to long-term collaboration occurring in other parts of the world, collaborative arrangements in WA appear fragile, are often under-funded and excessively dependent on specific individuals to maintain them. One of the challenges for Western Australia will be to find mechanisms to overcome the negative consequences of competition. Short and long-term benefits are required in order to nurture institutional collaboration. The development and articulation of the WA Knowledge Hub concept could provide a 'medium for cooperation'. The universities could potentially sustain fragile partnerships and consolidate different forms of global,

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22 Stakeholder interview, October, 2001.

23 *Report on Research in Western Australian State Government Agencies,* Premier's Science Council, February, 2002.

national and regional partnership. International experiences discussed in the following section suggest some ways forward.

WA universities, like their counterparts in other States, have commercial arms or technology transfer offices. In countries such as the US there is considerable collaborative activity between the technology transfer offices in the States where innovation is stronger. There is far less evidence of this occurring in WA

One of the key factors in knowledge transfer is the capacity of individuals to work across institutional boundaries. Much of the knowledge generated in universities is transferred to other research groups, businesses or professional organisations not through licenses, patents, or publications but through the know-how of individuals. *In order to maximise the role of the universities in a WA Knowledge Hub there is a need to increase the flow of highly trained personnel between the sectors. There is some evidence of this already occurring through joint supervision and through some secondments.*

WA universities contribute to a range of national Cooperative Research Centres and are engaged in partnerships with industry and institutions elsewhere in Australia and overseas. However, their national share in these programs is well below that of most of the eastern States. Recent evidence shows that the pattern of cooperation in the CRC program is changing. The relative level of CSIRO involvement in the program, for example, has dropped by 50 per cent since the program began. The proportion of Commonwealth funding has gone down, the level of industry funding has increased and the level of State funding has also increased. State governments are consequently taking on a more formative role in steering these sorts of collaborative activities. *A major challenge for WA is to ensure that the State's universities are embedded in these broader national networks but in ways that complement an emerging WA Knowledge Hub.*

In contrast to the international cases discussed in the following chapter, the links between other knowledge institutions or public authorities in WA appear rather loosely structured. While we observed many innovative and valuable examples of collaboration in WA, these were driven almost entirely by a small number of key individuals and, with only a few exceptions, have not generated the critical mass necessary to sustain a globally competitive knowledge hub. Unlike other regions around the world, governments in WA have played only a minor role in steering such collaboration toward strategic goals. For example, in WA, to what extent is university or State sponsored research compensating for the considerable downturn in business sector investment in manufacturing or mining?

(3) Knowledge Transmission

Studies around the world have shown how much industry relies on the role of universities for training highly specialised personnel. There are worrying trends in student enrolments in WA, particularly at postgraduate levels and in science and engineering.

The State's tertiary population appears to have reached a plateau, in terms of local student numbers. Australian enrolments overall continue to grow. However, in WA enrolments have actually decreased between 1999 and 2000. Between 1996 and 2000 overall student growth rate was 6.5 per cent. This contrasts with a national rate of 9.7 per cent, 14.5 per cent for Queensland and 15.7 per cent for Victoria. The WA share of all Australian postgraduates has also been falling. The number of postgraduate students in WA since 1989 has grown at only half the national rate. *In 1989 nearly 10 per cent of all Australian postgraduate students were enrolled at WA universities. That share is now only 7.7 per cent. That trend needs to be reversed and that will require considerable institutional cooperation.*

The postgraduate enrollment data reflect a State weakness in engineering and science. Only 3.3 per cent of the State's postgraduate students were enrolled in engineering and only 14% in science. In contrast, 20 per cent are enrolled in arts/social sciences, 21 per cent in education and over 25 per cent in business. Business, arts, education and the social sciences are important fields of study and an important ingredient in a knowledge hub, but the disproportionately low number of students in engineering and science fields present a major challenge. *If WA is to become an internationally recognized knowledge hub, the imbalance across the disciplines will need to change in favour of science and engineering.*

Given the rapidly evolving learning environments in knowledge economies there is a growing demand for the transmission of new specialized knowledge. This is not necessarily best managed only through traditional university degree courses. There is a need to explore creative options for the design and delivery of specialized training with industry partners. Further, specialised diversity is a feature of knowledge transmission. 'It simply doesn't make sense to combine some courses'.[24] The knowledge hubs discussed in the following chapter of this report are characterized by creative approaches to maintaining diversity in knowledge transmission.

2.3.1 WA Regional Issues

Regional issues raise some specific challenge for the WA university system. Numbers of university students from the WA regions have been decreasing. This is in spite of the fact that all WA universities have a regional presence of some form as well as an increasing proportion of 15-19 year olds living in the regions. Further our interviews with regional stakeholders indicated a strong demand for tertiary training. In areas such as the Pilbara there are strong demands from industry for specialised forms of training. Unemployment is extremely low and many employed are under-qualified for the positions they hold. Given the presence of all five universities in some parts of the State and the diversity of training available, closer cooperation, not only between universities but also between universities and the TAFE sector is desirable.

According to our regional stakeholders, a university presence in some form is essential. This is because distance education or on-line education is not yet widely accepted.

The sheer size of WA raises considerable challenges for the State's university system. The commonwealth competitive funding system provides insufficient incentive for individual institutions to make any real headway in regional higher education

[24] University stakeholder interview, August 2001.

delivery. *However, there are clearly opportunities for more cooperation between institutions in broadening the level of choice available to students in regional areas.*

> University presence is very important for the WA region. In general, industry does not distinguish between the WA universities. They perceive them as delivering a homogeneous product called 'university education'. Access to university services is more important than which university will deliver it.[25]

This view, that institutional boundaries needed to be fluid in order to improve regional higher education opportunities was also shared by many of our university stakeholder respondents.

One of the features of the international knowledge hubs discussed below is that postgraduate education is often managed in a different institutional setting from undergraduate teaching. This does not set aside undergraduate and postgraduate training in a pedagogical sense, but in an institutional sense. The evidence from WA shows that in some areas of postgraduate study small numbers of students are isolated from colleagues and academic staff because of institutional boundaries, in spite of the fact that they are working on similar problems. In the engineering field, for example, only 361 postgraduate students are spread across four institutions. A similar situation exists in various sub-fields in science. *Ways need to be found to build these smaller numbers into a larger critical mass that is linked to research and development, not only in universities but also in all institutions in the knowledge hub.*

These are challenges that face the WA university sector but they are not all unique. Many have been met elsewhere. Before considering a WA approach for optimising the role of universities in WA Knowledge Hub it is useful to consider experiences from other parts of the world.

[25] Regional stakeholder interviews, November 2001.

3. LEARNING FROM INTERNATIONAL EXPERIENCES

3.1 Examples and Implications for WA

WA is not alone in confronting the challenges identified in the previous chapter. Many of the experiences in North America, Europe and Asia reinforce the global nature of the challenges faced by universities in contributing to knowledge-intensive economies. However, the responses to these challenges, from governments, universities and industry, in these other parts of the world, offer some useful insights into how WA might best optimise the role of universities in creating a WA Knowledge Hub.

International evidence discussed below show that universities have distinctive functions in supporting a knowledge hub. Universities provide the institutional setting, specialised expertise, and infrastructure for research and the production of new knowledge. Universities do not do this in isolation, but in collaboration with other specialists in other universities, in research institutes, firms and other public institutions. Collaboration with industry requires special attention because most industrial innovation does not take place in universities, but within firms. In the process of generating new knowledge, universities perform an important role in creating an innovative culture and capability among the many other organisations that are part of the broader innovation system. In addition, as discussed in the introduction to this report they serve to disseminate or transfer new and existing knowledge into practice and to transmit knowledge and know-how through teaching and development.

(a) Collaboration with industry and the growth of greater knowledge intensity in the North Carolina Research Triangle

In the US the North Carolina Research Triangle exemplifies one way in which university, industry and government have collaborated to create a dynamic technology based economy – one of the fastest growing in the nation. Three universities - North Carolina State University (NCSU), Duke University and University of North Carolina, Chapel Hill, provide an academic base for industrial collaboration. Each of these three universities has a different academic profile and different historical trajectories but have complementary missions. Over the past few years the universities in the Triangle have attracted over US$400 million annually in sponsored research. The economic development in the "region", regarded as the nation's 'Entrepreneurial Hot Spot', has been attributed directly to these effective organisational partnerships.

High research expenditure in both public and private sectors contributes to and is a product of high skills concentrations and retention. Recent census data show that the Triangle has the highest concentration of residents with Masters or Doctoral qualifications in the United States – and that proportion is growing. Contributing to the sustained nature of organisational partnerships in the Research Triangle has been the role played by intermediary agencies, such as the Southern Growth Policies Board. The Board has recognised the critical role of developing partnerships between universities as well as between universities and firms.

> *When we identify solutions and best practices in building capacity for the knowledge economy we find that many share a common structure: that of public-private partnership.*[26]

b) Expanding the Role of the University Sector Among Knowledge Hub Populations

One of the key features of knowledge hubs in other parts of the world is the high level of knowledge-intensity in industry, universities and the population generally. One element of this concerns the profile of universities in these regions. In some parts of the world the centrality of universities and their role in generating and transmitting knowledge are obvious. In Pennsylvania, for example, there are 103 universities located in the State. With a population of 12.5 million this presents a university to population ratio of 1:119,000. In North Carolina, the location of the famous 'Research Triangle' it is 1:164,000 and in Massachusetts the ratio is 1:98,000. These are States with large populations. In States with populations considerably lower than Western Australia, such as New Hampshire (1,236,000 persons) and Rhode Island (1,048,000 persons) there are 17 and 11 universities, respectively, yielding university-population-ratios of 1:73,000 and 95,000. In WA the university-population-ratio is 1:372,000. This is a higher university-population-ratio than in most other States in Australia, but considerably lower than the ACT (1:155,000). From this perspective, WA's university-population-ratio is more consistent with the knowledge hubs in the US than are most other States in Australia. Only four States in the US have higher university-population ratios than that of WA (see Table A5 in Appendix 1).

Tertiary education participation rates in the US are no higher than they are in Australia. Indeed, the most recent comparative data (1995) for the two countries show the number of Australian tertiary students per 100,000 inhabitants to be slightly higher than in the US (5,401 in Australia compared to 5,339 in the US)[27]. However, the point to be noted is that university contributions to knowledge hubs may not necessarily be achieved through smaller numbers of larger universities but also through a considerable numbers of smaller and diverse institutions.

(c) Examples of Emerging Knowledge Hubs in Canada

In Canada the number of universities in different provinces varies considerably. In Nova Scotia, for example, there are 10 universities catering to a local population of only 900,000. Some are small religious institutions but all are degree granting.

British Columbia with a population of 3.5 million has 10 universities. Two new universities have opened recently, one private and one public.

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26 Southern Growth Policies Board (200) *Invented Here: Transforming the Southern Economy,* Southern Growth Policies Board 2001, Report on the Future of the South.

27 Peril and Promise, Report of the Task Force on Higher Education and Society, World Bank, Washington, 2000 Table B.

Example 1:

An interesting example from British Columbia is the collaboration or 'mesh' that has emerged between the two major universities: Simon Fraser University (SFU) and the University of British Columbia (UBC). In engineering UBC has the traditional disciplines such as electrical and mechanical while SFU emphasises computer and environmental engineering.

Example 2:

The Okanagan valley, also in British Columbia is now often referred to as the 'silicon vineyard' and is now promoted as a 'technology-based' community'. University and industry cooperation is becoming an increasingly important component in the region's development. Key components in the system include the Okanagan High Technology council (comprising a group of industry executives, academics, research institutions, government leaders and resource agencies). The Council sponsors projects concerned with human resource development, promotes research and development partnerships, and serves as a liaison between 'the technology industry and Okanagan's communities'.[28] The Okanagan University College has developed a Technology Access Centre for promoting partnerships in research and training. An interesting development is that the British Columbia Science Council and the National Research Council of Canada have both established offices at the Centre. The Centre also offers support for new companies working directly with faculty staff on development programs. Here there are lessons from this experience that suggest more could be made of a link between 'lifestyle' expectations of scientific communities and the so called 'new wave' of knowledge workers.

Example 3: Generating a 'knowledge mass' in the Ottawa Carleton region of Canada

The Ottawa-Carleton region in Ontario also provides an example of a more complex and organic approach to developing a regional knowledge system. Here it was business that took the lead. The information technology business sector took a leading role in establishing its own network or consortium of organizations as a source of entrepreneurs to lead economic growth in the region. Various other actors and agencies, including the universities, have contributed substantially to this process; a process which has been aided by a high degree of mobility and exchange among researchers and academic staff at each of the three sets of R&D institutions: universities, industry and the federal laboratories. Non-profit, private sector catalyst organizations, such as the Ottawa-Carleton Research Institute (OCRI), have found this regional economic context conducive to the development of a dense social web permitting ever more communication and interaction among the relevant actors. Into this landscape has flowed ample public sector funding to support world-class research. Here too, however, it was the business sector that provided the impetus for collaborative development in the region, although the public sector and universities were essential players in achieving a critical 'knowledge mass' and international reputation.

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[28] *Silicon Vineyard: Inspiring Growth in High Technology*, Okanagan High Technology Council, 1999.

Example 4: A Provincial strategy for developing an innovation-based economy: The Alberta approach

Perhaps the most striking example of an emerging knowledge hub from which WA might learn some valuable lessons is the case of Alberta. Alberta has many similarities to WA. The population is under 3 million and the Province has a rich legacy of natural resource wealth. There are seven universities and university colleges in Alberta, two with strong international reputations, the University of Alberta and the University of Calgary.

Although Alberta's economy (US$91 billion in 1998) is approximately three times the size of WA's, the Province, like WA, is falling behind the rest of its provincial counterparts in terms of innovation capacity. Comparative R&D investment in Alberta has been declining and growth is the slowest of all Provincial rates. Human capital is also declining in comparative terms. The proportion of post-secondary school graduates, knowledge workers and scientists and engineers in the workforce is growing more slowly than the competitive Provinces such as BC and Ontario and than the country as a whole. Further, with a population representing around 10 per cent of the Canadian population, venture capital investment in Alberta represents only about 3 per cent of total Canadian investments.

Hence the government decided to act. The Provincial government has recently developed a strategic plan to establish Alberta as a leading knowledge-based economy built around value-added resource-based industries and non-resource-based knowledge-intensive manufacturing industries.[29] The strategy document, 'Growing Alberta's Innovation Economy' recognises investment in science and R&D as a primary driver of business growth and success. The government has put in place an ambitious program to raise the level of innovation-based company investments in R&D and training from 10 per cent to 20 per cent of gross sales. In terms of GDP, the target is to raise the 'innovation-based economy from its present 7 per cent of GDP to 25 per cent by 2020.'

Underlying the strategy adopted is the recognition that it is not simply increases in R&D or technical training that are necessary to generate economic development, but linkages between knowledge producers, diffusers and users. Provincial government is increasing the level of targeted Provincial R&D investments to promote world-class research in strategic areas in industry. The strategic areas include information technology, telecommunications, energy, sustainable forestry, value-added agriculture products and environmental technologies. These investments are designed to run in parallel with policies to:

- expand the network of public and private institutions that support industry requirements for applied R&D, technology transfer, knowledge prospecting and acquisition;
- build joint industry/university R&D consortia; and
- recruit key companies to create critical mass in R&D intensive clusters such as biopharmaceuticals, agri-food, information technology and telecommunications.[30]

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29 *Sustaining the Alberta Advantage*, www.asra.gov.ab.ca//publications/sustain/sus01.html, p1.
30 *Ibid* pp. 5-6

Athabasca University in Alberta presents an interesting example of collaboration between universities, industry and professional agencies. The University has a student population around 22,000. The major emphasis of its courses is on degrees that have 'post-diploma routes, such as of bachelor of professional arts, bachelor of administration, bachelor of computing and information systems or bachelor of nursing.' The university operates on a model similar to that of the British Open University. Students from collaborating institutions are eligible to receive credit for 'university-level' work completed at these institutions.

Collaborating institutions are not only other universities but include a wide range of professional agencies such as, engineering associations, nursing and health care agencies, the armed forces, professional accounting groups, medical laboratories, Aboriginal institutions, and management associations.

The university was a founding member of the Canadian virtual university as well as a member of the Global University Alliance (a partnership of 10 universities from various parts of the world).

(d) Technology Transfer: Some Exemplary Institutions

In a recent study carried out by the Southern Growth Policies Board in the US a sample of national experts on economic development and industry-university technology transfer were polled to identify US universities that maintained what were considered to be outstanding examples in technology transfer. From a list of 164 major research institutions the study came up with 16 'exemplary' institutions. Georgia Institute of Technology topped the list. It is instructive to note the outstanding characteristics of Georgia Tech and some of the common characteristics with other universities that made the 'exemplary' institutions list. These common traits serve to illustrate the evolving nature of universities in stimulating knowledge-based economic development.

As the authors of the study have pointed out in a follow-up review:

> We seemed to be observing the emergence of a new, 21st century model of the research university: one that was progressively partnering with technology-based industry and regional economic development interests, exhibiting and encouraging entrepreneurial behaviour, and championing these new directions in its public pronouncements and internal values.[31]

Example 1: Georgia Institute of Technology

Georgia Tech was founded in the late nineteenth century as a centrepiece of the State's industrial resurgence plan after the Civil War. Through the first half of the 20th century it gradually grew from an initial trade school orientation to offer a broader range of engineering and supporting programs. Through the second half of the century it grew to become one of the nation's top research institutions. The Atlanta region currently has a population of four million. There are four major research universities in the metropolitan area and several degree granting colleges. Georgia Tech currently

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[31] Tornatzky, Louis, G., Denis O. Gray, and Paul G. Waugaman, *Making the Future: Universities, their States, and the Knowledge Economy,* Southern Growth Policies Board 2001 (Draft provided by the authors)

enrols around 14,000 students at the main Atlanta campus and has recently opened a new small regional campus in Savannah.

In 1999 Georgia Tech's research expenditure was US$263 million (more than twice WA's total higher education R&D expenditure). Student entry scores are among the highest of any public university in the US and the university ranks second in the country in the percentage of national merit scholars.

Georgia Tech also presents a unique example of external partnering.

> Virtually every combination of industry relationships or economic development activity can be found at Georgia Tech, and in a very real sense the school is an operating partner with Georgia State government in the implementation and management of a variety of technology-focused initiatives. …The Georgia Tech culture from President to academic unit, is pervasively oriented toward outreach engagement with the external world.'[32]

A third characteristic of Georgia Tech is the central role it plays in supporting alliances with other universities. The Georgia Research Alliance, for example, involves six Georgia universities and makes strategic investments in building centres of research excellence, primarily in the sciences where there are obvious linkages to current or expected economic growth. Since it was established in 1990, the alliance has disbursed US$276 million in State funds, making it the most significant component of the State's technology-based economic development strategy.

What stands out about Georgia Tech?

First, it graduates more engineers than any other university in the country, turns out a higher proportion of female engineers, and ranks third in the proportion of graduated African-American engineers (1st at the Masters level and 4th at the doctoral level). Second, the university has continued to maintain its institutional emphasis on engineering and science. It has not cultivated a growth in the liberal arts disciplines that characterize many other institutions, except where they relate to science and technology issues. This stands in marked contrast to many of the Australian previous institutes of technology such as UTS, QUT, RMIT and, in WA, Curtin University.

Numerous other collaborative activities stand out. The University is, for example, a major partner in the industrial enterprise 'Yamacraw'. Through Yamacraw, private industry, universities and the State government leverage Georgia's technology base in broadband technology and have built the state into a world leader in broadband infrastructure systems, devices and chips. Academic participation in Yamacraw involves researchers from a cross-section of faculty at Georgia Tech as well as faculty members from several other Georgia universities. The Yamacraw initiative provides Georgia-based companies with 'elite faculty researchers and their graduate students'. Companies have the choice of either committing US$1.25 million over a five year period or (and preferably) paying a $25,000 annual membership fee and committing to hire 100 high-tech employees in Georgia.

32 Ibid, pp 2.

Another example of national 'best-practice' at Georgia Tech is the university's Advanced Technology Development Center (ATDC). Within ATDC the Faculty Research Commercialisation Program (FRCP) allocates small grants from State funds to faculty researchers to develop early stage innovations into workable prototypes or to conduct 'proof-of-concept applied research'. Although Georgia Tech administers the program, faculty from all of Georgia's research universities are eligible.

There are many other collaborative examples in which Georgia Tech is a State leader. The outstanding feature is that in almost all cases the initiatives involve State government in one way or another. The partnerships draw together the various strengths of the State Universities to support regional industrial development through R&D and provide graduates for firms developing globally competitive areas of economic activity.

Example 2: Carnegie Mellon

Another exemplar institution identified by the Southern Growth Policies Board is Carnegie-Mellon University (CMU) located in Pittsburgh, Pennslvaynia. CMU was founded in 1900 as a vocational training school for the sons and daughters of working-class Pittsburghers. It remains a small university with only 7,500 students, but has become one of the nation's premier research universities.

CMUs research infrastructure was expanded through the 1960s when, as the Carnegie Institute of Technology, it merged with the Mellon Institute. The University's research activities expanded rapidly through the 1970s and 1980s. CMU research expenditure grew from US$12 million in 1972 to US$110 million in 1990. Research expenditure in 1999 was reported as US$142 million, US$18 million of which was industry-sponsored research.

The Pittsburgh metropolitan area has faced many social and economic challenges over the last few decades. Traditional manufacturing industries have been forced to down-size or close in the face of increasing global competition as a result of the region's outmoded production facilities. The past decade, however, saw emerging technology clusters built around information technology, biotechnology and advanced manufacturing. As a result, numbers of technology workers increased by 12 per cent between 1996 and 1998 and venture capital investments increased by 439 percent between 1995 and 1998. CMU has made some major contributions to these developments. However, like Georgia Tech, CMU's success in contributing to the transformation of the Pittsburgh economy has not been inhibited by its comparatively small size.

> One might be tempted to conclude that smaller institutions can have only a limited role in technology-based economic development. However, the experience of CMU and greater Pittsburgh suggests that this not need be the case. While CMU does not have great size or even a huge endowment, its commitment to excellence in a variety of technical/scientific areas, its supportive culture and an enhanced commitment to local economic development have allowed it to become a major regional asset.[33]

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[33] Tornatzky et al, op cit, 'Carnegie Mellon', p 2.

CMU has retained a strong focus on supporting local and regional development and has always been strongly industry-focused. The University's teaching programs have been developed over many years in close cooperation with industry. Formal courses in entrepreneurship have been offered since 1972. A more recent innovation in supporting local recruitment of graduates is that local employers can post job openings on the University's web-site.

CMU's experiences provide many examples of participation with government in developing knowledge-based industry clusters. Pittsburgh Digital Greenhouse (PDG), for example, is a partnership between CMU, metropolitan and State governments and local economic development organizations and other local universities. It was designed to facilitate the development of an industry cluster around the application of System On Chip (SOC) technology in the digital multimedia. PDG has around 25 industry members and supports R&D at local institutions. Plans are under way to use the same model as the basis for a Life Science Greenhouse.

Multi-member knowledge networks such as these represent creative coalitions of interest both to individuals in universities and industry and the institutions that employ them. While the structural boundaries between the employing institutions can remain intact at an institutional level, they are extremely fluid in the specific knowledge-intensive areas where common interests coincide.

(e) University and Industry Collaboration in a State-based University Research System in Oregon

The US State of Oregon has a population of 3.4 million. Higher education is provided through 27 universities. Seven universities are major state research institutions that comprise what has become known as the Oregon University System. A feature of the Oregon University System in recent years is the trend toward building collaborative networks involving researchers at all institutions, industry and State or national research laboratories. Examples of such collaboration are given below.

Example 1:

Oregon's university system and one of the largest research laboratories Department of Energy's Pacific Northwest National Laboratory (PNNL) in the American Northwest have established an agreement to join forces to 'improve human health, create sustainable industrial practices and create high-tech business.'[34] In a recent memorandum of understanding, the Oregon University System, Oregon Health and Science University and PNNL agreed to form a cooperative relationship for research and educational activities. The initial focus for collaboration is in life and physical sciences and economic development. However, it is planned to extend these areas as the cooperation matures.

According to a spokesperson from PNNL, 'combining PNNL's expertise in informatics and proteomics with the functional genomic efforts at Oregon Health and Science University should aid the development of new tools that allow biomedical

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[34] *Oregan universities, PNNL sign collaborative research agreement,* www.pnl.gov/news/2001/oregon.html

researchers at other universities to take advantage of the information generated by the human genome sequencing project. [35] This example illustrates how a system of universities can contribute to, and benefit from, clustering around a major research facility.

Example 2:

Another development in Oregon has been the formation of the Northwest Virtual Entrepreneurial Support Network. This network is being established to share technology management, money and marketing resources in Oregon and Washington. The Oregon Technology Transfer Council, which is composed of the technology transfer officers from Oregon's research universities, has established a partnership with PNNL to contribute to the creation of new high-tech business ventures. The Network will identify, develop and commercialise intellectual property derived from the participating universities and PNNL.

The critical mass of research capacity in these cooperative ventures is evident from the number and status of participating institutions. The university system includes: Eastern Oregon University, La Grande; Oregon Institute of Technology, Klamath Falls; Oregon State University, Corvallis; Portland State University; Southern Oregon University, Ashland; the University of Oregon, Eugene; and Western Oregon University. The Oregon Health and Science University (OHSU) is not a single university but a coalition of institutional partners. These include Schools of Dentistry, Health and Nursing as well as the OGI School of Science and Engineering, the OHSU Hospital, the Doernbecher Children's Hospital, dozens of primary care and specialty clinics, multiple research institutes and several public service and outreach units.

Example 3: The Oregon Higher Education Technology Transfer Fund

Oregon has established a Higher Education Technology Transfer Fund designed to promote technology transfer programs and activities that make technology developed at higher education institutions available to private industry. The rationale for the establishing the Fund (and the Board that manages it) is contained in the preamble to the legislation introduced in 2001.

> By its nature, technology developed at higher education institutions does not produce results that can be immediately used for commercial purposes. Additional research and funding is needed to determine whether the technology has commercial potential, to develop that potential and to protect the interests in the intellectual property. Transfer of technology developed at higher education institutions to private industry permits additional research and development by private industry and can potentially provide funding for higher education institutions. Assisting higher education institutions to transfer technology to new or small growth business within Oregon will promote state economic growth and development. Appropriate technology transfers to these businesses will generate significant high-skill, high-wage employment in the state.[36]

The fund is managed by a board comprising representatives from the State and private universities and industry. The fund provides financial assistance to universities to establish, support or improve their technology transfer programs or to reimburse a higher education institution that provides substantial technology transfer assistance to

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35 *Ibid*, pp. 1
36 www.leg.state.or.us/01reg/measures/sb0100.dir/sb0101.intro.html

other higher education institutions. This latter provision reflects a creative approach to encouraging cooperation between universities in the Oregon system.

The source of funds for the scheme is interesting. There is provision to transfer a proportion of the State's higher education funds, to solicit endowments, and to allocate funds from state revenue received from levies such as mineral leasing, grazing leases, sale of timber, and funds from the sale of public lands.

(f) Collaboration for the Transmission of Knowledge - Postgraduate Cooperation Across the Dutch University System

A problem confronting many smaller countries or States is the achievement of critical mass in research and research training. The following example from the Netherlands shows one way that such critical mass can be achieved in the area of postgraduate training.

The Netherlands, recognising that it is a small country with relatively limited expertise in several fields have put policies in place that enable students to come together to learn in a common environment. There is, for example, a national Graduate School of Management that brings together all the universities in the country teaching management into common courses and advanced student teaching and research. Several smaller scale initiatives are also in operation.

Graduate Schools can be organised across several universities, whether close-by or not. They must achieve a certain size and be accredited every five years by the Dutch Academy. One such example is that which involves the University of Twente and two others in the field of science, technology and society and was created five years ago. In this example, students from the participating universities are required to participate in a series of workshops across the first three years of their four-year doctoral course. In each of the first two years students attend two long weekends and one Summer School of a week's duration. These periods are times when particular courses are offered. These are offered in a number of ways and may vary in content from year to year. They usually provide the opportunity, however, for students to revisit classic texts in their field. This is to overcome the feeling that many students have that they do not know how to devise a research idea because the field is daunting when they look with only their undergraduate experience to rely on. The point of rediscovering the classic texts is to remind students that there are 'shoulders that they can stand on' in finding their research question and to enable them to feel that their work is part of an ongoing body of knowledge. In addition to these common weeks students also undertake training within their own departments, in for example sociology and philosophy.

The students also have to take part in a Winter School in their third year of candidature. During this week they take a number of theses that have been successful in the field and de-construct them to see how they are put together, what worked best and not so well. This is to provide the students with the means to assess what the best models for presenting their own work might be. The students explore the exact topics of their thesis during the first 12 months and progress is formally assessed at the end of that period.

The students are enrolled in the participating departments, not in the Graduate Schools. The students usually work on a project devised by a member of the host department's staff, which receives the necessary internal or external funding. Thus, doctoral positions may become available in a department on the basis that a staff member has such a project. There is an informal agreement that the student will undertake the project and the student has input into the design of the project. This system, has the advantage that the students can be sure that their supervisor is both expert in and interested in the topic and that the two people will work together to ensure success. The students are supervised by a panel of two or three staff.

Each Graduate School is reviewed every five years by the Academy which examines numbers of students enrolled, how the training is organised, how members of the school are selected or rejected, the qualifications of the staff who teach in them (number of international publications) and the preparation and motivations of the students who are enrolled.

Such arrangements go far towards reducing the isolation of students in emerging and multidisciplinary fields and in situations where the expertise they need is spread between several institutions. The students' work on projects that are devised by others more experienced than themselves, an approach, which ensures that the students do not waste time devising un-doable projects.

These support arrangements have been put in place in response to the national funding arrangements for departments and universities. As will be increasingly the case in Australia, doctoral completions are important to Dutch universities because they receive quite large funding amounts (around $40,000) for each completion. The universities need to have a minimum number of research students in order to receive the maximum block grant available, part of which is dependent on student numbers. There is thus incentive for universities to treat their students well and to provide a supportive environment. These graduate schools are funded by the departments in which the students are located and sometime receive extra money from the university as a whole from the block grants that they will receive when the students graduate.

The students are also valuable in another sense. In most universities, doctoral students are not on scholarship but on four-year employment contracts. Under these contracts they receive 75% of a lecturer's salary, the remaining 25% being payment by the student for the training received, as recognition that the student is an 'apprentice' rather than as yet a fully qualified professional. The remaining 75% is divided into 10-20% (maximum) teaching time with the rest for research. The students are thus in training for several aspects of an academic career at the same time. This example is one that should be studied carefully in WA and perhaps in Australia more generally.

(g) Germany: The Role of a University in the Transition to a Knowledge Intensive City

This case concerns a strategy led by a city government. Jena, a city with a population of 100,000, is in Southern Thuringia in the former East Germany. In spite of its comparatively small size, Jena has become one of the most important cities in Thuringia and hosts a large part of Thuringia's high-tech industry and public R&D capacity. Around 200 new firms have set up in the city over the past nine years and have contributed to a doubling of production in the region. Nearly 6,000 new jobs were created by the new start-up firms, 1,000 of which were in the biotechnology sector. Much of this development has been stimulated by policies directed toward making Jena a 'learning city'. The local university has played a major role in this process.

The city embarked on a conscious policy of supporting industry development in activities associated with the major industry sector in the region, principally around one firm, Carl Zeiss, and its successors. This approach served to transform an entrenched vertical industry structure to a more horizontal structure with an increasingly wide range of specialisations.

Associated with this strategy, the city decided to pool the specialised knowledge resources in universities and non-university research institutes. The basis of the strategy has been summed up as follows.

> Contrary to some other regions or cities that experience a severe loss of competitiveness, it is a central element for the city council in Jena that learning policies should not primarily create new local resources. Rather they should aim at enhancing the efficiency of the utilisation of the existing resources, notably the market value of the existing knowledge contained in local industry and the workforce. Such a knowledge-oriented strategy implies a focus and specialisation on the areas in which Jena's dominant firms … universities and non-university research institutes possess specialised knowledge. The pooling, building, and the utilisation of knowledge in these areas is to be strengthened.[37]

The strategy in Jena was to attract investment through building an image of Jena as an emerging 'high-tech' city. This was supported in practice by creating traded networks to pool the resources of small firms as well as to disseminate the knowledge created in universities and research institutes'.[38]

Parallel reforms were carried out in the city's major university, Friedrich-Schiller University, and other higher education institutions in and around the city. While Friedrich-Schiller is a large university offering a full range of courses and its undergraduate programs are currently not specifically directed to local industry, graduate and research programs have been substantially restructured to generate concentrations in the technical sciences. This concentration has attracted highly qualified lecturers and researchers from the former West Germany and led to the doubling of the student population over a period of seven years.

The restructuring of the university has been carried out to accommodate the changing structure of industrial production in Jena and surrounding districts. In the biotech sector, one of the largest employers in the region, firms are able to recruit sufficient numbers of appropriately qualified workers locally. Jena now has the highest proportion of employees with tertiary qualifications in the former East Germany and the highest share of workers in the technical professions.[39]

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37 OECD, *Cities and Regions in the New Learning Economy,* Paris, 2001, p.59.
38 *Ibid*.
39 *Ibid.*

(h) Some Lessons from South East Asia

Numerous lessons for Australian policy makers emerge from South East Asia - and not necessarily from the 'Tiger Economies'. In these cases an important issue is the relationship between the international business interests of multinational firms and how these can be usefully aligned with attempts to establish 'knowledge clusters'.

In Thailand, for example, the Ayuthaya Technical Training Centre (ATTC) is a joint-venture between the Hi-Tech Industrial Estate and the King Mongkut's Institute of Technology North Bangkok (KMITNB). The ATTC provides training for high tech business development. It receives ongoing technical support and equipment donations from international firms in the area - principally Japanese. Short courses are held on a regular basis in areas ranging from metal working to CNC usage and automation and quality assurance and ISO 9000. Canon is a major client for longer-term courses and the ATTC plans to introduce an apprenticeship program for a wider range of companies. Over 200 companies from the surrounding industrial estates send their workers to the short courses each year. While still in its early days, and still just a vocational-level institute, the ATTC offers the potential for KMITNB to interact with numerous private companies and identify their longer-term training needs. At the same time, the private companies can access a wide variety of university services, beyond the training provided by the ATTC.

While the social and economic context in Thailand is quite different from the situation in WA, the case is interesting because it provides ideas as to how educational programs and international business linkages in an off-shore education importing country might be aligned with options for developing a dynamic WA Knowledge Hub. The example offers an interesting illustration of the ways that international firms are well aware of the need to develop the local knowledge systems in which they operate, and are prepared to support their development. An interesting and important area of research into these emerging systems, that are both local and transnational, concerns the extent to which local communities can benefit from their transnational involvement.

3.2 Conclusions

International experiences have much to offer in terms of forming policies for optimising the role of universities in a regional knowledge hub. Critical questions for WA include: how can the State best retain and employ the skills and expertise that are developed through the higher education system? How can universities lead an education system throughout Western Australia that provides effective and well 'signposted' pathways between schooling, learning, employment and innovative practices?

The examples presented above illustrate the complex set of interactions taking place between universities and industry in the production and diffusion of knowledge. While geographic, economic and social factors lead toward different policy responses and solutions there are some clear underlying structural features, the lessons from which can be summarised as follows.

- A formative role is played by regional or local governments. *In almost all cases, some form of agency or authority has been instrumental in promoting partnerships***.** In some cases, they are directly involved in the partnerships themselves. But perhaps more significant is their role in steering the development of new organisational structures and collaborative arrangements. *In almost all cases this has required the commitment of public resources.*

- *Two-way partnerships between universities and industry are important for the creation of a knowledge hub, but collaboration across a whole range of institutions and organisations is equally critical.* Universities and industrial firms are only two of the institutional components in these systems.

- In most cases *collaboration in postgraduate training and research rather than in undergraduate teaching programs provides the core of the knowledge hub.* If these areas are functioning effectively undergraduate programs tend to follow.

- In all the cases discussed above, *universities have had to undergo considerable organisational change.* This has been necessary to enable them to adapt to changing industrial and social demands. This has required building more flexibility into the ways knowledge generation, transfer and transmission is managed.

- *Partnerships may be driven by business, by governments or by universities themselves.* Within these partnerships there is increasing potential for flexibility or even ambiguity about the roles of the partners. Universities and industrial firms are both producers and users in 'knowledge networks': both provide knowledge, both deliver financial resources, both are involved in curriculum development and delivery and both are involved in research. Some collaborative mechanisms have been driven more by university partners, others have been driven more by industry. Yet others have emerged as a direct result of intervention by an intermediary agency such as a government department.

- In the cases described above *the formative role of universities in strengthening knowledge capacity has not been a function of their size.* On the contrary, in many cases quite small universities have been able to maximise their contribution by collaborating in a few key strategic areas. In cases such as Georgia Tech and Friedrich-Schiller, they have subsequently grown because they chose to concentrate their efforts into a comparatively small number of strategic areas. It is not a matter of the size of universities or the number of universities for a given population. Nor is it simply how much research revenue is secured and expended. Rather, it is to do with how universities' knowledge-producing and transferring capabilities are harnessed and used by the other institutions and stakeholders in their knowledge hub.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Optimising the Role of Universities in a Western Australian Knowledge Hub

In Australia we are still grappling with the implications of the changing role of universities. We have made considerable progress with developing and strengthening structures for technological collaboration through collaborative research programs and through collaborative research training. Yet, it appears that we are still only making *use* of a *part* of what universities can contribute to knowledge production and diffusion throughout the economy. This failure to maximise university contributions is in part a product of policy that is still embedded in a policy paradigm that no longer fits with globalising economies. In globalising economies, innovation and knowledge systems are not easily bound by national boundaries and the regulatory mechanisms of the state. Neither are they totally subject to 'globalising forces'. Rather, they are a feature of creative knowledge alliances *across* institutions at international, national and quite localised levels. *Effective policies for promoting knowledge based development therefore call for a new paradigm that emphasises state development built around institutional collaboration within a state structure but linked to national and transnational knowledge systems.*

4.2 The Organisation of Universities: Developing a Critical Mass

During discussions held for this study some of the stakeholders expressed the view that the population of WA is not sufficient to support five universities. The argument was thus put that there is a need for institutional amalgamations in order to achieve critical mass for generating sufficient knowledge intensity. On the other hand, others argued that a knowledge hub requires *more* not fewer universities. The common ground was an acknowledgment of a need for critical mass in the specific fields in which WA sought to make a global impact.

Our international review and analysis of the present situation in WA leads us to the conclusion that a well functioning knowledge hubs relies on a diversity of universities, each of which may contribute to the hub in a variety ways. We argue that the current level of diversity provided through the four public and one private university is an asset for developing a WA Knowledge Hub. We propose that this diversity should be maintained but strengthened through initiatives to promote collaboration in a few key strategic areas.

Thus, we do not believe that institutional amalgamations will serve to optimise outcomes for the state from the WA university system. Rather, as we argue below, critical mass should be concentrated around specific fields of knowledge and new institutional structures created to maximise innovation in the region.

There are alternatives to amalgamations that can be used to achieve critical mass while at the same time providing for the institutional flexibility that knowledge hubs require.

4.2.1 Reorganising Knowledge Production and Application

To tackle the task of creatively rethinking the organisation of both knowledge generation and transmission we need to take seriously the problems and experiences in Western Australia and the solutions applied elsewhere. A knowledge hub calls for organisational as well as technological innovation and existing organisations may need to make paradigm shifts as well as gentler changes. Many high tech firms have been experimenting in recent years with hybrid, sometimes ‘cellular’, forms of organisation which represent an attempt to come to terms with the value systems and peer interlinkages which drive scientific research in the universities and mix these in new ways to meet the needs of the production system.

It is time for universities to rethink both their internal organisation and their external relationships. If universities can be thought of as loose and flexible collections of staff united in the aim of teaching students and furthering knowledge creation we may move one step ahead. We need to return again to the fact that most research does not take place *inside* particular institutions except when the focus is on provision of resources (laboratories etc). Why therefore do staff have to pursue research careers within the same formal organisation as they teach? Why can they not teach in one place and research in another, more specialist, arena where the small, flexible groups with which they actually work are more relevant? Why could they not spend part of their time working in a university department and part in another section of the knowledge generation world, remembering that universities are only one among many such arenas?

One possible way forward and it is one in which WA could lead the nation, therefore involves deliberately separating out the research function from the teaching functions in which staff engage. This does not mean the separation of teaching and research in the intellectual sense. It could mean devising new organisational forms whereby staff could choose different organisational environments for the different segments of their activities.

The organisations where staff do their research need not be ‘universities’ as such at all. They could be units which, as it were, ‘rent’ space within universities. Physical inclusion inside university spaces where that is appropriate should in no sense imply organisational ‘ownership’ but simply a decision about the location of management. Expensive scientific research could thus be concentrated in a geographical sense but the arrangement would remove the link between such facilities and the organisational boundaries that presently fuel so much competition for resources and prevent the most effective use of what is provided.

Funding for these flexible research organisations could be on a competitive basis over a given period. Proposals would have to show that the research teams were indeed open to the best staff regardless of the organisations in which they chose to teach. Each research team’s ‘centre’ would be a node in a network and have to operate as a network structure. Equally, if the network did not reach the standards agreed with the funding body(ies) all would have to accept that the formal part of its activity would be closed after the regular reviews and the money reallocated elsewhere in the system.

Specific incentives in the funding allocation system would ensure that smaller players had the chance to bid for new networks or new nodes in existing ones.

Some staff may also make the choice to work part of their time in governments, community organisations or businesses. Others, concerned more with pursuing basic research questions, may prefer to work across a range of universities or research institutes. Universities are encouraging the commercialisation of research by getting into business themselves (spin-off firms etc); it may be better, less risky and less expensive when capital is scarce for universities to let their staff transfer the technology themselves by transferring in person to existing firms in partnership with universities and for part of their time. Many observers now recognise that research and teaching, and indeed other activities, can be conducted serially over time as well as within the same academic year. This can mean spells of research followed by spells of teaching.

In practice, many university organisations are already moving towards such divisions of function and the creation of special arrangements for different disciplines. In the professional faculties of medicine and law, staff often have dual appointments, partly, for instance, within the medical school for teaching and part with hospitals for research and professional practice. The Cooperative Research Centres are another variant on the same theme; their university staff teach within one framework and conduct at least part of their research in another. Consulting to outside organisations by staff is another and very longstanding variant. The American system of nine month contracts is another.

Thus we propose that in optimising the role of universities in a WA Knowledge Hub, the government of Western Australia develop a system of research organisations that cross present university boundaries in innovative ways.

The new research organisations could each be centred at one of the existing universities that has the relevant strength. State government funding contributions for them would depend on collaboration and centres would be selected on the basis of statewide industry priorities. This would be rather different from the current Centres of Excellence that serve to lever additional funding and build infrastructure. Rather, they would be key State resources to serve as a platform for attracting knowledge intensive development. A major feature is that they would serve to coalesce the interests and expertise of organisations and highly qualified staff already working in universities, State and Commonwealth research institutes and associated agencies and industry.

It would seem important to have social as well as physical science centres because much of what happens in modern societies, especially as it concerns the effectiveness of innovation and economic development strategies, depends on good social science understandings.

Four or five 'critical areas' in postgraduate training and research excellence could be selected as key components of the hub. At least one institution could be identified to lead each key component. For example, the five areas might include:

- Mining engineering/mineral processing;

- Environmental management and sustainable development;
- Medicine and health delivery;
- Asian studies; and
- Information technology and telecommunications.

Each of these is an area of strength in at least one institution. The first choices should be made through a process that involves all relevant stakeholders but is essentially steered by government. The lead institution would be those of greatest strength but all would contribute staff and resources. Staff of the centres would have *joint appointments* between participating universities and the centres (on a pro rata time basis, for example).

4.2.2 Organising Postgraduate Collaboration

The evidence collected through this study suggests that institutional competition is most constructive at the undergraduate level. However there could be a far greater emphasis on collaboration at the postgraduate level and linking this to research.

We propose that with the creation of the centres go the creation of high level graduate teaching schools in the same fields.

Students in these fields could 'belong' to the centres and the participating universities in the same way as the staff.

Where appropriate the centres and the graduate schools should have a regional presence to support the development of industries and other socio-economic activities in the regions. The research organizations we propose would therefore serve to coalesce the research interests of universities, research institutes, firms and government agencies as well as provide a critical mass for research training and employment focused graduate studies.

4.3 The Role of State Government: Establishing the drivers for change

International evidence reflects the need for both competition and collaboration. A successful knowledge hub builds on national and international competition but requires cooperation to become consolidated and sustainable within a global competitive market. International evidence suggests that there is a need for strong state leadership in promoting cooperation between institutions to achieve competitive advantage. Achieving cooperation in developing a small set of internationally competitive key areas appears a critical feature for successes in other countries. However, as our case studies show, this requires a concerted and unambiguous effort on the part of State or Provincial government authorities.

Our view is that there is an important role for the State government in driving cooperation across selected areas of postgraduate training and research and that this will be an essential ingredient in building a strong WA 'knowledge hub'.

However, there will need to be sufficient resources identified to overcome the fragility of cooperation and some of the negative consequences of our national system of higher education that emphasises institutional competition. Without strong local or

State government involvement many of the creative overseas initiatives discussed above would not have occurred. In WA, in particular, we believe the State must act quickly and decisively to offset the negative consequences of competition in the centralised Australian university sector. As one of our stakeholder respondents pointed out: '

> Now is the time to act, we need some very significant groupings and there is a need for protocols to sustain and drive them. …we have here a window of opportunity.[40]

In order to drive the changes proposed above we recommend that the State Government establish a small but influential Higher Education Policy Group, which will report to the Ministerial Education Exports Advisory Committee established by the Minister for State Development. The work of this group should be focused specifically on driving cooperation across the higher education sector to underpin economic development in the State through a WA Knowledge Hub. This would include setting targets and priorities for maximising the contribution of the WA higher education system (including Universities and TAFE) to state economic development.

A specific role of this group would be to: identify key areas for concentrating state investment in the university system and maximise contributions toward the knowledge-hub; identify resources and set 'state-defined benchmarks' for WA higher education achievements toward the knowledge-hub. We view the role of the Higher Education Policy Group as different but complementary to the work of the WA Higher Education Council but more specifically focused on issues concerning the State's economic development.

A distinctive and globally competitive 'knowledge hub' requires globally competitive 'beacons'. This can be provided by individual institutions as centres of excellence, by fields of excellence supported by coalitions of institutions, or both. The proposal offered above to create research organisations that transcend university boundaries is an extension of this concept.

Progress toward achieving this in the mining and minerals area has already taken place. This concerns the formation of three of the State's universities into a national innovation consortium (Uniseed) for leading global R&D in the field of mining and minerals and generating internationally competitive commercial outcomes. Importantly, the venture not only draws together the separate strengths of three WA universities but also expands this into a national critical mass that can compete and attract global attention.

'Uniseed' is intended to link all faculties through the Deans to research, venture capital, development and commercialisation. An important feature of this development is that it involves three levels of cooperation: a formal structure that ensures participation and cooperation at the institutional level (including universities, CSIRO and industry); a faculty level that involves the on-going participation of heads of schools in the three universities; and a research project level that brings together key individuals providing vision, leadership and creative capacity. The global network in this area extends through the Global Mineral Alliance where Australia has the

[40] Stakeholder interviews October 2001.

potential to play a significant role in global research and development along with South Africa, Canada and Germany.

We propose that the Uniseed approach serve as a useful model for developing the research concentrations referred to above.

4.4 Establishing a consolidated regional emphasis

Regional pathways are critical for a truly WA Knowledge Hub. The growth of regional campuses could be of considerable benefit for the State as a whole. The geographic and demographic characteristics of Western Australia appear to be contributing to fragile pathways to postgraduate enrolments and subsequent state based employment. This is not helped by the Commonwealth government's competitive funding formulae.

A more focused collaborative approach to regional campuses should be a feature of the WA Knowledge Hub.

This could be achieved by using regional campuses, operated by single institutions, as a pathway to studies at any of the State's universities. Cross-institutional accreditation or joint courses at regional campuses would provide opportunities for regional students to progress into specialisations that would not otherwise be available through a single institution.

Each university, through its regional presence, should coordinate a collective university approach to work with industry, TAFE and regional authorities to offer and deliver campus-based specialized professional courses with additional capacity for 'alternative delivery'.

Institutional competition and excellence would continue to drive the development of regional campuses but pathways *between* institutions (in addition to campus pathways) might better serve the State as a whole.

4.5 Extending an International Presence – The application of knowledge through consulting

One of the characteristics of knowledge hubs, their institutions and groups of specialists is their international recognition for solving problems. International agencies, like global businesses, regularly seek out global specialists for development and problem solving in all manner of areas from crop improvement in fertile agriculture areas to mine-site rehabilitation in remote and inaccessible areas. It is clear that while a number of international experts are employed in knowledge-intensive institutions in WA they do not constitute a critical mass that attracts the attention of many international agencies not to mention our own AusAID.

We believe that there is considerable scope for WA to market the State's knowledge and skills through international development activities. A step toward achieving this would be to enhance collaboration among staff in universities and other knowledge intensive sectors in WA in submitting for international tenders. Such activities could serve to raise the profile of WA's knowledge intensive profile as well as promoting collaboration across institutions. Some steps toward this have already been made through the work of the Department of Industry and Technology. These activities could be developed further and make a major contribution to an emerging knowledge hub.

The proposed Higher Education Policy Group should work with other relevant government agencies such as DoIT to promote collaborative approaches to international development with a view to establishing, in the longer term, an internationally recognised WA based international development consortium.

A step toward achieving this would be to establish a database of specialised skills, expertise and experience among WA based specialists in universities, research institutions and industry. Such an agency could serve an important function in marketing the skills and expertise embedded in WA institutions as well as raising the profile of WA generally as a knowledge intensive region. A starting point for establishing such a consortium could be to convene a working group comprising the technology transfer offices of the universities, the CSIRO, AIMS and other State research agencies

4.6 Monitoring Progress

We propose that the State government should take on the role of monitoring progress toward building the State's university sector into a more central and formative role in a WA Knowledge Hub. As we were reminded by a number of respondents during our consultations, 'there is a need for the State to define targets and to put in place accountability measures.'[41] A number of state or provincial governments and their agencies have consistently applied indicators for benchmarking progress in university and industry transfer. The Alberta Provincial government in Canada and the Southern Technology Council, in the US, offer examples of good practice in monitoring knowledge hub progress and the contribution made by universities. These provide a useful set of indicators from which WA might consider developing some benchmarks for monitoring progress towards a WA Knowledge Hub.

We suggest that the WA government convene a forum involving universities, industry, research institutes and other relevant stakeholders to identify a set of indicators for monitoring progress toward optimising the role of universities in a WA Knowledge Hub.

[41] Stakeholder interviews, October 2001.

4.7 Recommendations

Effective policies for promoting knowledge based development call for a new paradigm that emphasises Western Australia as a region built around institutional collaboration within a state structure but linked to national and transnational knowledge systems.

(i) It is recommended that the State develop a Western Australian Knowledge Hub and give consideration to:

- (a) Developing critical mass concentrated around specific fields of knowledge across institutional boundaries.
- (b) Establishing the drivers for change.
- (c) Establishing a consolidated regional emphasis.
- (d) Extending an International Presence.
- (e) Monitoring Progress.

(ii) It is recommended that the recently established Ministerial Education Exports Advisory Committee be given responsibility for the development of a Western Australian Knowledge Hub.

APPENDICES 1 - 5

Appendix One

Additional Tables and Figures

Table A1: Business Location (a) (b) of R&D Expenditure by ANZSIC Western Australia and Total Australia (Per cent)

	1996-1997		1997-1998		1998-1999		1999-2000	
ANZSIC	*WA*	*Australia*	*WA*	*Australia*	*WA*	*Australia*	*WA*	*Australia*
Total Current Prices	($ 492m)	($4,124m)	($384m)	($4,044m)	($435m)	($3,992)	($342m)	**($3,045m)**
Mining (inc. services to mining)	41.6	13.2	30.7	9.7	49.3	12.0	29.2	**6.7**
Manufacturing								
Food, beverages and tobacco	3.7	5.5	2.9	4.4	1.1	5.2	1.9	4.6
Textiles, Clothing, footwear and leather	0.4	0.5	0.3	0.5	0.3	0.5	np	0.4
Wood and paper products	np	4.6	np	2.9	0.7	2.2	np	2.6
Printing, publishing and recorded media	0.3	0.4	np	0.5	np	0.6	0.4	0.4
Petroleum, coal, chemical and ass.product	3.1	7.8	3.3	7.6	3.2	8.5	4.0	10.2
Non-metalic mineral product	1.8	1.6	3.1	1.8	1.5	1.4	1.7	1.2
Metal product	21.6	9.0	np	8.3	np	6.7	12.0	5.6
Motor vehicle and part and other transport	4.7	9.6	np	10.8	np	9.3	10.9	10.4
Photographic and scientific equipment	0.6	1.9	0.5	2.3	0.9	2.6	1.7	3.1
Electronic and elect. Equip. & appliances	3.6	14.2	8.1	10.9	3.2	9.5	9.0	8.5
Industrial machinery and equipment	1.8	3.3	2.7	3.1	1.9	2.7	3.5	3.3
Other manufacturing	np	0.4	0.2	0.9	0.2	0.4	0.6	0.5
Total manufacturing	*43.1*	*59.0*	*49.9*	*53.9*	*33.6*	*49.7*	*47.8*	*50.7*
Other industries								
Wholesale and retail trade	2.5	4.9	2.6	7.9	2.1	8.6	2.2	8.7
Finance and insurance	np	2.3	2.6	2.1	np	1.1	np	3.1
Property and business services	9.1	12.5	10.0	15.3	7.5	15.8	10.8	17.8
Scientific research	1.3	3.7	2.2	4.0	2.1	4.5	3.2	5.2
Other n.e.c.	np	4.4	2.0	7.1	np	8.3	np	7.7
Total other industries	*15.3*	*27.7*	*19.4*	*36.4*	*17.2*	*38.3*	*23.0*	*42.5*
TOTAL ALL INDUSTRIES	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	***100.0***

Notes: (a)Includes all businesses whose primary activity is the production of goods or services for sale to the general public at a price intended to cover at least the cost of production, and the private non-profit institutions mainly serving them. Excludes businesses mainly engaged in Agriculture, forestry, and fishing (I.e. in ANZSIC Division A).
(b) This may not be the location of the organisation's head office.
np not available for publication but included in totals where applicable, unless otherwise indicated.

Source: ABS, 'Research and Experimental Development', catalogue No. 8104

Table A2: Postgraduate Student Enrolments, Australia and WA by Fields of Study: 1989 - 2000

Year	*Agriculture*			*Architecture*			*Arts/Soc. Sc.*			*Business/Econ.*			*Education*		
	Aust.	*WA*	*%*	*Aust.*	*WA*	*%*	*Aust.*	*WA*	*%*	*Aust.*	*WA*	*%*	*Aust.*	*WA*	*%*
1989	1,121	140	12.5	1,522	66	4.3	12,269	1,257	10.2	12,206	1,670	13.7	20,963	1,508	7.2
1990	1,147	140	12.2	1,777	121	6.8	13,531	1,303	9.6	14,542	1,909	13.1	22,738	1,589	7.0
1991	1,335	150	11.2	2,046	134	6.5	16,922	1,572	9.3	17,459	2,059	11.8	24,887	1,900	7.6
1992	1,584	143	9.0	2,269	176	7.8	19,062	1,653	8.7	20,005	2,019	10.1	25,567	1,879	7.3
1993	1,768	144	8.1	2,374	193	8.1	20,863	1,722	8.3	22,858	2,067	9.0	27,125	2,002	7.4
1994	1,872	162	8.7	2,261	159	7.0	21,925	1,838	8.4	25,207	2,076	8.2	23,860	2,006	8.4
1995	1,943	163	8.4	2,354	149	6.3	23,517	1,969	8.4	27,561	2,322	8.4	24,323	2,089	8.6
1996	1,881	194	10.3	2,564	140	5.5	25,044	2,086	8.3	31,408	2,809	8.9	24,450	2,164	8.9
1997	1,970	204	10.4	2,538	137	5.4	25,963	2,157	8.3	34,227	3,138	9.2	24,546	2,358	9.6
1998	1,919	177	9.2	2,341	143	6.1	24,485	1,987	8.1	36,876	2,949	8.0	23,263	2,222	9.6
1999	1,864	197	10.6	2,498	134	5.4	24,507	1,961	8.0	40,587	3,218	7.9	21,036	2,195	10.4
2000	1,664	159	9.6	2,383	109	4.6	24,740	2,199	8.9	42,637	2,787	6.5	20,393	2,306	11.3

Note: % = proportion WA enrolments of all national enrolments in each field for each year.

Source: DEST Student Statistics

Table A2 (contd.)

Year	*Engineering*			*Health Science*			*Law*			*Science*			*Veterinary Science*		
	Aust	*WA*	*%*	*Aust.*	*WA*	*%*	*Aust*	*WA*	*%*	*Aust*	*WA*	*%*	*Aust.*	*WA*	*%*
1989	4,557	268	5.9	5,216	750	14.4	2,493	165	6.6	9,399	1,099	11.7	247	33	13.4
1990	4,780	267	5.6	6,552	891	13.6	2,861	166	5.8	10,675	1,283	12.0	248	48	19.4
1991	5,698	314	5.5	8,605	937	10.9	3,094	73	2.4	12,572	1,399	11.1	261	54	20.7
1992	7,002	332	4.7	9,966	995	10.0	3,663	112	3.1	14,038	1,578	11.2	315	72	22.9
1993	7,233	362	5.0	12,156	1,055	8.7	3,741	149	4.0	15,177	1,565	10.3	347	75	21.6
1994	7,480	402	5.4	13,876	1,191	8.6	4,058	121	3.0	15,885	1,621	10.2	351	71	20.2
1995	7,879	416	5.3	15,857	1,341	8.5	4,203	131	3.1	16,122	1,572	9.8	364	77	21.2
1996	7,678	443	5.8	17,737	1,394	7.9	4,293	142	3.3	17,090	1,634	9.6	355	69	19.4
1997	7,666	442	5.8	18,920	1,509	8.0	4,374	149	3.4	17,524	1,616	9.2	323	74	22.9
1998	7,075	404	5.7	19,280	1,490	7.7	4,143	138	3.3	17,319	1,507	8.7	305	79	25.9
1999	7,064	440	6.2	19,224	1,496	7.8	4,161	131	3.1	18,601	1,658	8.9	307	89	29
2000	7,275	366	5.0	18,661	1,256	6.7	4,236	122	2.9	20,221	1,547	7.7	298	87	29.2

Source: DEST Student Statistics

Table A3: Postgraduate Student Enrolments by selected States and Universities: 2000

State/University		*Broad Field of Study*																				
		Agriculture, Animal Husbandry		*Architecture, Building*		*Arts, Human. and SS*		*Bus., Admin., Econ.*		*Education*		*Engineer., Survey.*		*Health*		*Law, Legal Stud.*		*Science*		*Vet. Science*		*TOTAL*
		No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	
Western Australia	Curtin	27	0.8	101	2.9	812	23.2	892	25.5	491	14.0	137	3.9	671	19.1	13	0.4	360	10.3	0	0.0	**3,504**
	Edith Cowan	0	0.0	0	0.0	503	18.1	717	25.8	801	28.8	29	1.0	335	12	13	0.5	386	13.9	0	0.0	**2,784**
	Murdoch	0	0.0	0	0.0	412	20.1	763	37.2	426	20.8	14	0.7	2	0.1	21	1.0	324	15.8	87	4.2	**2,049**
	UWA	132	5.2	8	0.3	462	18.3	409	16.2	543	21.5	186	7.3	248	9.8	75	3.0	477	18.8	0	0.0	**2,531**
	Notre Dame	0	0.0	0	0.0	1	1.6	6	9.8	54	88.5	0	0.0	0	0	0	0.0	0	0.0	0	0.0	**61**
	Total	*159*	*1.5*	*109*	*1.0*	*2,190*	*20.0*	*2,787*	*25.5*	*2,315*	*21.2*	*366*	*3.3*	*1,256*	*11.5*	*122*	***1.1***	***1,547***	***14.2***	***87***	***0.8***	***10,929***
NSW	*Total*	*454*	*0.9*	*985*	*1.9*	*7,927*	*15.3*	*18,538*	*35.8*	*5,960*	*11.5*	*2,520*	*4.9*	*6,581*	*12.7*	*2,148*	***4.2***	***6,531***	***12.6***	***74***	***0.1***	***51,718***
VIC	*Total*	*306*	*0.8*	*656*	*1.6*	*7,012*	*17.5*	*10,646*	*26.5*	*5,768*	*14.4*	*2,582*	*6.4*	*5,680*	*14.1*	*825*	***2.1***	***6,605***	***16.5***	***66***	***0.2***	***40,146***

Source: DEST, Consolidated Statistics 2001

Table A4: University R&D expenditure by field of research, 1992 – 1998 ($'000s, current prices).

Field of Research	*Total 1992*	*WA 1992*	*%*	*Total 1995*	*WA 1995*	*%*	*Total 1998*	*WA 1998*	*%*
					WA				
Math. sciences	45,091	2,606	5.8	57,298	3,645	6.4	63,058	2,163	3.4
Physical sciences	80,214	4,121	5.1	94,811	5,253	5.5	106,474	7,109	6.7
Chemical sciences	92,364	6,599	7.1	98,367	7,263	7.4	121,038	8,492	7.0
Earth sciences	76,265	7,521	9.9	98,669	11,533	11.7	113,002	11,728	10.4
Inf. & comp. Tech.	74,876	6,398	8.5	105,705	11,917	11.3	139,173	12,632	9.1
Applied sciences	71,030	6,708	9.4	80,954	9,416	11.6	98,821	8,267	8.4
General eng.	115,787	10,191	8.8	133,549	15,628	11.7	182,275	18,516	10.2
Biological sciences	194,370	15,649	8.1	241,848	21,109	8.7	311,813	29,345	9.4
Agricultural sciences	97,151	12,888	13.3	123,427	17,289	14.0	170,655	23,206	13.6
Med. & health sc.	314,309	29,293	9.3	453,795	48,359	10.7	592,431	52,164	8.8
Social sciences	370,505	29,749	8.0	388,318	36,765	9.5	506,524	39,486	7.8
Humanities	163,247	12,850	7.9	162,353	12,432	7.7	197,468	12,439	6.3
Total	*1,695,209*	*144,574*	*8.5*	*2,039,094*	*200,607*	*9.8*	*2,602,733*	*225,547*	*8.7*

Source: ABS, R&D Expenditure, Tables prepared for the Centre for Research Policy, 2002.

Table A5: Population and universities in US States

State	Population 2000	No. Universities	Per cent of all US Universities	Pop. Per University
California	33,871,648	85	5.6	398490
Texas	20,851,820	70	4.6	297883
New York	18,976,457	97	6.4	195634
Florida	15,982,378	50	3.3	319648
Illinois	12,419,293	66	4.3	188171
Pennsylvania	12,281,054	103	6.8	119234
Ohio	11,353,140	68	4.5	166958
Michigan	9,938,444	44	2.9	225874
New Jersey	8,414,350	27	1.8	311643
Georgia	8,186,453	31	2.0	264079
North Carolina	8,049,313	49	3.2	164272
Virginia	7,078,515	48	3.1	147469
Massachusetts	6,349,097	65	4.3	97678
Indiana	6,080,485	37	2.4	164337
Washington	5,894,121	27	1.8	218301
Tennessee	5,689,283	41	2.7	138763
Missouri	5,595,211	45	3.0	124338
Wisconsin	5,363,675	24	1.6	223486
Maryland	5,296,486	29	1.9	182637
Arizona	5,130,632	14	0.9	366474
Minnesota	4,919,479	31	2.0	158693
Louisiana	4,468,976	17	1.1	262881
Alabama	4,447,100	29	1.9	153348
Colorado	4,301,261	21	1.4	204822
Kentucky	4,041,769	32	2.1	126305
South Carolina	4,012,012	31	2.0	129420
Oklahoma	3,450,654	22	1.4	156848
Oregon	3,421,399	27	1.8	126718
Connecticut	3,405,565	23	1.5	148068
Iowa	2,926,324	35	2.3	83609
Mississippi	2,844,658	17	1.1	167333
Kansas	2,688,418	27	1.8	99571
Arkansas	2,673,400	15	1.0	178227
Utah	2,233,169	8	0.5	279146
Nevada	1,998,257	2	0.1	999129
New Mexico	1,819,046	9	0.6	202116
West Virginia	1,808,344	20	1.3	90417
Nebraska	1,711,263	18	1.2	95070
Idaho	1,293,953	6	0.4	215659
Maine	1,274,923	12	0.8	106244
New Hampshire	1,235,786	17	1.1	72693
Hawaii	1,211,537	4	0.3	302884
Rhode Island	1,048,319	11	0.7	95302
Montana	902,195	6	0.4	150366
Delaware	783,600	5	0.3	156720
South Dakota	754,844	15	1.0	50323
North Dakota	642,200	9	0.6	71356
Alaska	626,932	4	0.3	156733
Vermont	608,827	19	1.2	32044
District of Columbia	572,059	12	0.8	47672
Wyoming	493,782	1	0.1	493782
United States	***281,421,906***	***1525***	***100.0***	***9928866***

Source: www.canadainfolink.com/1998(pop)2000(unis)

Table A6: Selected source of Ideas and Information used by Businesses in WA and Australia to Undertake Technological Innovation (%)

	Businesses undertaking technological innovation that rated the source as important					
	Initial idea		*Throughout the project*		*Technical Information*	
Source	*WA*	*Australia*	*WA*	*Australia*	*WA*	*Australia*
Internal sources	*92.6*	*90.9*	*97.4*	*93.1*	*56.7*	*55.8*
Management	74.6	79.4	73.2	66.7	39.1	34.1
Production staff	35.6	23.4	53.2	44.4	*22.5	19.3
Technical staff	*23.2	17.8	34.5	31.4	*24.6	22.1
R&D staff	*17.4	12.1	23.0	16.2	*17.1	11.0
Marketing staff	30.1	26.7	35.1	22.6	*19.8	10.9
Other sources (total)	*61.5*	*63.9*	*49.5*	*53.2*	*35.4*	*44.8*
Competitors	*20.4	24.5	*2.7	6.3	**0.3	*3.8
Clients or customers	36.1	31.7	*12.2	19.8	*3.5	7.5
Universities	*3.6	1.7	*7.0	*2.9	*5.5	2.9

* indicates a RSE >= 25%
** indicates a RSE >= 50%
reference period is 1/7/94 to 30/6/97

Source: Innovation Surveys Special Tables Prepared for AEGIS, 2001.

Figure A1:

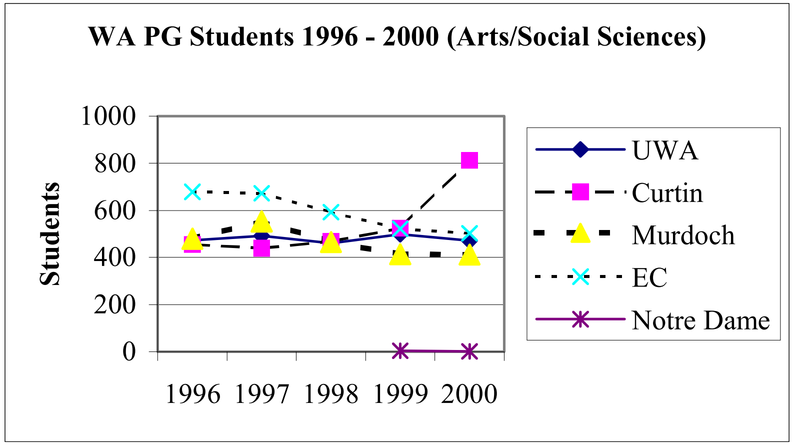


Figure A2:

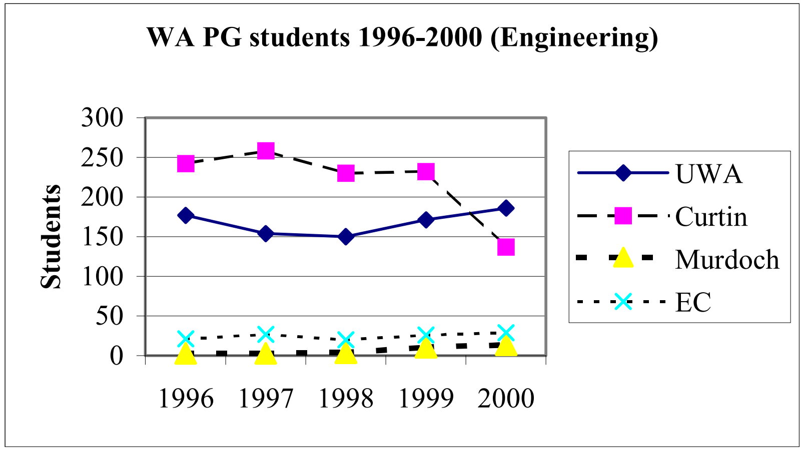


Figure A3:

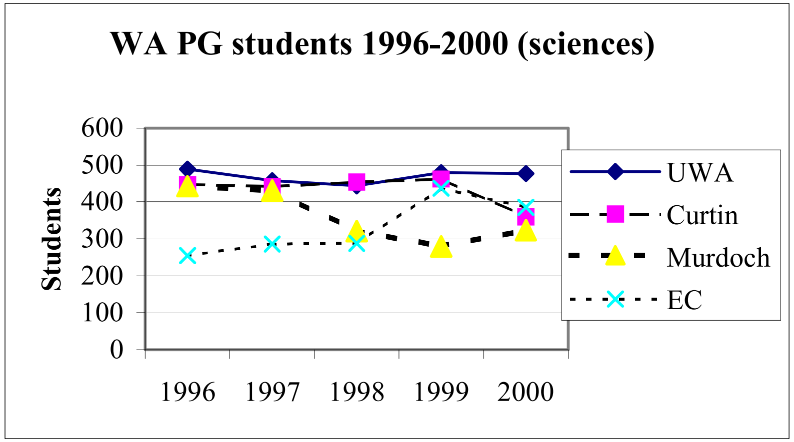


Figure A4:

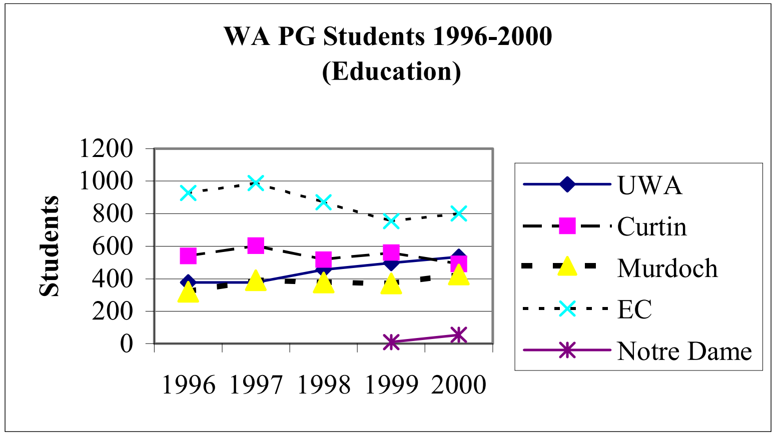
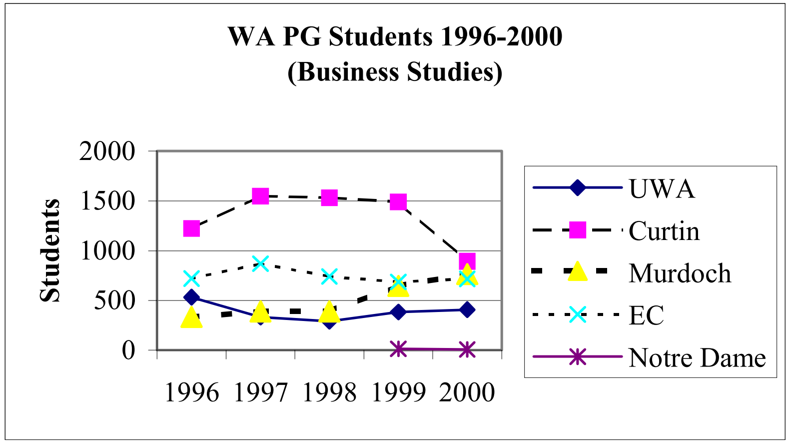


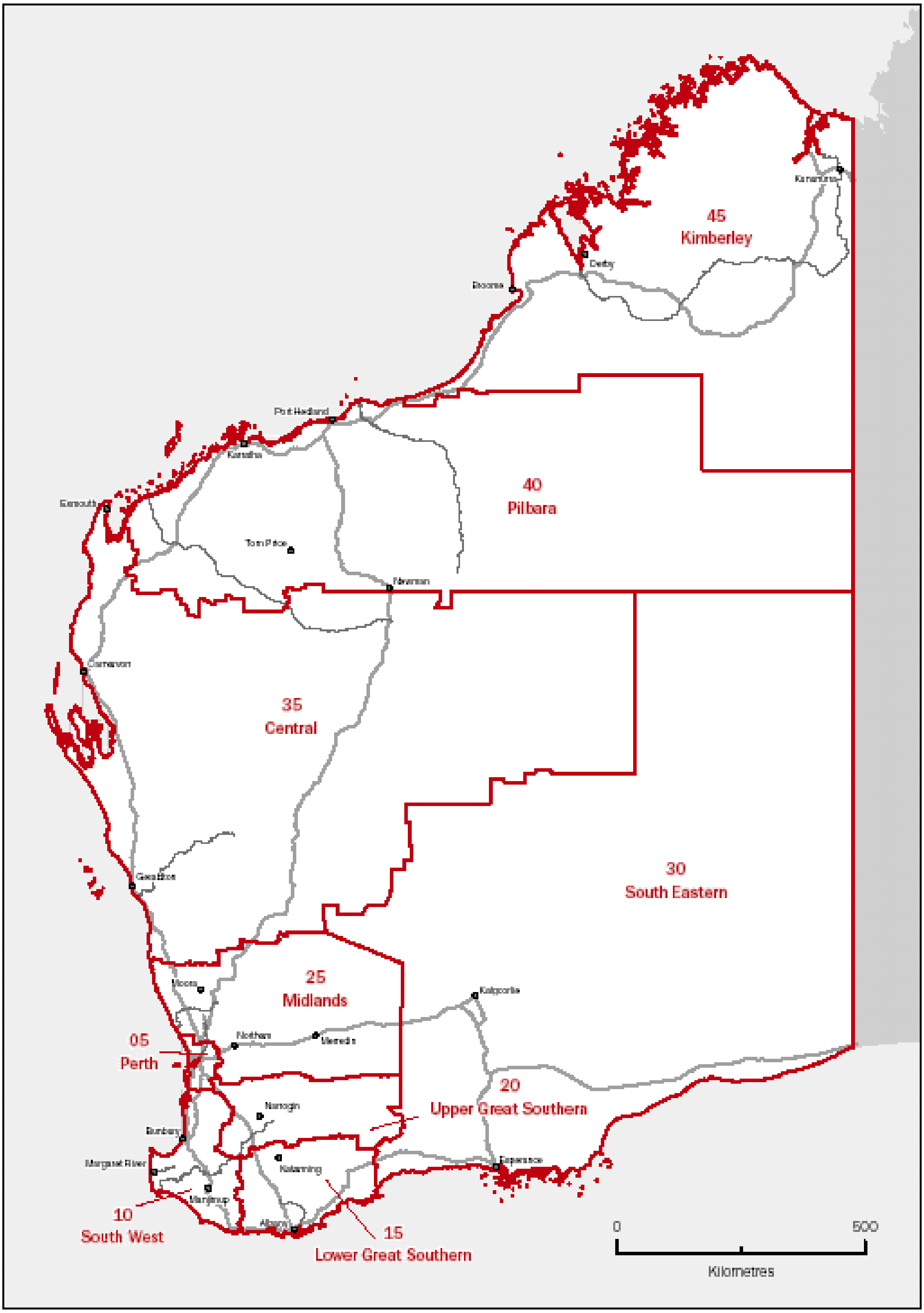
Figure A5:


WA PG Students 1996-2000
(Business Studies)
Students
2000
1500
1000
500
0
1996
1997
1998
1999
2000
UWA
Curtin
Murdoch
EC
Notre Dame

Appendix Two

Analysis of Regional Trends

Map One: WA Regions



Source: ABS, Australian Standard Geographical Classifications, Cat No.1216.0, 2001, p. 186.

UNIVERSITY SERVICES TO THE WA REGIONS: 1996-2001

Prepared by Dora Marinova

PART I. REGIONAL TRENDS

1. Overview of the regions

1.1 Undergraduate enrolments

• The overall number of undergraduate students at WA universities from the State's regions was the highest in 1997 (when it reached 2,054 students) but has been dropping since and is currently at 1,840 (see Table 1).

Table 1. Commencing undergraduate students by WA region, 1996-2001

	1996	*1997*	*1998*	*1999*	*2000*	*2001*
Gascoyne	20	22	19	13	12	13
Goldfields-Esperance	240	330	442	295	209	200
Great Southern	261	230	244	245	235	193
Kimberley	92	105	84	67	108	87
Mid West	238	258	204	319	242	240
Peel	165	175	191	238	248	213
Pilbara	109	76	70	49	56	47
South West	683	695	638	725	656	686
Wheatbelt	188	233	162	225	193	159
Total regions	*1,996*	*2,124*	*2,054*	*2,176*	*1,959*	*1,838*

• Compared with the 1996 levels, all regions have decreased the absolute number of their student enrolments with the exception of Peel where the number has increased by close to 30% and South West and Mid West where the numbers are unchanged (see Table 1).

• The number of commencing undergraduate students in the WA public universities per 1,000 people living in the WA regions, has also steadily decreased (see Table 2). There were around 4.2 - 4.4 new undergraduate students per 1,000 people between 1996 and 1999; this figure has now dropped to 3.6 in 2001. For comparison, the respective 2001 figure for Perth was 8.8 commencing undergraduate students per 1,000 persons living in the metropolitan area (or close to two and a half times higher than the regions).

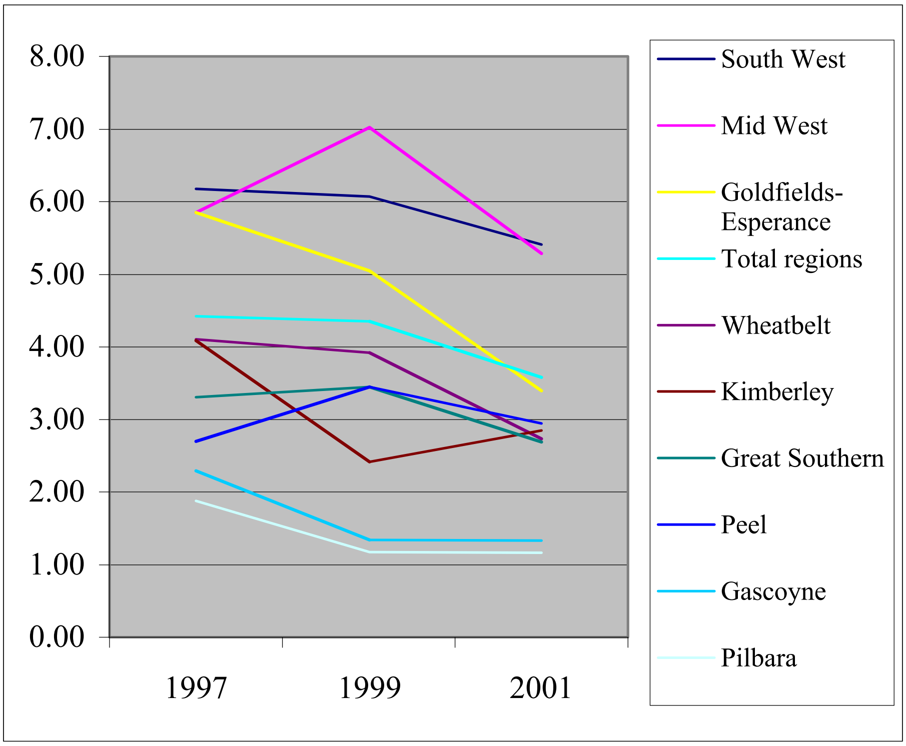
Table 2. Commencing undergraduate regional students per 1,000 regional population *, 1996-2001

	1996	*1997*	*1998*	*1999*	*2000*	*2001*
Regional students	4.17	4.42	4.19	4.35	3.86	3.57

* Population numbers refer to the previous calendar year.

Figure 1 shows that with the exception of the Kimberley, the relative share of commencing undergraduate students has decreased in all regions since 1997. Due to the relative closeness to the Perth metropolitan area, the Mid West has the highest share of students (5.3 per 1,000 population in 2001). Not surprisingly, the most remote regions of Pilbara and Gascoyne have the lowest relative number of students (1.2 and 1.3 respectively).

Figure 1. Commencing undergraduate regional students per 1,000 regional population* by WA region, 1997-2001



* Population numbers refer to the previous calendar year.

• During the analysed period, ECU had the largest share of students from the regions (see Table 3), which has been around 43% on average (41% in 2001). Curtin University of Technology is second (with 27% on average and 25% in 2001) and Murdoch University has the lowest share (4% and 13% respectively). It is interesting to note that during the studied period only UWA has been increasing its share of regional undergraduate students, which has reached 21% in 2001 (from 16% in 1996).

Table 3. Shares of regional commencing undergraduate students in WA public universities, 1996-2001 (%)

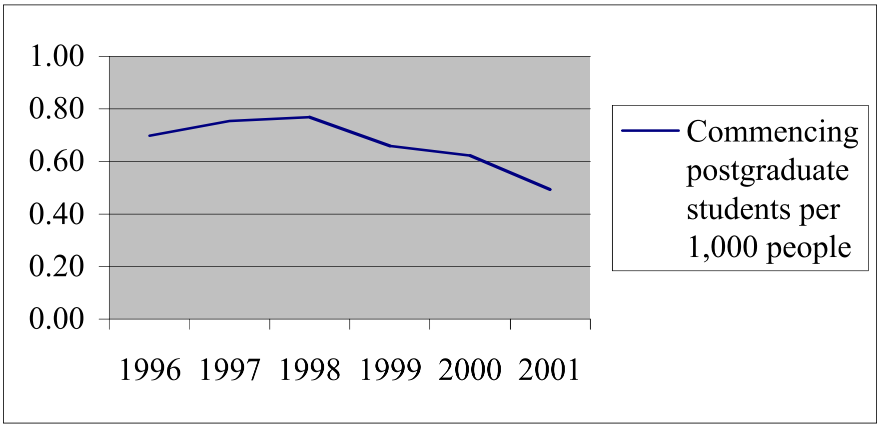
	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Curtin	27	27	29	27	24	25	27
ECU	44	43	42	44	43	41	43
Murdoch	13	16	13	13	15	13	14
UWA	16	15	16	15	18	21	17
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*

1.2 Postgraduate enrolments

• The overall number of postgraduate students at WA universities from the State's regions has been increasing until 1998 (when it reached 379 students) but has been dropping since then to reach the record low 253 in 2001.

• The share of commencing postgraduate students per 1,000 people living in the regions (see Figure 2) has been steadily dropping since 1998 and is currently at 1 starting postgraduate per every 2,000 people. For comparison, the respective 2001 figure for the metropolitan area is 1 commencing postgraduate student per every 500 people (or 4 times higher).

Figure 2.Commencing postgraduate regional students per 1,000 regional population *, 1996-2001



* Population numbers refer to the previous calendar year.

• In 1996, the largest part of postgraduate students from the regions were studying at ECU (40%), followed by Curtin (31%). This trend has been reversed and in 2001, Curtin has the largest share (32%) while UWA and ECU have an equal share of 27%. Murdoch's share has fluctuated to as high as 23% in 2000 and as low as 12% in 1998 and 1999. Again, UWA is the only university, which has been increasing its share of regional postgraduate students since 1998.

Table 4. Shares of regional commencing postgraduate students in WA public universities, 1996-2001 (%)

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Curtin	31	36	49	43	25	32	36
ECU	40	30	22	26	31	27	29
Murdoch	14	15	12	12	23	13	15
UWA	14	19	17	19	21	27	20
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*

PART II. INSTITUTIONAL TRENDS

2. Edith Cowan University

2.1 Undergraduate enrolments

•After a peak in 1997 of 5,565 new enrolments, the undergraduate student population has been declining to record 4,500 new enrolments in 2001 (Table 5).

Table 5. Commencing ECU undergraduate students by place of residence, 1996-2001

ECU	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Peel	48	49	51	77	74	54	59
South West	403	426	367	432	402	417	408
Great Southern	88	89	71	85	65	60	76
Goldfields-Esperance	82	100	194	117	42	39	96
Mid West	94	89	62	113	109	85	92
Gascoyne	8	12	9	6	9	6	8
Pilbara	36	17	18	22	21	11	21
Kimberley	61	41	22	33	65	35	43
Wheatbelt	60	88	68	76	59	42	66
Total regions	*880*	*911*	*862*	*961*	*846*	*749*	868
Regions as % of total students	*16*	*16*	*16*	*18*	*17*	*17*	17
Islands	4	0	1	3	2	0	2
Metropolitan	4,231	4,422	4,252	4,214	3,867	3,627	4,102
Outside WA	249	232	148	184	136	125	179
Total students	*5,364*	*5,565*	*5,263*	*5,362*	*4,851*	*4,501*	*5,151*

• The overall percentage of students from the regions has remained stable during 1996-2001 at around 17% (Table 5).

• The relative high share of regional students is mainly due to the Bunbury campus where the enrolment from the regions is around 97% (see Table 6). However, the 2001 enrolments in Bunbury represent only 8% of the overall student population.

• The share of regional students enrolled to study externally has increased from 32% in 1996 to 43 % in 2001 (see Table 6).

• The regional enrolments on the remaining ECU campuses have been decreasing to reach around 5% in 2001 (see Table 6).

Table 6. Share of commencing regional undergraduate students at ECU by campus, 1996-2001 (%)

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Churchlands	6	6	5	7	7	5	6
Joondalup	5	6	5	6	7	5	6
Midland	n/a	2	4	0	7	0	2
MtLawley	12	12	8	9	6	4	9
Bunbury	97	96	98	97	96	97	97
External Studies	32	30	43	39	39	43	38

2.2 Postgraduate new enrolments

• The total number of commencing postgraduate students has remained around 1,000 during 1996-2001.

• They are located predominantly in Churchlands and Mt Lawley. However, the share of students from the regions on these campuses is extremely small (i.e. 2-3% in 2001).

• The overall share of postgraduate students from the regions in the ECU postgraduate population has dropped from 11% (or 135 students) in 1996 to 7% (or 69 students) in 2001 (see Table 7).

Table 7. Commencing regional postgraduate students at ECU, 1996-2001

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Students	135	107	81	85	97	69	96
% of total students	11	9	9	8	11	7	9

• Most of the postgraduate students study externally (more than 50%).

• The mass of the postgraduates in Bunbury (up to 100% in 1996, 1999 and 2000) are from the surrounding region.

3. Murdoch University

3.1 Undergraduate enrolments

• The total number of undergraduate students has increased from 1,800 in 1996 to 2,250 in 2001 (see Table 8). The year 1999 had a peak enrolment of 2,540 students.

• The absolute number of students from the regions has generally decreased from 256 in 1996 (see Table 8) reaching a minimum of 244 in 2001 (around a 30% drop in comparison with 1997).

Table 8. Commencing Murdoch undergraduate students by place of residence, 1996-2001

Murdoch	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Peel	51	66	67	78	85	69	69
South West	64	68	43	59	65	54	59
Great Southern	39	37	39	38	40	9	34
Goldfields-Esperance	26	47	43	27	27	39	35
Mid West	30	39	27	27	27	27	30
Gascoyne	2	1	3	3	2	0	2
Pilbara	15	20	17	17	6	7	14
Kimberley	10	16	20	13	8	17	14
Wheatbelt	19	39	12	29	30	22	25
Total regions	*256*	*333*	*271*	*291*	*290*	*244*	281
Regions as % of total students	*14*	*13*	*12*	*11*	*13*	*11*	12
Islands	0	0	1	8	1	4	2
Metropolitan	1,476	2,080	1,967	2,139	1,763	1,921	1,891
Outside WA	73	91	88	101	96	81	88
Total	*1,805*	*2,504*	*2,352*	*2,542*	*2,155*	*2,251*	*2,268*

• The share of students from the regions (see Table 8) has dropped in 2001 to 11% (from around 13-14% in the previous years).

• Although physically located within the metropolitan area, the Rockingham campus is treated by DETYA as a regional campus. Nevertheless, the student population on this campus is predominantly from the Perth area, with students from the regions constituting only 16% in 2001, a drop from 22% in 1996 (see Table 9).

Table 9. Share of commencing regional undergraduate students at Murdoch University by campus, 1996-2001 (%)

	1996	1997	1998	1999	2000	2001	Average
Murdoch	14	13	12	11	13	10	12
Rockingham	26	21	16	18	18	16	19

• At the main Murdoch campus, the share of students from the regions has dropped from 14% in 1996 to 10% in 2001 (see Table 9).

3.2 Postgraduate enrolments

• The total number of commencing postgraduate students has been fluctuating between 479 in 1997 and 274 (or more than 40% drop) in 2001.

• The overall share of postgraduate students in the Murdoch postgraduate population has increased from 11% (or 47 students) in 1996 to 22% (or 74 students) in 2000 but then dropped to 12% (or only 34 students) in 2001 (see Table 10).

Table 10. Commencing regional postgraduate students at Murdoch University, 1996-2001

	1996	1997	1998	1999	2000	2001	Average
Students	47	55	46	41	74	34	50
% of total students	11	11	15	14	22	12	14

• The postgraduate students are overwhelmingly located at the main Murdoch campus. The share of regional students on this campus has fluctuated largely from 22% in 2000 to 11% in 1996, the latest 2001 figure being 12%.

• The number of postgraduate students at the Rockingham campus of Murdoch University is negligibly small.

4. University of Western Australia

4.1 Undergraduate enrolments

• The total number of undergraduate students has been steadily increasing from 3,100 in 1996 to 3,470 in 2001, i.e. by 12% (see Table 11).

• The number of students from the regions has been increasing at a faster rate from 318 in 1996 to 385 in 2001, i.e. by 21% (see Table 11).

• The share of students from the regions has also slightly increased and is 11% in 2001 (see Table 11)
.

• UWA currently has enrolments only on its Crawley campus.

4.2 Postgraduate enrolments

• The total number of commencing postgraduate students has been fluctuating between 998 in 2000 and 1,190 in 2001.

• During 1996-2001, the share of regional postgraduate students at UWA has been around 6% (see Table 12). Although their actual number has increased from 47 in 1996 to 69 in 2001, it is still quite low in comparison with the other WA universities.

Table 11. Commencing UWA undergraduate students by place of residence, 1996-2001

UWA	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Peel	21	26	24	34	36	37	30
South West	114	77	102	97	88	114	99
Great Southern	57	45	65	51	77	65	60
Goldfields-Esperance	35	49	41	30	44	32	39
Mid West	43	41	37	55	33	53	44
Gascoyne	1	4	3	4	0	6	3
Pilbara	8	12	10	9	15	15	12
Kimberley	4	12	12	14	15	15	12
Wheatbelt	35	43	27	43	46	48	40
Total regions	*318*	*309*	*321*	*337*	*354*	*385*	337
Regions as % of total students	*10*	*10*	*10*	*10*	*11*	*11*	10
Islands	2	3	4	1	1	2	2
Metropolitan	2730	2719	2721	2907	2911	3044	2839
Outside WA	41	65	55	54	49	40	51
Total	*3091*	*3096*	*3101*	*3299*	*3311*	*3471*	*3228*

Table 12. Commencing regional postgraduate students at UWA, 1996-2001

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Students	47	69	65	63	3	69	53
% of total students	5	7	6	6	0	6	5

5. Curtin University of Technology

5.1 Undergraduate enrolments

• After a peak in 1998 of around 4,580 new enrolments, the student population has been gradually declining to reach 4,030 new enrolments in 2001 (see Table 13).

• The percentage of students from the regions has been around 13% for most of the period but has decreased to 11% in 2001 (see Table 13).

• Curtin University has a number of regional campuses with very high share of regional enrolments; however, the largest number of students from the regions are actually attending the main Bentley campus. During 1996-2001, their number is in average 400 and their share has remained constant at around 10%.

Table 13. Commencing Curtin undergraduate students by place of residence, 1996-2001

Curtin	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Peel	45	34	49	49	53	53	47
South West	102	124	126	137	101	101	115
Great Southern	77	59	69	71	53	59	65
Goldfields-Esperance	97	134	164	121	96	90	117
Mid West	71	89	78	124	73	75	85
Gascoyne	9	5	4	0	1	1	3
Pilbara	50	27	25	1	14	14	22
Kimberley	17	36	30	7	20	20	22
Wheatbelt	74	63	55	77	58	47	62
Total regions	*542*	*571*	*600*	*587*	*469*	*460*	538
Regions as % of total students	*13*	*13*	*13*	*14*	*12*	*11*	13
Islands	0	1	0	0	3	10	2
	0	0	0	0	0	0	
Metropolitan	3576	3767	3851	3547	3480	3476	3616
Outside WA	151	136	126	156	87	86	124
Total	*4269*	*4475*	*4577*	*4290*	*4039*	*4032*	*4280*

• In 2001, 77% of all students enrolled in Kalgoorlie (i.e. 52) are from the regions (see Table 14). The share of students from the regions in Muresk is even higher (i.e. 86%) but their number is smaller (only 36).

Table 14. Share of commencing regional undergraduate students at Curtin University by campus, 1996-2001 (%)

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Bentley	10	10	11	11	10	10	10
Kalgoorlie	48	96	75	70	78	77	74
Muresk	71	70	70	72	86	86	76
Shenton Park	13	12	15	12	14	16	14

5.2 Postgraduate enrolments

• The total number of commencing postgraduate students has decreased from around 1,000 in 1996 to the current levels of around 770 (i.e. drop of around 20%).

• They are located predominantly at the Bentley campus. However, more recently the Perth City campus has become quite important in teaching postgraduate courses. The share of regional students on both these locations is very low (9% and 5% respectively).

• Curtin's major campus in the regions is Kalgoorlie. Although the share of regional students enrolled there is at a high 72% in 2001, it has fluctuated to as low as 16% in 1997.

• The overall share of postgraduate students from the regions in the Curtin postgraduate population currently represents 11% (or 81 students) but has been as high as 22 (or 184 students) in 1998 (see Table 15).

Table 15. Commencing regional postgraduate students at Curtin University of Technology, 1996-2001

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Average*
Students	105	131	184	140	80	81	120
% of total students	11	13	22	16	10	11	14

Appendix Three

Steering Committee And Project Team

Steering Committee and Project Team

The membership of the Technology and Industry Advisory Council (TIAC) Steering Committee for this project is listed below:

Mr John Thompson	TIAC Member (Chairperson)
Mr Bruce Sutherland	TIAC Member
Prof. Nigel Radford	TIAC Member
Mr Rex Baker	TIAC Member
Mr Earl White	Executive Officer (TIAC)

The Steering Committee was assisted in its task by:

Professor Tim Turpin	International Business, Department of Management, Faculty of Commerce, University of Wollongong & Centre for Research Policy and Innovation Studies (CRP), University of Wollongong;
Professor Jane Marceau	Australian Expert Group in Industry Studies (AEGIS), University of Western Sydney;
Professor Reg Appleyard	University of Western Australia;
Dr Dora Marinova	Institute for Sustainability and Technology Policy (ISTP) Murdoch University;
Associate Prof. Sam Garrett-Jones	Centre for Research Policy and Innovation Studies (CRP) University of Wollongong;
Mr David Aylward	Faculty of Commerce University of Wollongong.

Appendix Four

Diagram

“Towards a Western Australian Knowledge Economy”

"Towards a Western Australian Knowledge Economy"

"Drivers and Shapers of Economic Development in Western Australia in the 21st Century" (9/00)
(Discusses the long-term sustainability of the Western Australian economy.)

"From Mines to Minds: Western Australia in the Global Information Economy" (2/99)
(Develops the vision for an enterprising online culture in Western Australia as the foundation for an integrated and sustainable indigenous network of globally–oriented Information Industries.)

"Western Australia's Mineral & Energy Expertise: How can it be optimised? – Growing the R&D Sector" *(6/99)*
(Proposes the development of a world class R&D capability in minerals and energy.)

"Export of Western Australian Education & Training: Constraints & Opportunities" (10/00)
(Proposes increasing WA market share in this sustainable established industry.)

"Biotechnology West: Strengths, Weaknesses & Opportunities" (12/00)
(Proposes the development of a State strategy to grow this new enabling technology in Western Australia.)

"Directions for Industry Policy in Western Australia within the Global Knowledge Economy" (3/02)
(Proposes strategies and policy options for the development of a comprehensive Industry Policy for Western Australia.)

"The Organisation of Knowledge: Optimising the Role of Universities in a Western Australian Knowledge Hub" (6/02)
(Discusses issues relating to optimising the participation of the State's universities in a Western Australian Knowledge Economy.)

2002-2003 Reporting Programme
(to be finalised)

Copies of completed reports can be obtained from our website – **www.wa.gov.au/tiac**.

Appendix Five

Western Australian Technology Advisory Council

Western Australian Technology & Industry Advisory Council

Background

The Technology and Industry Advisory Council (TIAC) was created by legislation in 1987 (Technology Development Amendment Act - No. 32 of 1987) and was continued under Section 20 of the Industry and Technology Development Act 1998.

TIAC was preceded by the Technology Review Group 1978-83, and the Science, Industry and Technology Council (SITCO) 1983-87.

Council is made up of representatives from various sectors of the State's economy who, in terms of the relevant Act, use their varied background and experience to provide independent policy advice to the Minister so as to make a significant contribution to the development of strategies relating to the State's economic development.

Members of the Council are appointed by the Minister, under Section 22 of the Industry and Technology Development Act 1998 so as to be representative of the interests of the people of the State.

TIAC reports through the Minister to Parliament under Section 26(1) and Section 26(2) of the Industry and Technology Act 1998.

TIAC reports under the Financial Administration and Audit Act 1985 through the Department of Commerce and Trade under Section 26(3) of the Industry and Technology Development Act 1998.

Objectives of the Industry and Technology Development Act 1998

The objectives of the Industry and Technology Development Act 1998 under Section 3 are:

(a) To promote and foster the growth and development of industry, trade, science, technology and research in the State;

(b) To improve the efficiency of State industry and its ability to compete internationally;

(c) To encourage the establishment of new industry in the State;

(d) To encourage the broadening of the industrial base of the State;

(e) To promote an environment which supports the development of industry, science and technology and the emergence of internationally competitive industries in the State.

Functions of the Western Australian Technology and Industry Advisory Council

The Council, under Section 21 of the Act is required to:

(a) Provide advice to the Minister, at the initiative of the Council or at the request of the Minister, on any matter relating to the objects of the Industry and Technology Development Act 1998;

(b) Carry out, collaborate in or produce research, studies or investigations on any matter relating to the objects of this Act, including matters relating to:

- (i) the role of industry, science and technology in the policies of Government,
- (ii) the social and economic impact of industrial and technological change,
- (iii) employment and training needs and opportunities relating to industrial, scientific and technological activities in the State,
- (iv) the adequacy of, priorities among and co-ordination of, scientific, industrial and technological activities in the State,
- (v) methods of stimulating desirable industrial and technological advances in the State,
- (vi) the application of industrial, scientific and technological advances to the services of the Government,
- (vii) the promotion of public awareness and understanding of development in industry, science and technology.

The Ministerial advice takes the form of reports and discussion papers, which undergo a public consultation phase before submission to the Minister.

Participation on State and Federal Government Advisory and Funding Committees and Councils

Council has accepted invitations for representation and participated in:

(a) The State's Co-ordination Committee on Science and Technology;

(b) The Steering Committee for the CSIRO National Centre for Petroleum and Mineral Resources Research;

(c) The “State Funding Advisory Committee” (SFAC);

(d) The State’s “Information and Communications Policy Advisory Council” (ICPAC);

(e) The Department of Commerce and Trade’s “Technology Operations Group” (TECHOP);

(f) The Federal Government’s “Commonwealth, State and Territory Advisory Council on Innovation”.

Promotion and Public Awareness Raising Activities

Council's promotional and public awareness raising programs consist of two main types:

a) The 2020 Breakfast Seminars, which are short, economic development focused, information dissemination events;

(b) The Science and Technology Forums which were established under the State's Science and Technology Policy in April 1997 in order to "raise the awareness of science and technology in the community and increase the community's input in the State's directions in Science and Technology".

Financial Provisions

The expenses of Council are provided for under Section 15 of the Industry and Technology Development Act 1998 via the Western Australian Industry and Technology Development Account.

Present Membership

Mr John Thompson
TIAC Chairman
National Chief Executive (Australia)
SGS Australia Pty Ltd

Mr Rex Baker

Ms Sharon Brown
Strategic Business Manager
AlphaWest

Dr Brian Hewitt
Chairman
Clough Engineering Limited

Mr Mick McGinniss
Agricultural Producer

Mr Rob Meecham
Director of the Business Development Unit
South Metropolitan of TAFE

Professor Nigel Radford
Curtin University Applied Geology
CSIRO

Professor Beverley Ronalds
Woodside Chair
Centre for Oil & Gas Engineering
University of Western Australia

Dr Paul Schapper
A/Director General
Department of Industry and Technology

Mr Bruce Sutherland
Managing Director
Gunn Sutherland Corporate Pty Ltd

Professor Lance Twomey
Vice Chancellor
Curtin University of Technology

Mr Tim Ungar
Chairman
Telecommunications Services Australia

PUBLIC COMMENT
REPLY SHEET

TO: THE EXECUTIVE OFFICER
WESTERN AUSTRALIAN TECHNOLOGY AND INDUSTRY ADVISORY COUNCIL

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TECHNOLOGY PARK
BENTLEY WA 6102

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Comments on the Report entitled:

The Organisation of Knowledge:
Optimising the Role of Universities in a Western Australian 'Knowledge Hub'

Closing Date: 1st August 2002

(Please tear out and return with your comments.)