Building Brain-Based Industries? First, find the Brains

Peter Andrews
Chief Scientist, Queensland
Department of Innovation & Information Economy

Abstract

Knowledge-based industries are generally recognised as the pathway to international competitiveness and its associated social, economic and environmental benefits. Australia has an opportunity to transform itself into a knowledge-based society, particularly in emerging industries such as biotechnology and nanotechnology, but will require substantially larger numbers of highly trained researchers than currently available. For emerging industries, the supply of excellent scientists in the 'hard' sciences areas (chemistry, physics and mathematics) is especially important.

Two major issues impact on the availability of such people. The first is brain drain, where better salaries and work opportunities (career paths, research and commercialisation funding, job security etc) attract Australian researchers overseas. While obviously important for Australian scientists to play a major role in the international community through links, training and exchanges, it is also vital that a reasonable proportion are encouraged to either return, maintain positive links or be replaced by international equivalents. The second issue is brain loss, where students who might have chosen to study science choose otherwise, or opt for `soft' rather than `hard' sciences, and scientists who might have pursued science careers leave to pursue other opportunities. Unlike brain drain, brain loss is a world problem, but its impact will be proportionately greater for those nations like Australia, that cannot hope to outbid the world's biggest economies for limited numbers of trained scientists.

This paper will briefly consider the likely demands for 'hard' scientists in Australia's knowledge-based industries, scan the national and international evidence for brain loss from the 'hard' sciences, and offer some preliminary thoughts on financial, social and cultural initiatives that might help Australia to train sufficient 'hard' scientists to enable us to take our place in the global knowledge economy.

Introduction

In the year that I completed my PhD (1969), Australia produced 18 PhD's in Chemistry per million of population. The US produced 9. According to the report 'Science at the Crossroads' (Australian Council of Deans of Science, 2001), the number of PhD completions in Chemistry for 2001 was 8 per million (just above the US which has decreased from 8 per mill in 1993 to 7 per mill in 2002) (NSF, 2003).

These numbers lie at the heart of the four issues that I want to discuss today.

1 How many scientists do we need?
2 What is the impact of brain drain/gain?
3 What about brain loss?
4 What are the solutions?

National Needs for Scientists

Politicians sometimes claim that Australia has already made the transition from a resource-based economy to a knowledge-based economy, but it is hard to find evidence that benchmarks these claims against the performance of our competitors. Let's consider biotechnology.

The following are some international figures for biotechnology revenues generated per head of population:

Nation	**Biotechnology revenues/ head of population (A$)**
Belgium	$260
Finland	$220
United States	$150
Netherlands	$120
United Kingdom	$80
Australia	$50

Obviously, we do not compare favourably with our competitors. Why is this so? All available data suggest that the quality of our underlying science is not an issue. Rather, our failure appears to lie in the conversion of science into revenue. What measures can we use to detect shortcomings in the commercialisation process? There are essentially only two.

The first, and most direct measure, is the number of people employed in knowledge-based industry: the grist for the mill, the brains. Numbers of biotechnology employees per million of population range from 200 in the Netherlands to 800 in Finland and Scotland. Australia has around 300, while the US has about 700 and this is projected to double in the next six years.

The second measure, which is clearly linked to the first, is business investment in Research and Development (R&D). You all know the numbers. We are pathetic. Australia spends around $10 million (per million of population) on R&D in listed core biotechnology companies, the US invests over $100 million. Listed Australian core biotechnology companies invest an average of $4 million/annum on R&D expenditure, their US counterparts invest $100 million. If unlisted companies are included the corresponding figures are $2m and $12m.

Companies like Ford, IBM and GM spend more on R&D than the entire Australian business community. Pfizer estimates its (medical research) R&D budget for 2004 at US$ 7.9 billion (Pfizer, 2004). Total Australian domestic R&D in 2000- 2001 accounted for A$ 10.3 billion of which medical and health research was 12.9% of the total (DEST 2003, Charts 1,8). US companies spend 80 cents in the dollar on development. Australian universities, their de facto equivalents, spend 20 cents in dollar. Whatever we decide today, we need our industries to invest vastly more in R&D.

So what if we fix the investment problem? What if we actually make the cultural change that sees Australians investing in knowledge-based industries rather than horse-races, real estate and holes in the ground. What would happen then?

In the case of biotechnology, based on direct comparisons with our international competitors, our biotechnology revenues would grow from $1 billion to $12 billion per annum, and our biotechnology industry workforce would grow from 5,700 to 30,000. Our biotechnology industry would need an additional 25,000 employees.

What does this mean in total? I can't tell you what fraction of Australia's knowledge-based industries biotechnology might represent, but I would guess that it's about a third. So, the total need for a knowledge-based industry in Australia is on the order of 75,000 additional scientists by 2010. Obviously this figure is rubbery. On the one hand, I've made no allowance for the indirect employment requirements to support these industries. On the other hand, not all of the direct or indirect employees will be scientists.

Is there some way that I can verify this number? Yes, look at the international projections. The EU is saying that they need an additional 500,000 to 700,000 scientists by 2010. The corresponding figure for the US is 2.2 million. Normalise on a population basis and what do you get? Between 40,000 (Europe projection) and 150,000 (US projection) required by 2010. And that's without allowing for catching up!

Another check. In 2001, Australia had just over 10 R&D staff per thousand total employment, compared with 23, 16, and 13 per thousand in Finland, Sweden and Japan respectively (OECD, 2004). To get to their average, say 20 per thousand, we need an extra 70,000 scientists. So, whatever way you stack it, we need somewhere around an extra 75,000 scientists by 2010.

What sort of scientists will they be? I don't have the statistics, but for reasons that will become evident below, I think the major needs are going to be at the top end (doctoral level) and in the enabling sciences (chemistry, physics and mathematics). By way of an anecdotal example, I mention Alchemia, a Brisbane start-up of which I am a founder and which specialises in carbohydrate chemistry. Alchemia scoured Australia for carbohydrate chemists, but fell far short of its needs. At last count, this small Brisbane company (less than fifty staff) had hired carbohydrate chemists from 23 countries.

The 2003 DITR/DEST report *Mapping Australian Science and Innovation* agrees, saying that the long term sustainability of Australia's skill base in the enabling sciences is under particular pressure. So there's the headline! Wanted: 75,000 additional scientists, preferably with PhDs in the enabling sciences, by 2010. How will we get there?

Impact of Brain Drain/ Gain

If you read Business Review Weekly (BRW) of 16 Feb 2004, you would no doubt have been impressed by the fact that the Chief Operating Officiers (CEOs) of News Corporation, DOW Chemicals, British Airways, Coca-Cola and the World Bank are all expatriate Australians. Likewise, the CEOs of DuPont and MacDonalds. Add the fact that the CEOs of Australia's two biggest biotechnology companies, CSL and ResMed, are resident in the US, and you would have to start saying there is something fishy going on.

You can also bet your bottom dollar that most of those 18 PhDs in Chemistry per million of population that finished with me in 1969 are well and truly scattered around the globe. They have risen through the ranks of big pharma and universities in Europe and the US, many at President and Vice-President level. And we are still losing them: net movements of Australian residents shows a small negative flow of chemists from Australia (approx 50-75 people each year since 97/98) (DITR & DEST, 2003). But that is hardly significant in the scheme of things unless, as some suspect, those 50-75 people are the best of the best.

On the other hand, we and other nations benefit from the reverse, brain gain. In the US, 12% of people in science or engineering jobs are of foreign origin. The 2 million Indians working in the US, mainly in the IT industry, earn roughly double the per capita income of the US population at large. Many will stay there, but others will return home to build India's IT industry. In the long run, brain gains such as this will benefit both nations.

A key source of brain gains such as the US/ Indian example is the provision of training for international students. In 2001, Australia had the third highest number (approx 7000) and fifth highest percentage (22%) of foreign PhD students in the OECD. But, take heed of Simon Marginson (2004), writing in *The Howard Years* (edited by Robert Manne) when he talks of the ability of the US to attract students at postgraduate levels. In fact, OECD-wide, most foreign students enrol in social sciences, business and law or arts/humanities (OECD, 2004).

Frankly, the numbers of researchers won or lost by international migration are really quite small compared to the problem we need to address. An increase in our R&D workforce of 10% resulting from affirmative immigration and training policies would only give us an extra 7,000 to 10,000 scientists. Where does Australia find 75,000 researchers by 2010? To answer that question, we need to address the question of what I will term 'brain loss'.

Brain Loss

I am not sure whether or not there is a standard definition for 'brain loss'. My personal one refers to those situations where students who might have chosen to study science choose otherwise, those who do choose science opt for soft sciences rather than hard sciences, and scientists who might have pursued careers in science leave to pursue other opportunities. Unlike brain drain, brain loss is a problem for all nations, but its impact will be proportionately greater in those nations, like Australia, that cannot hope to outbid the world's biggest economies in competition for limited numbers of trained scientists.

Let us consider the evidence at four levels: primary school, secondary school, undergraduate and postgraduate studies.

Primary School

At the primary school level, the clear issue is the lack of teachers with training and/or interest in science. Kids are naturally curious, but that curiosity must be stimulated and nurtured. The impact of a primary teacher who revels in helping children to explore the wonders of natural science cannot be underestimated. Oliver Sachs' (2002) book, *Uncle Tungsten*, gives insights into what follows in the presence and absence of such nurturing.

In Australia, the proportion of BEd and DipEd students taking maths and science subjects dropped between 1991 and 2000 (DITR & DEST, 2003). At the same time, national assessment of the labour market for teachers suggested shortages in maths, physics/ chemistry and general science teaching (Dept Employment & Workplace Relations, cited by DITR & DEST, 2003).

Secondary School

The *Mapping Australia's Science and Innovation* (2003) report refers to declining participation in the more demanding mathematics and sciences in Year 12 at school, and falling participation in Science and Technology (S&T) subjects recently at the undergraduate level in university.

Year 12 enrolments in Australia:

- o Downward trend since 1976 in the percentage of students enrolling for physics, chemistry and biology.
    - Chemistry 33% in 1980, 17% in 2002
    - Physics 29% in 1980; 16% in 2002
    - Drop in enrolments for two physical sciences subjects studied **in combination** (eg as basis for tertiary education in physical science) dropped to 9.7% of year 12 students in 2001, compared with 15% in 1990 (DITR & DEST, 2003).

Tertiary

- o In 2001, only 1% of tertiary graduates in Australia were in the Physical Sciences (physics, chemistry); Sweden 2.5%; UK 5.2%; US 1.5%, OECD mean 2.6% (OECD, 2003)
- o Total student load (units are full-time student equivalents rather than 'bums on seats') in chemical sciences dropped by almost 5% from 1989-2002
- o Total student load in physics and materials sciences dropped by over 31% from 1989-2002
- o Total number of new places announced by Minister Brendan Nelson would not meet our needs

Postgraduate

As noted at the outset, the number of PhD graduates in chemistry has declined. This applies right across the physical sciences (in Australia only 8% of doctorates are in the physical sciences) and it applies around the globe (in the US the number of PhDs in Physical Sciences has declined from 3700 to 3200 over the past ten years, although they still represent 16% of the total).

So, far from solving the problem of finding 75,000 researchers in Australia and 2.2 million in the US, we are producing less of the very scientists we need most. What's to be done?

Solutions

Let me address these issues at the same four levels, and let me offer you a mish-mash of solutions - some financial, some social and some cultural – that are representative of what I think is the real need –' brain train'.

Primary School

We need to pay primary school teachers with science qualifications sufficient to attract them into teaching. We need the salaries that we pay them to refect the fact that we hold them in high esteem.

We need to expose primary school students to scientists. How many retired scientists do you know who would love to spend a day a week sharing their knowledge with children in their local primary school?

And we need to get the community involved in understanding and doing science in schools. Appoint a science co-ordinator for each primary school (from the grey army?)

Secondary School

Again, teacher salaries.

And again, we need students to be exposed to practising scientists whose roles illustrate the importance of science to all. People who can talk about their work making better vaccines, creating more nutritional foods, or protecting our rain forests.

We need to create science committees involving parents, teachers and scientists to encourage linkages between schools, research organisations, industry, and the wider community to raise awareness of science subjects, career paths, and the importance of science to the community at large.

Tertiary

We need to honour our champion scientists as we honour our champion athletes.

We need to create scholarships for science students, and bonuses for high achievers.

We need to involve eminent scientists from industry and learned societies in our tertiary teaching, and to promote links between postgraduate and undergraduate science students.

We need elite courses in the enabling sciences that offer students fast tracks and industrial experience. We need to involve scientists from industry on University councils.

Postgraduate

We need to increase scholarships for PhD students in the enabling sciences and to improve pay and conditions for young researchers.

One of the other things we need to do is to look at increasing the representation of women in science; while the proportion of females studying physical sciences has increased, more work needs to be done. More particularly, encouragement is needed for women to pursue a career in science as well as flexibility to enable them to return to the work force (Dr Pauline Gallagher, 2004, personal communication).

We need to encourage the entrepreneurs driving the development of knowledge-based industries to park their Porsches at the University gates while they tell postgraduate students their stories.

And we need to persuade the Minister, Brendan Nelson, that every one of the approximately 25,000 additional places being proposed for the tertiary sector for this decade should be for graduates and postgraduates in the enabling sciences, not more low cost places for accountants and lawyers. Then we will have made a start!

References

Australian Council of Deans of Science (2001) *Science at the Crossroads*. Canberra: Australian Council of Deans of Science.

(DITR) & (DEST) (2003) *Mapping Australian Science & Innovation*. Canberra: Australian Government.

(DEST) (2003) *Australian Science and technology at a glance 2003*, Canberra, Commonwealth of Australia.

Marginson, Simon (2004) 'Higher Education'. In *The Howard Years*, Robert Manne (Ed.), Black Inc Agenda Publishers.

NSF. (2003) *Science and Engineering Indicators 2002*. Washington DC: NSF.

OECD. (2003) *Education at a Glance*. Paris.

OECD. (2004 29-30 January 2004). *Science and Technology Statistical Compendium.* Paper presented at the Meeting of the OECD Committee for Scientific and Technological Policy at Ministerial Level, Paris.

Pfizer (2004) *About Pfizer*, at company website – www.pfizer.com

Sachs, Oliver (2003) *Uncle Tungsten*, Knopf Publishing Group, VINTAGE.