Is the Study of Science in Decline?

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Australian Council of Deans of Science

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Table of Contents

List of Tables

List of Figures

Is the Study of **Science in Decline?**

In 1998 the Australian Council of Deans of Science (ACDS) released an authoritative report, *Trends in Science Education*. It revealed a significant and systematic decline in enrolments in the fundamental sciences, physics, chemistry and mathematics, both at university and secondary school, relative to other areas of study.

The report was a breakthrough in two important respects. First, policy makers and the public recognised the significance of basic science for advancing Australia as a knowledge based economy, and winning a place for its young people in the new global economy. They acknowledged that it was important to reverse the decline in the study of fundamental science for this reason. Secondly, there was recognition of the worrying extent to which important trends such as these are masked by the way that government statistics are reported; that it takes detailed and expert interpretation to reveal such trends.

The concerns expressed by the ACDS in *Trends in Science Education*, and particularly its interpretive paper *Who Is Studying Science?*, were injected into the debate at that time about provision for Australia's technological future; particularly through the Innovations Summit and the report of the Chief Scientist *The Chance to Change* (Batterham, 2000). The Government's response has been through its initiative *Backing Australia's Ability*, which promised increased funding for science, and included a review of Education focussed on science and technology.

Five years on, the ACDS has commissioned a follow up study *Science at the Crossroads? A study of the trends in university science from Dawkins to now 1989-2002* conducted in 2003 by the same leading expert Ian Dobson. It shows that over the last five years the decline in the study of basic sciences, which so alarmed everyone concerned with positioning Australia as a high technology nation, has proceeded unabated if not more dramatically than indicated. None of the initiatives of government have been of any effect in arresting the decline.

From the point of view of the innovations economy the picture is even more disturbing. The science education agenda has broadened over the last 15 years, so that there is now a strong component of science literacy. Many subjects and courses classified as 'science' have this character. While this is a welcome development for creating a more science aware society, these courses are usually not designed to provide the level of scientific skill required for technology invention and innovation. The student enrolments devoted to the innovations end of science will be only a part of the 30% or so increase in general science enrolments, and may well follow more closely those areas like physics, chemistry and mathematics that are in decline.

The impact of a decline in basic science enrolments, even relative to enrolments in other disciplines, affects the whole of Australia's innovations effort. Despite the research role of university scientists, the staff complement that undertakes scientific research in universities is largely funded in proportion to its undergraduate teaching. Government derived funding to universities has remained static in real terms over this period, or even declined, and business investment in R&D, a measure of private support for research, has fallen, so there is no means by which to make countervailing investments in science. As a consequence universities, driven by government policy to be responsive to short term student demand, are shifting resources out of science and technology. Confirmation is provided by reference to DEST's most recent publication of staff statistics. In the decade between 1991 and 2000, the number of Teaching-Only and Teaching-and-Research academic staff in science, mathematics and computing declined in number by 730 (DEST, 2003, Table 10).

This situation is not set to improve, but rather will grow worse. *Science at the Crossroads?* also examined enrolment trends in science and mathematics in high schools. The decline is dramatic, and will translate through to undergraduate enrolments over the next few years.

Some 90% of fundamental technology research takes place in universities. These are meant to be the powerhouses that contribute new ideas and techniques to Co-operative Research Centres, collaborate with CSIRO and other national research organisations, as well as produce technology spin-off companies. They are a key part of the innovations system in every developed economy. PhD students are a critical element of this infrastructure, their projects and their career aspirations forming crucial linkages and knowledge transfer elements in the whole innovations system.
Their numbers have doubled or trebled over the past five years, except in mathematics. However, PhD enrolments are fuelled by undergraduate completions and sustained by staff supervision and university infrastructure. It has to be expected that the decline in these will soon follow through to PhD enrolments.

Crises in education and innovations systems do not occur dramatically. It is hard to pick one particular point in time when they can be said to have happened. The ACDS study *Trends in Science Education* warned five years ago of the declining trend in Australia's human infrastructure in science and technology. *Science at the Crossroads?* provides a second warning, and shows how seriously the first one needed to be taken. A third warning will be unnecessary, either because Governments and public authorities will acknowledge the problem and act, or because it will be too late. We would prefer them to act now.

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Science in Australian Universities

This Occasional Paper examines enrolments trends at discipline level within the broad heading of "Science", especially in areas such as chemistry, physics and mathematics - the enabling sciences. A full consideration of these issues can be found in *Science at the Crossroads? A study of trends in university science from Dawkins to now1989 – 2002.*

In an earlier report, *Trends in Science education: Learning, Teaching and Outcomes 1989-1997* the ACDS demonstrated that apparent growth in "Science" masked a serious decline in the enabling sciences. Has this situation been arrested?

During the period 1989-2002 the number of students enrolled in Science, not including Information Technology (IT) increased by 37.0%. However in the same period there has been growth over the sector of 70.3%. That is, growth in Science has in no way matched the growth in the sector overall. Growth in IT over this period has been an amazing 342.2%. If IT were to continue to grow in this way there would be more IT students than science students in two to three years. Taking science and IT together the growth over the period has been 104.8%.

While the growth in science is not as impressive as for the sector at large, or for IT, it does appear healthy, and to indicate a sustainable future. However "Science" covers a very broad range of areas and needs to be and considered in more detail. Is this "growth" continuing to mask the decline in the enabling sciences that was clearly seen in *Trends…*? There are reports that the growth in IT numbers has reached a peak and may now be falling! Are these reports borne out by experience across the sector?

In the period between the publication of *Trends…* and the current publication there have been substantial changes in what is categorised as Science by The Department of Education, Science & Training (DEST) (The Department of Education, Training & Youth Affairs (DETYA) in the earlier report). *Science at the Crossroads?* explains in great detail the methods and decisions that have been used to ensure that the data reported for the period 1999-2002 are indeed comparable with those for 1989-1997.

The previous system in which courses and subject areas were categorised under Broad Fields of Study and Discipline Groups respectively was replaced by a new system where Broad Fields of Education have been used from 2001 onwards.

Importantly for this study, the courses contained within Field of Study *09 Science* do not exactly map to Field of Education *01 Natural and Physical Sciences*. To make the data described in *Trends…..* consistent with data reported here, enrolments in discipline areas such as Soil Science, Medical Science, Human Movement and Environmental Science, which have been either added to "Science" for the years 1989-1997 or to "Science" for the years 2001 and 2002.

In summary the category "Science" as used in this report to identify science courses, includes some courses that were not categorised as science by DEST for the years 1989-1997 and some that were not described as science by DEST in 2001 and 2002.

These adjustments allow an examination of Science and IT enrolments over the 14 year period since 1989. Table 1 shows the growth in enrolments in Science, IT and All Other Courses across the range of courses including bachelor degrees, masters degrees and PhD degrees for All Students (which includes domestic and overseas students).

Table 1: Growth in Enrolments in Science, Information Technology and All Other Courses –All Students

Course Group	Growth				
	1989-93	**1993-97**	**1997-01**	**2001-02**	**1989-02**
Science Courses	17097	6067	-7081	1950	18033
Per Cent	35.1%	9.2%	-9.9%	3.0%	37.0%
Information Technology Courses	7107	6987	28483	4972	47549
Per Cent	51.1%	33.3%	101.8%	8.8%	342.2%
Science & Information Technology Courses	24204	13054	21402	6922	65582
Per Cent	38.7%	15.0%	21.4%	5.7%	104.8%
Other than Science & Information Technology Courses	110338	70179	44848	18919	244284
Per Cent	29.2%	14.4%	8.0%	3.1%	64.5%
Total	**134542**	**83233**	**66250**	**25841**	**309866**
Per Cent	30.5%	14.5%	10.1%	3.6%	70.3%

Source: DEST Aggregated Data Sets

- As far as science was concerned the strongest growth was in the early 1990s with an actual fall in enrolments in the 1997-2001 period (this may have been the result of students shifting preference to IT courses).
- There is some evidence of a small growth in the period 2001-2002.
- Compared to the growth in Other than Science & IT courses, growth in Science has been small.

Using enrolment data to track student choice aggregates student choice at the level of a course, and may give no insights into the discipline areas studied. For example a student enrolling in a BSc with majors in physics and chemistry will simply be shown as enrolled in a general science degree. Student Load data (**E**quivalent **F**ull Time **S**tudent **U**nit, EFTSU) however, are aggregated at subject level into Discipline Groups (to 2000; Fields of Education in 2001-2002) and, as well, takes into account whether the student is taking a full or part time load. Using an EFTSU measure allows a close examination of the trends down to discipline level, so important in assessing the health of science overall.

The **Student Load,** shown in Table 2 can be summarised:

- In Student Load terms the growth in Science has been 27.6%;
- This growth can be seen to be largely made up of growth (69.2%) in Other Sciences (which comprises teaching in pharmacology, medical technology, medical science, forensic science, food science and biotechnology, and laboratory technology) and;
- Behavioural Science and Biological Sciences have continued to grow over the period.
- There has been growth in Earth Sciences over the period but from a low base. The peak year for enrolments in Earth Sciences was 1997.
- **Mathematical Sciences, Chemical sciences and Physical and Material Sciences continue to show an absolute decline.**
- **The inclusion of Materials Science within the physical sciences could mask an even greater decline in physics.**
- The table also shows that teaching in science subjects peaked in 1997 and while there has been some growth over 2001-2002 levels in 2002 have not yet reached those in 1997.

Bachelor's degrees comprise about 75% of all enrolments and therefore have a major effect in determining the trends in Table2.

Table 2: Student Load (EFTSU) Generated by All students, by Subject Group

Subject Group						Growth 1989-2002	
	1989	**1993**	**1997**	**2001**	**2002**	**No**	**%**
Science							
Behavioural Science	14520	18197	22055	21572	23017	8497	58.5%
Biological Sciences	18637	24462	28041	28794	30512	11875	63.7%
Chemical Sciences	8003	9124	9048	7503	7621	-383	-4.8%
Earth Sciences	2792	4113	4065	3927	3897	1106	39.6%
Mathematical Sciences	20937	22813	22564	20193	20519	-417	-2.0%
Other Sciences	3659	5261	6176	5974	6192	2533	69.2%
Physical/Materials Sciences	7284	7940	7155	4892	4994	-2290	-31.4%
Science Sub Total	**75832**	**91909**	**99103**	**92855**	**96753**	**20921**	**27.6%**
Information Technology	17856	24057	31139	52002	55237	37381	209.4%
Science & Information Technology	**93688**	**115965**	**130242**	**144857**	**151990**	**58302**	**62.2%**

Source: DEST Aggregated Data Sets

These data are of even more concern than those presented five years ago. It is clear that Science is not growing as fast as the university sector as a whole and within this limited growth important areas such as Chemistry, Physics and Mathematics are showing serious decline.

This decline needs to be seen in the context of great efforts being made by a number of groups including Government to turn the decline around. There is little evidence that this effort has had any effect.

A large part of the Government's Science and Innovation policy rests on a strong science sector:

> "It is critical that our education system teaches entrepreneurship and enterprise at all levels, and that we develop community awareness of how science and innovation contribute to wealth generation and job creation. There is a range of initiatives under Backing Australia's Ability that promote such values and that highlight the world-class skills and talents of our people in the areas of science, technology, innovation and enterprise". (Backing Australia's Ability: Real Results, Real Jobs, The Commonwealth Government's Innovation Report 2002-03).

Backing Australia's Ability is based on a strong science base in this country.
The findings of this study indicate that the science base is very shaky indeed—especially the enabling sciences.

The Information Technology Bubble? Burst or just deflated?

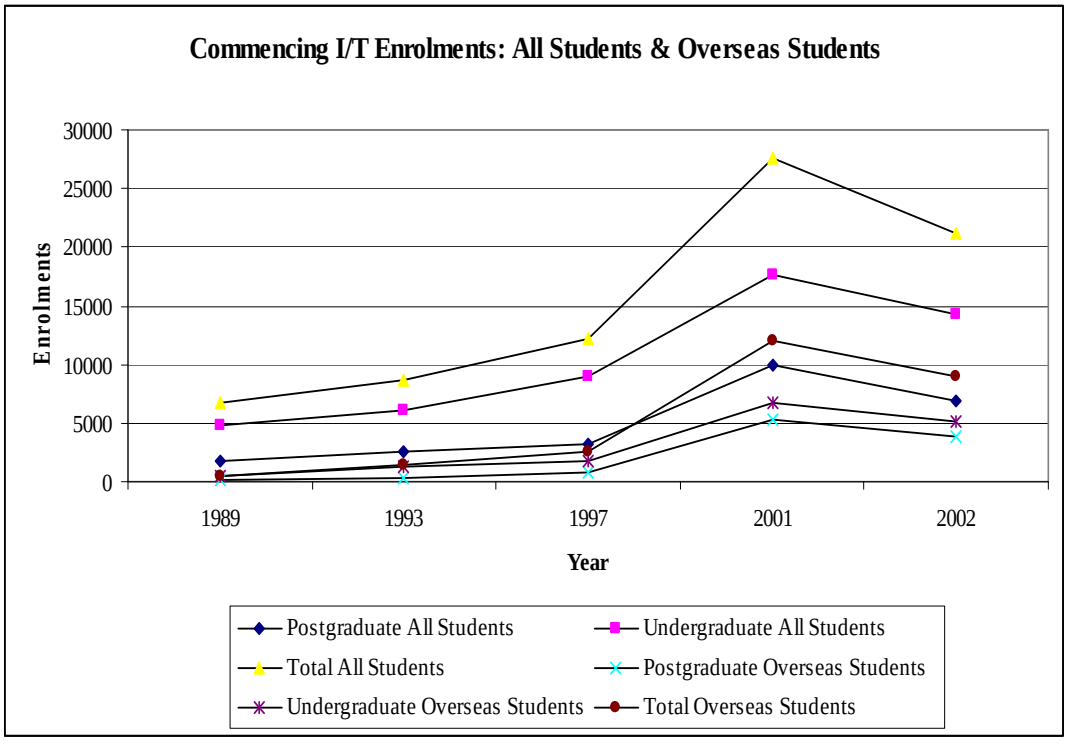
Information Technology has had a strong growth in enrolments in Australian Universities over the study period. Following the drop in NASDAC stocks during 2000 there has been pressure on these enrolments. It is important to examine these enrolment trends both for Australian students but also because a large number of enrolments in IT are from overseas students studying Australian degrees. Any decrease in enrolments amongst these students will have an immediate effect on income to the country and the university sector. As well a decrease in any given year will continue to have an effect for the duration of an IT degree which is commonly four years.

Figure 1 shows the enrolment trends for both All (domestic and overseas) students and for overseas students alone.

Despite the phenomenal growth in Information Technology over the study period there are signs that this growth has turned to decline;

- The growth in Information Technology enrolments of 342%, is not reflected in similar growth in Mathematics or Physics disciplines.
- All categories of enrolment in Information Technology; Bachelor, Masters, PhD have each shown a decrease in enrolments over the period 2001-2002.
- Both Australian and Overseas students have turned away from Information technology between 2001 and 2002.
- There were 2965 fewer overseas students studying IT in 2002 when compared to 2001 figures. In round terms this amounts to $44 million loss if an average course fee of $15,000 is assumed.

Figure 1. Commencing Enrolments in Information Technology 1989-2002
All Students and Overseas Students



Apart from the fall in the NASDAC index, enrolment in IT courses are also said to be conditioned by immigration rules as they pertain to the gaining of permanent residency. These rules have changed again since 2002 and the effect on enrolments is difficult to anticipate.

Information Technology enrolments are an important part of the Science and Technology mix in the country. The decrease in enrolments shown above provides a great insight into the 'market driven' nature of student choice.

Gender and Science enrolments

Across the sector, women now comprise over 55% of total enrolments. Of the 70.3% growth in the sector over the 1989-2002 period, enrolments by female students has increased by 80.8% and by male students by 58.8%.

It is possible within the analyses contained with *Science at the Crossroads?* to examine enrolments by women within the discipline areas of the science group.

- **Behavioural Science**: Only a relatively small proportion of Behavioural Science teaching at University is to science students (2,434 EFTSU, about 10.5%). The proportion is even smaller to Information Technology students (1.2%). Behavioural Science is preferred by female students where in 1989, female science students comprised 59.7% of all behavioural science; this had risen to 68.2% in 2002.

- **Biological Science:** The area continues to be a growth area among Science students, especially by female students, where their proportion of total Biological Sciences teaching increased from 57.2% in 1989 to 63.8% in 2002. Among female science students, the proportion increased from 53.2% to 60.4%.

- **Chemical Sciences:** Although the teaching of Chemical Sciences increased between 1989 and 1993, it declined between 1993 and 1997, and even further to 2002. Chemical Science's decline was greatest among students in Science courses (-502 EFTSU, or –8.5%), slightly off set by an increase in its teaching to students in Other Courses. The decline in Chemical Sciences has been in its teaching to male students. Female science students increased their amount of the Chemical Sciences between 1989 and 2002. If the Chemical Sciences have been considered as one of the non-traditional science disciplines for female students, this is no longer the case. Gender balance was all but achieved in 1997, and the pattern of increased female participation in chemistry has continued to such an extent that women now comprise 53.2% of the recipients of teaching in the Chemical Sciences.

- **Earth Sciences:** Earth Sciences teaching, which has increased in size over the period (from 2173 EFTSU in 1989 to 2843 in 2002), but among science students it has yet to return to the level of 1997 (3106 EFTSU). Earth Science enrolments, as a proportion of all science enrolments remained constant over the period at 5%. More women are now taking Earth Sciences, with growth among both science and non-science students. The female proportion of all Earth Sciences teaching has increased from 26.4% to 41.6% among Science students.

- **Mathematical Sciences:** Mathematics continues to be in difficulty. The high point for the teaching of mathematics was 1993, and in 2002 2,294 EFTSU less teaching of Mathematics subjects occurred, compared to that high point. The amount of Mathematical Sciences taken by students in Information Technology and Other Courses increased over the period, but among Science students, Mathematics declined by 2,522 EFTSU, by over a third. The proportion of female students taking Mathematical Sciences has remained fairly static, at around 38%, but the high point of mathematics teaching to women occurred in 1997. Female students enrolled in Science degrees have reduced their intake of the Mathematical Sciences but it is male Science students who are responsible for most of the decline in Mathematics teaching.

- **Other Sciences:** Other Sciences includes teaching in pharmacology, medical science, forensic medicine, food science and biotechnology and laboratory technology, and as a

group, it is growing. Teaching in this group of disciplines more than doubled between 1989 and 2002. Female students are now in the majority in both Science and Other Courses.

- **Physical /Materials Sciences:** Physical/Materials Sciences continue to decline, in both in science and all other courses. Physical/Materials Science teaching was 2,290 EFTSU less in 2002 that it had been in 1989, and 2,946 EFTSU lower than for Physics' peak in 1993. Female Science students increased their proportion of Physics, but the 2002 result was scarcely larger than in 1989. For women, 1997 represents the high point for studying Physical/ Materials Science subjects

- **Information Technology:** Information Technology has boomed since 1989. Information Technology teaching has increased by 37,381 EFTSU over the period, an increase of 209.4%. The decline in Information Technology taken by science students is in part a reflection of the course re-badging. In days gone by, many universities enrolled 'computer science' students within a generic BSc degree; some continue to do so. The proportion of student load in Information Technology subjects has remained almost constant over the period, at around 30%, but there has been strong absolute growth in teaching Information Technology to women, an increase of 10,134, or 183.6%. However, this strong rate of growth was outstripped by that of male Information Technology students.

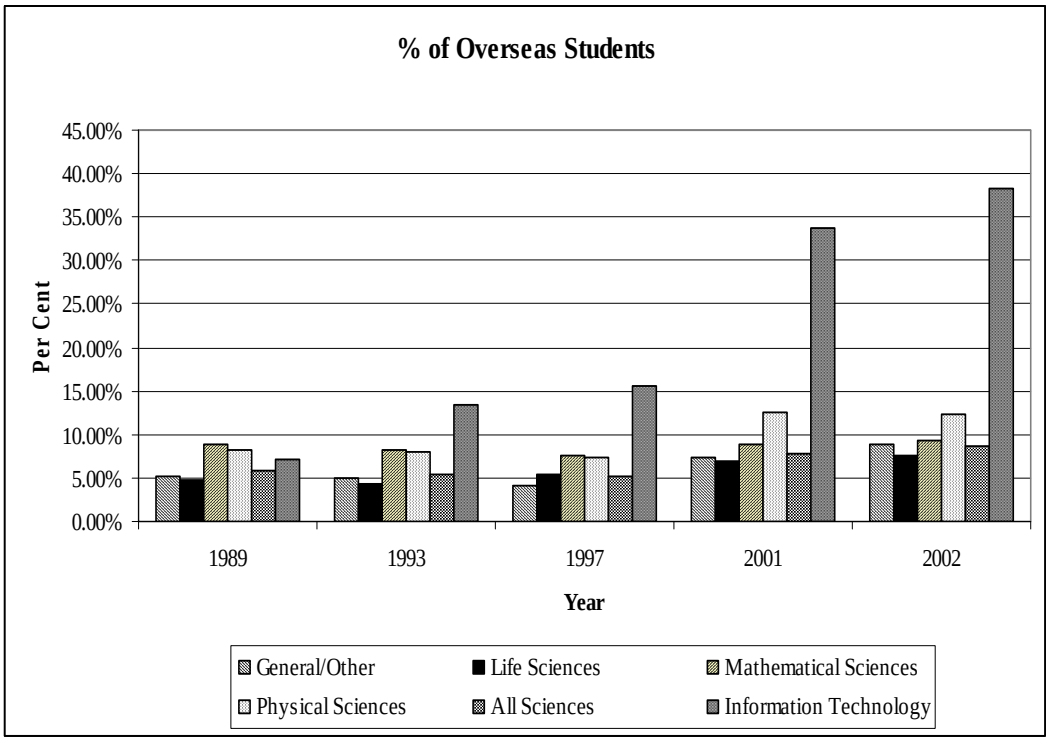
There has been a very pleasing growth in the number of female students enrolling to study science in a variety of areas—including Biological sciences, chemistry, other sciences, earth sciences and behavioural science. The lack of interest by females in areas such as Mathematics and Physical Sciences is of great concern when coupled with the data from secondary schools presented later.

Overseas student enrolments in Science and IT

Overseas student enrolments across the sector total some 125,000 which represents 16.6% of all enrolments. For science courses the increase has been from enrolments of 2,805 in 1989 to 5,817 in 2002 a growth of 107.4%. For IT, the growth has been from 982 to 23,502, or 2293.3%, over the same period. Growth across the sector has been 490.8% over this time. Figure 2 summarises changes over time.

The importance of overseas enrolments in Information Technology was commented upon above. Of note is the strong growth in General/Other areas of Science and in Life sciences. The strong interest in Physical sciences by overseas students is in marked contrast to the declining interest by Australian students.

Figure 2 Overseas students studying in different areas of science for selected years between 1989 -2002.

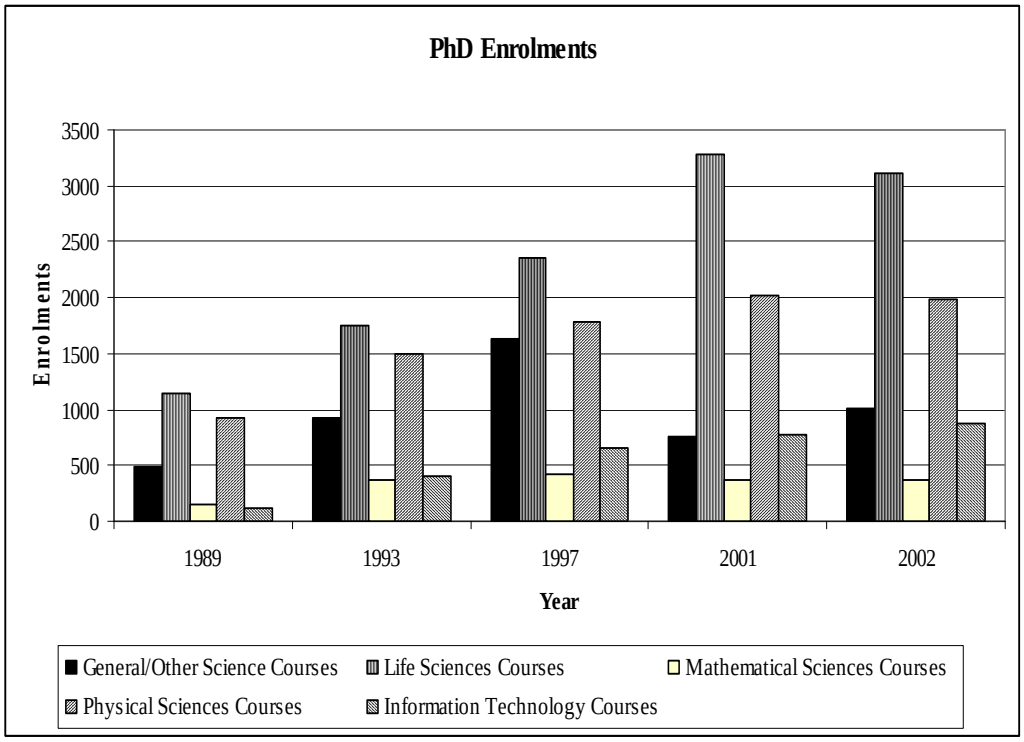


PhD enrolments in Science

The research and teaching emphases of faculties of science is importantly expressed in research degree enrolments. Increasingly this is seen in PhD enrolments as opposed to masters by research enrolments. Over the period 1989-2002 PhD enrolments in science and IT increased by 159.4% whereas over the same period masters by research degrees fell by 12%.

Figure 3 shows that the growth in PhD numbers has been strong in all course groupings and has been especially strong in IT.

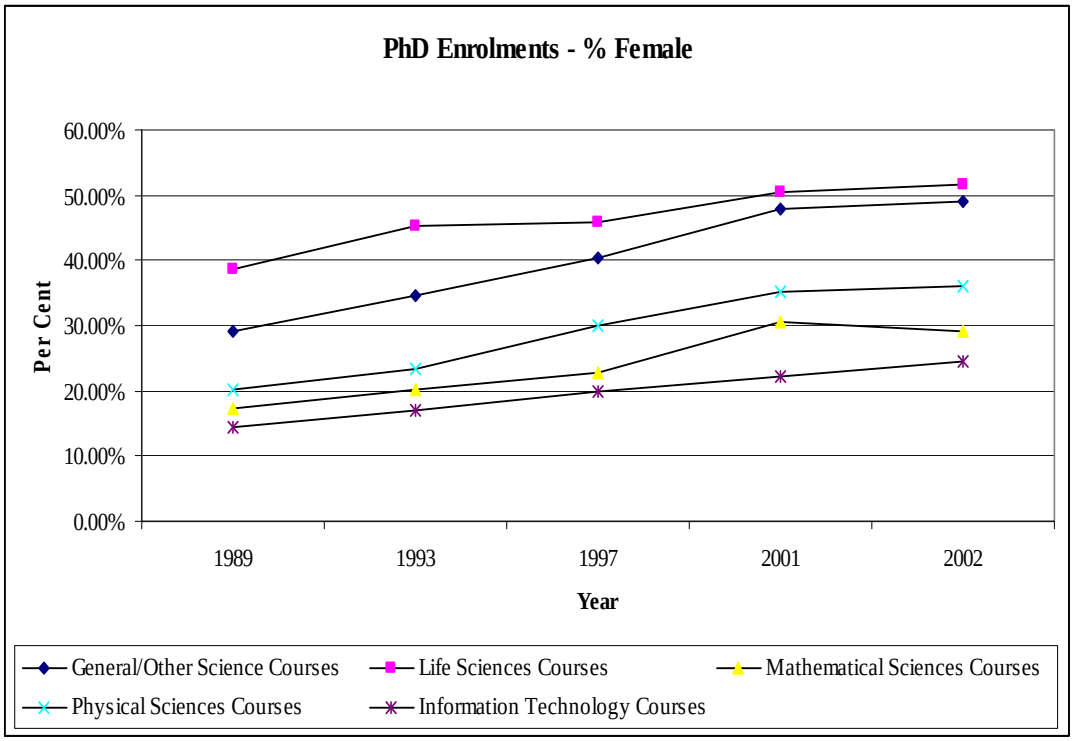
Figure 3. PhD enrolments in course groupings from 1989-2002



Enrolments can also be shown by the female percentage of total enrolment as seen in Figure 4.

Clearly General/Other Science courses and Life sciences are the areas which attract female enrolment whereas enrolments by females in areas such as Mathematical Sciences; Physical Sciences and It courses are not as strong.

Figure 4 PhD enrolments by female students for discipline areas over the period 1989-2002



The predominance of Life Sciences as an area of enrolment by females is apparent as is the growing interest in Physical Science.

It is also interesting to look at overseas student enrolments as a proportion of the total PhD student enrolment where student numbers are spread fairly evenly across all discipline areas.

Table 3: PhD Enrolments in Science/Information Technology Courses – By Per Cent Overseas Students

Course Group	1989	1993	1997	2001	2002
General/Other Science Courses	16.4%	13.2%	11.1%	15.7%	15.2%
Life Sciences Courses	21.4%	18.6%	13.6%	12.7%	12.2%
Mathematical Sciences Courses	16.0%	17.8%	14.7%	21.0%	15.4%
Physical Sciences Courses	24.7%	23.3%	14.9%	13.4%	14.5%
Information Technology Courses	27.7%	21.1%	16.1%	20.9%	20.3%
Total	**21.6%**	**19.2%**	**13.7%**	**14.5%**	**14.4%**

Source: DEST Aggregated Data Sets

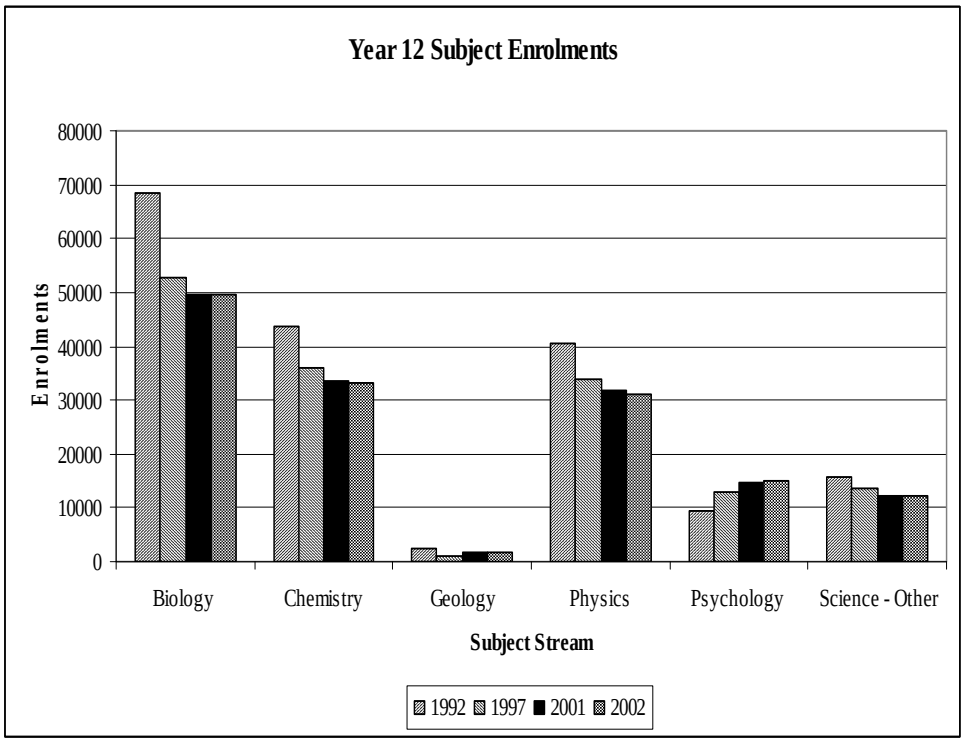
Science in Secondary Schools

Enrolments in science and mathematics at school level are critical to future enrolments in these areas at Universities. The current information is derived from a data set maintained by DEST for the whole of Australia

Key Learning Areas (KLAs) are groupings of subjects within broad categories. For example the KLA Science covers areas such as physical, biological and other sciences and from 1991, psychology. Most KLAs have increased in student numbers over the years 1986 to 2002. Science subject enrolments increased by 16% from 129,507 in 1986 to 150,223 in 1997 but declined steadily to 142,923 in 2003.

Declines in enrolment are seen in Figure 5 in all subject streams, within the Science KLA, except Psychology where some growth is seen.

Figure 5: Year 12 Subject Enrolments by Subject Stream 1992, 1997, 2001 and 2002.



So far as Science is concerned, the figure shows a decline in senior school science, which must go at least part of the way to explaining the decline in the fortunes of university science. In the case of Mathematics, there has been an increase in Year 12 enrolments. However, it is possible that that growth has come about by students enrolling in lower level or, terminal mathematics subjects, successful completion of which would not prepare them for university mathematics.

Concluding remarks

The report shows clearly that enrolments in the enabling sciences—Chemistry, Physics and Mathematics—in universities are in decline. The major efforts that have been expended since the last report *Trends…*, including the plans by Government arising from Backing Australia's ability, are not reflected in increasing enrolments in critical areas of science. There are small increases in each of these areas from 2001 to 2002 but they would need to be considerably bigger and sustained over a considerable number of years before a turn around could be claimed.

DEST has been involved in 2002-2003 in a review of Teaching and Teacher Education related specifically to the issues surrounding the teaching of science and mathematics in our schools. The report "Australia's Teachers: Australia's Future" (DEST, 2003) highlights shortages in "mathematics and technology teachers, and to shortages of physics and chemistry teachers" and makes a number of recommendations dealing with this broad issue.

The ACDS is very supportive of the thrust of the report and advocates that future teachers of science, technology and mathematics should have solid, discipline-based teaching in the area of their teaching specialisation(s). The falling numbers of students enrolling in discipline areas such as physics, chemistry and mathematics around Australia highlights the seriousness of the problem and the short- and long-term difficulties that will be found in finding the science, technology and mathematics teachers to adequately staff schools and to replace an aging teaching workforce. **It is critical that this issue is attended to directly and quickly**.

Although there has been a growth in PhD numbers, the data overall suggest a future decrease in PhD enrolments by Australian students in the areas of mathematics, chemistry and physical sciences. Government is already considering recommendations by the House of Representatives Standing Committee on Science and Innovation (2003) *Riding the Innovation Wave*. Recommendation 37 proposes "an additional 100 post-doctoral students could be placed in businesses with the cost shared equally between government and business". Although there may be a supply of such post-doctoral positions at the moment the clear message of the data in this report is that they will not be available in key areas of science in the near future.

Science enrolment trends at Year 12 level are alarming. The decrease in all areas except psychology goes a good way to explaining the decrease in science enrolments at university level. The timeliness of the recently completed review *Australia's Teachers: Australia's Future* is evident as is the need to get well qualified and enthusiastic teachers of science into our schools-both urban and regional.

Many countries around the world are building their science base in order to benefit from participation in the new technologies and to enable their populations to engage in meaningful debate on important scientific and technological issues. It is evident that the Australian Government sees the benefits of participation in the new technologies as well. The data presented here however indicate that the science base in this country is weakening rather than strengthening.

There are exciting technological changes occurring in science and technology. Australia needs to be part of these changes and to do so will require a solid base well educated in science and the new technologies. Indeed to not utilise the undoubted intellectual capital of the country will sell short the current population and the talented youth of tomorrow. The ACDS, in releasing this report, wishes to promote public debate on matters of importance to the whole country.

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