science teaching and research

WHICH WAY FORWARD FOR AUSTRALIAN UNIVERSITIES?

18th – 19th November 2004

An international conference held at
The University of Queensland, Australia

Conference Report

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Overview

Governments worldwide are now recognizing that the key to social and economic success is productivity in the areas of science, engineering and technology (SET). The central question considered by the Science Teaching and Research conference was how to ensure that the next generation of Australian scientists are nurtured and trained to be at the leading edge of scientific and technological innovation, with particular respect to the way this should be achieved through quality undergraduate educational programs. The key problems identified were: (i) an alarming decline in university enrolments in the traditional enabling sciences such as chemistry, physics and mathematics; (ii) a corresponding further decline in high school science enrolments; (iii) decreasing university staff: student ratios which is reducing the quality of the undergraduate science experience and (iv) the likely inability of the current enrolments and structures to cope with the projected future demand for scientists.

The Conference also highlighted that the "flight from science" was not restricted to Australia and was becoming a global phenomenon, at least in Western countries. In recognizing such a trend participants re-emphasized the importance for students to have the right to expect that they will be intellectually challenged and be part of a learning community at a research university. The Federal Government, in delivering Backing Australia's Ability in 2001 and more recently Backing Australia's Ability–Building Our Future through Science and Innovation (2004), has attempted to address many of the issues in the research area. The importance of strong and visible connections between research and undergraduate education was repeatedly highlighted at the conference, particularly in terms of the need for student learning to be based on discovery and guided by mentoring, rather than the passive transmission of knowledge. In this sense, the importance of linking scientific research and undergraduate education was emphasized and the value of a four-year science degree to impart a high quality educational experience was actively canvassed. Unfortunately, at the present time in the Australian context, many of the changes in the research area are being enacted without critical discussion on how this is impacting on traditional science faculties. The net outcome is that many institutions are struggling to deliver a quality research-led undergraduate experience.

The conference recommended the following general courses of action: (i) adoption of the innovative approaches supported by the US National Science Foundation (NSF) and the blueprint provided by the Boyer Commission on educating undergraduates, or at least their consideration as models for similar initiatives and developments in Australia; (ii) the proper funding of research and research infrastructure rather than its subsidization from university teaching funds, as this practice is counterproductive and puts research into financial conflict with teaching; (iii) strengthening of links between industry and universities to enrich both educational and mutual support opportunities; (iv) better co-operation and collaboration between universities both locally and nationally to obtain greater efficiencies in the development and delivery of quality teaching programs and to enrich the undergraduate experience; (v) promotion of a "culture of teaching" within universities (e.g. by rewarding individuals that excel in this area in significant ways, such as promotion); (vi) implementation of innovative teaching approaches based on new methodologies and technologies; and (vii) active promotion of interdisciplinary education and the development of communication skills. Specific recommendations relating to these courses of action are detailed on the following page.

The conference was seen as an important first step in the re-invigoration of science teaching and its intersection with research in Australian higher education. To progress the many issues raised during the conference, the formation of a "Science Council" was proposed with representatives from Deans of Science, CSIRO, Australian Academy of Science, Institute Directors and the Business Council of Australia. In this regard, the Science Audit currently being conducted by the Department of Education, Science and Training (DEST) will be another vital step in providing the Science Council with data and policy directions.

Summary of Recommendations

Recommendation 1

Make research-oriented, enquiry-based programs, similar to the innovative approaches of the NSF and Boyer Commission as the standard for science education in Australian universities. As part of this objective a high level of co-operation and collaboration between universities should be fostered, both locally and nationally, to obtain greater efficiencies in the development and delivery of quality teaching programs.

Recommendation 2

Make science a "national priority" in the Student Higher Education Contribution Scheme (HECS) thereby substantially reducing the cost to students. Science should also be moved into the same Commonwealth Course Contribution Schedule as agriculture e.g. from Cluster 8 - $12,303 to Cluster 10 – $16, 394.

Recommendation 3

Extend the university science degree from 3 to 4 years to accommodate the specific professional aspirations of science students e.g. Honours (for those students intent on pursuing a research/academic career); Internship (for those wishing to take up positions in industry); Teaching (teacher-training course); Hospital/pathology (laboratory placements); Biotechnology (business/project management course); Science communication (media/editing placements)

Recommendation 4

Foster strategic interactions between science faculties and research institutes by making 100 special "researcher-teacher" positions available (at 30% of a Level C appointment) to facilitate institute staff participation in undergraduate education.

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Foster strategic interactions between science and education faculties to elevate the development of science education; especially for the training of primary and secondary science teachers by funding 100 special cross appointments nationally between science and education faculties to promote instruction in the combined programs with a science and education component.

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Establish a Federal Government endorsed "Science Council" to advise on best practice reform in the integration of science teaching and research in higher education. The Science Council should have representatives from Deans of Science, CSIRO, Australian Academy of Science, Institute Directors and the Business Council of Australia and be in close contact with major funding bodies.

Recommendation 7

Utilize the full potential of university academics as teachers, researchers and entrepreneurs by ensuring that the costs associated with research and research infrastructure are fully covered in grants and that these areas are not subsidized from university allocations for undergraduate education. The Science Council should meet annually with federal granting agencies (ARC and NH&MRC) to discuss the effect of research funding on science education at the tertiary level, focusing on extending successful US initiatives in tying educational commitments to research grants.

Recommendation 8

Establish close contacts with industry and business, through the proposed Science Council, to increase funding from these sources for both research and teaching and monitor whether universities are producing the right balance of graduates for industry.

Recommendation 9

Foster the importance of pedagogical training in academic science, especially in mathematics, chemistry, physics and biology, by funding 75 special-category "teacher scholars" at a minimum of $650,000 per award, distributed over five years.

Recommendation 10

Increase the number of ARC Professorial Fellowships 10-fold to enable full time academics to upgrade their research skills and make a proportion of these Fellowships renewable. Fellowship applications should include details of how the research would lead to better undergraduate teaching at the end of the award period.

Recommendation 11

Provide 2000 undergraduate scholarships at $8,000-$10,000 per year for outstanding undergraduate science students to access the best programs in Australian universities.

Recommendation 12

Establish a strategic planning group to progress the outcomes of the conference within a prescribed timeframe. The working group should be comprised of 2-3 international experts (preferably those who attended the conference), 1-2 representatives from the Australian Council of Deans of Science, 1-2 representatives from Research Institutes, 1-2 representatives from industry, a Vice Chancellor and a representative from DEST.

Introduction

In recent years there have been a plethora of reports in numerous countries and by the OECD on the performance and importance of higher education (1, 2, 3, 4, 5). Overwhelmingly, education and research in the fields of science, engineering and technology (SET) are now seen as key factors in determining both the economic growth of a nation and patterns of social development (6,7,8). Countries such as Germany (9), Ireland (10), Singapore (11) and the United States (12) are proactively strengthening their science base as an endorsement that SET holds the key to future prosperity.

Within SET the pace of change and discovery has quickened to the point that the doubling time for new information is estimated to be less than seven years and this is having a significant effect on how the sciences are being taught. In Australia, universities have traditionally played the major role in generating new knowledge through their research endeavors. However, equally important is their core function of nurturing the potential of students through their undergraduate teaching and learning programs. In the opening remarks of the Conference, the Vice-Chancellor of the University of Queensland, Professor John Hay, stated that best practice incorporates both teaching and research, and that students are best served when horizons and imaginative possibilities in their fields of interest are "available to them sooner rather than later." However, with an increasingly concentrated focus on research outputs the current situation in Australian Higher Education suggests a certain imbalance between the resources and intellectual input that are devoted to maintaining standards of research, compared to those devoted to teaching and learning in the tertiary education sector as a whole.

THE IMPORTANCE OF INQUIRY-BASED LEARNING

This drift away from emphasis on undergraduate education is a similar phenomenon to that identified in the United States in 1995 and which led to the establishment of a "National Commission on Educating Undergraduates in the Research University". The report of this commission, "Reinventing Undergraduate Education: A blueprint for America's Research Universities", commonly known as "The Boyer Report" (14), specifically addressed the need to move from transmission-based to inquiry-based learning, and presented a new model where undergraduate teaching is inherently integrated into the general processes of postgraduate training and academic research, rather than these being separated. The aim of this model is to effectively integrate students into the core processes of the university from the start of their course and thereby avoid the dislocation and disillusionment that arises from unmet expectations, as well as the lack of engagement of gifted students who have not been exposed to the leading edge.

> "For all the discussion of the changes, often profound, that have taken place in contemporary higher education, the undergraduate curriculum has commanded rather less attention than might be expected. Yet the curriculum remains one of the most important products that higher education institutions offer to their customers." (13)

STUDENT EXPECTATIONS

This then raises the question of what are reasonable expectations of Australian students as they enter the 21st Century and are faced with a rapidly changing, highly technological world?

Students, as always, have the right to expect that they will be intellectually challenged and will be part of a community of learners at a research university. The best way to do this is within a research-based learning system where several methods of interaction take place between lecturer and student, the least desirable being the large lecture theatre with a "non-accessible" academic at the front. Inquiry/discovery-based learning inherently implies exchange of elements in both directions between lecturer and student to the mutual benefit of both.

Secondly, students have the right to expect that the outcome of their educational experiences at a research university will equip them, not only to be worthwhile citizens, but also with the knowledge and technical and communication skills to make a significant contribution to their chosen field of endeavor, and to be internationally competitive.

Finally, students have the right to expect a significant amount of contact with academic researchers and scholars and that these people take the role of advisors and mentors. Importantly, academic staff should not be constrained in this role because of pressures due to other aspects of their university commitments.

Providing students with an integrated education wherein their rightful expectations are met as a matter of course, rather than being the exception, requires extensive restructuring and curriculum reform in the Australian higher education sector. It may also require reassessment of the available resources. As a first step, teaching excellence must be placed high on the political and higher education agenda. It should not be obscured by token short term projects and individual awards which in many cases do not represent the bulk of the teaching in the institution from which they are gained, even though pockets of excellence are found everywhere and the people involved should form the core of input into reform.

FUNDING ISSUES

Similarly, whilst there is no doubt that the Australian Research Council (ARC) and National Health and Medical Research Council (NH&MRC) have tried to be innovative in the way they fund research, most of their engineering of this area has gone on with very little input from Deans of Science, who are responsible for the interface between research and teaching. This group should be afforded more input into the decision making process, or at the very least, routinely included in strategic discussions regarding best use of Federal funds.

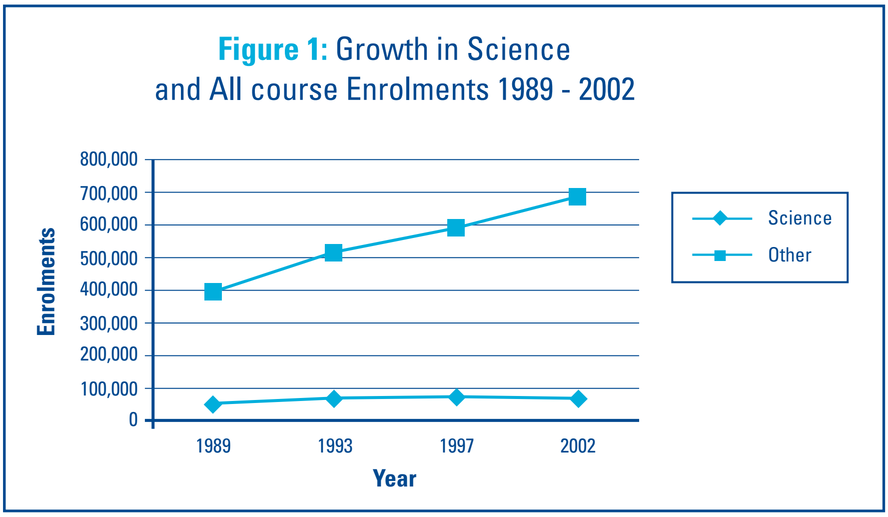
Further to the funding issue, not only is there a dislocation between the research and teaching budgets allocated to Australian universities, at present there is little synergy between the major funding bodies (NH&MRC, ARC, Teaching and Learning Performance Fund) themselves, and this can lead to lack of efficiencies. University researchers, industry, and business are all recognizing the need to increase productivity and performance by integrating skills and knowledge across disciplines. The way funds are distributed should also be an integrative process with input from those with the best sense of how they will be most productively used.

THE DECLINE IN SCIENCE ENROLMENTS

Recent reports on science education within Australian universities show an alarming decline in the enrolments in science courses relative to all other courses (Fig. 1), especially in the traditional enabling sciences such as chemistry, physics and mathematics (15). If we are to believe that economic growth will be driven by new knowledge, the fact that science enrolments peaked in 1997 and have since declined is cause for immediate concern.

Figure 1.

Enrolment growth in science and all other courses. The strongest proportionate growth occurred in information technology, but despite the fact that there was also growth in science, it was considerably less than the sector average (15)



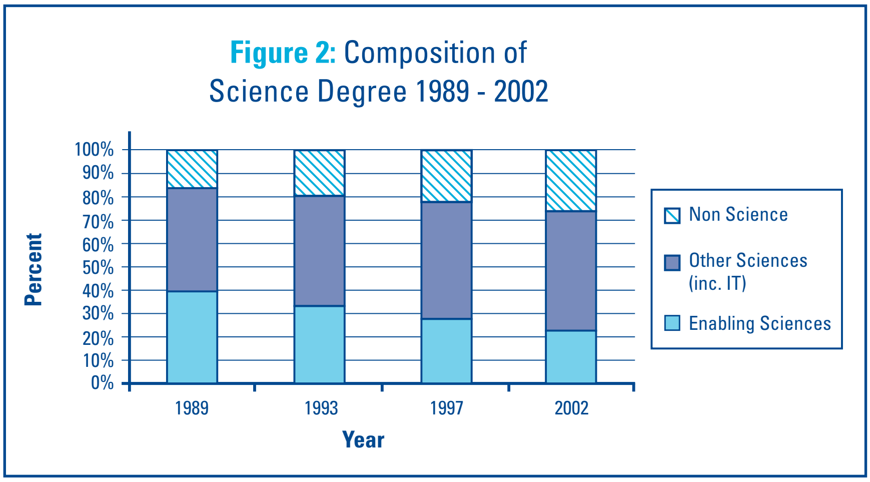
A US Commerce Department study found that in less than two decades 60% of the nations jobs will require technical skills possessed by only 22% of today's workers (16)

In addition, the overall structure of the Bachelor of Science degree has changed with the proportion of the enabling sciences (chemistry, physics & mathematics) declining markedly with a concomitant increase in the "soft science" and non-science components (Fig. 2) (15).

Figure 2.

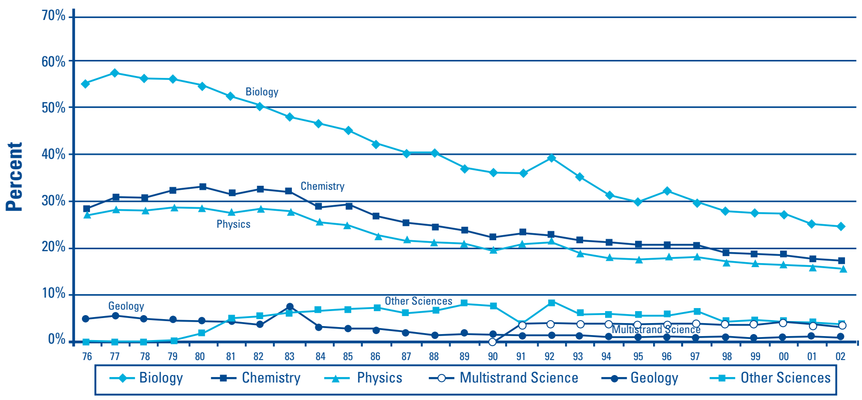
Composition of a Science Degree 1989-2002

Source: Dobson, I.R. (2004) Science at the Crossroads? The Decline of Science in Australian Higher Education (15)



The potential for this situation to further deteriorate is real as high school science enrolments are also declining (Fig. 3)(17). This demise is happening at a time when biology has also become an enabling science and additional skills to be an effective entrepreneur (business, marketing, communication, leadership and psychology) are being demanded of science graduates.

Figure 3: Percentage of Australian Year 12 Students enrolled in science subjects 1976 - 2002



Source: Committee for the Review of Teaching and Teacher Education (2003). Australia's Teachers: Australia's Future, Advancing Innovation, Science, Technology and Mathematics, Background Data and Analysis. Commonwealth of Australia

Figure 3.

Percentage of Australian Year 12 students enrolled in science subjects, 1976 – 2000 (17)

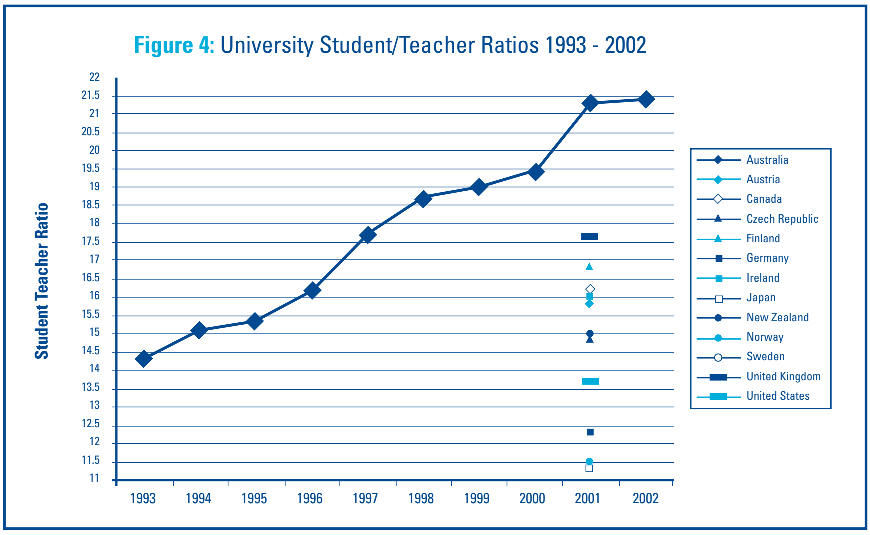
THE IMPACT OF HIGH STUDENT:STAFF RATIOS

The Federal Government has in part responded to this situation by launching Backing Australia's Ability in 2001 (18) and more recently Backing Australia's Ability–Building: Our Future through Science and Innovation in 2004 (19). Later that year, they followed up with a commitment to promoting excellence in teaching and learning in Australian higher education by launching the Learning and Teaching Performance Fund and the Carrick Institute for Learning and Teaching in Higher Education (20). Whilst this is a welcome initiative, it will not be possible to implement innovative teaching programs that maximize the learning opportunities of undergraduates, if student:staff ratios in Australian universities are not reduced, at least in line with OECD standards (Fig. 4). Proficiency in writing and speaking i.e. communication skills must also be an integral part of the undergraduate educational experience. However, the current high student:staff ratio in Australian universities works against written skills being inculcated into best practice assessment and this is seen as a shortfall of the Australian Higher Education system.

Figure 4.

University Student Staff Ratios in OECD Countries.

Source:
AVCC student teacher ratio tables derived from DEST (21) OECD education at a Glance, 2003 (5)
Productivity Commission (22)
Higher Education – The Facts (23)



ADDITIONAL EXPECTATIONS OF UNIVERSITIES

Add to this picture the emergence of research institutes and the expectation that universities will play a more significant role in the area of innovation and commercialization, and the whole game plan has changed for a traditional science academic and faculty. The data highlight that there are no quick fixes as resources to develop a scientific base require trained staff, educational facilities, research funding and a student base backed up by a long-term commitment to the integrated framework of science. Indeed it is becoming even more complicated by the fact that new science is happening at the intersections of disciplines. This demands new approaches to ensure that Australian students of today are provided with the right opportunities to be competitive in 2010 – 2020. There is also an emerging tendency on the part of some to see institutes as the answer for Australia to maintain an internationally competitive scientific edge. However, it is important to stress that most institutes in Australia have a medical focus and therefore have very little exposure to the physical, engineering, information or social sciences, even though they are dependent to a large extent, on the production of excellent university graduates in these areas. The opportunity here is for new pathways to be found to link such institutes into the teaching and research fabric of the nation.

Conference Outcomes

Recommendation 1

Make research-oriented, enquiry-based programs, similar to the innovative approaches of the NSF and Boyer Commission as the standard for science education in Australian universities. As part of this objective a high level of co-operation and collaboration between universities should be fostered, both locally and nationally, to obtain greater efficiencies in the development and delivery of quality teaching programs.

The undergraduate learning experience should be research orientated and based on an enquiry approach. New types of learning require new skills and the way to engage students, maintain their interest in science subjects, and turn out scientists, educators, technologists and innovators that can take a leadership roles internationally, is to expose them to excellent researchers and cutting edge technologies. They must also be taught to think and communicate scientifically. Strengthening and supporting basic science teaching at 1st and 2nd year levels would be the first step to achieving higher retention rates especially if the courses were interesting, stimulating, and had work experience placements (industry, university research lab, hospital etc) built in.

For 1st year students, a clearly identified obstacle to a quality learning experience is the diversity of pre-requisite knowledge with which students enter university. The Boyer Report expressed the strong view that "Remediation should not be a function of a research university" and that remedial content was detrimental to maintaining the interest and enthusiasm of high achieving students (14). However, the diversity of students entering science degrees and the fact that the secondary school sector has diluted its commitment to science education has made remediation a reality and a problem.

Re-establishing pre-requisites for university entry in the sciences would standardize content knowledge but exclude potentially (scientifically) gifted students who for various reasons could not fit pre-requisite science subjects into their secondary school curriculum. Alternative options could be to introduce streaming into standard and advanced classes in Ist year or institute a core 1st year curriculum, supplemented by electives associated with the long term goals of the students i.e. general, vocational, or research science/academia. In this way courses could be tailored in both content and complexity to accommodate different student objectives.

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Make science a "national priority" in the Student Higher Education Contribution Scheme (HECS) thereby substantially reducing the cost to students. Science should also be moved into the same Commonwealth Course Contribution Schedule as agriculture e.g. from Cluster 8 - $12,303 to Cluster 10 – $16, 394 (3).

Recommendation 3

Extend the university science degree from 3 to 4 years to accommodate the specific professional aspirations of science students e.g. Honours (for those students intent on pursuing a research/academic career); Internship (for those wishing to take up positions in industry); Teaching (teacher-training course); Hospital/pathology (laboratory placements); Biotechnology (business/project management course); Science communication (media/ editing placements).

Included in the 4-year degree should be training in a number of non-negotiable graduate attributes. These should be the focus of all science lecturers in universities, as part of their teaching program and include:

- Communication – the ability to communicate ideas both verbally and in written form, including logical reasoning and presentation of argument. Students should be literate in both the general and the scientific sense.
- Numeracy – students should have a basic understanding of mathematical principles and practice.
- Problem solving and the ability to be part of a collaborative team project - including a compulsory unit within the course (2nd or 3rd year) where the students work in small teams to apply scientific processes to solve a given problem.
- Information retrieval – Information Technology literate.
- The ability to distinguish between statements and claims supported by vigorous investigation, and non-supported information.
- The ability to analyze information not only in terms of science but taking into account scientific principles, community values and needs.
- Biocomplexity – the need to understand the ethical and societal implications of endeavours as well as the basic scientific implications.

This brings us to the question of how this integrated education could be achieved in Australian universities. Firstly, mechanisms must be put in place to promote engagement of all the expertise available on any particular university campus. At the present time in most Australian universities links between science and education faculties are mixed and on many occasions barely exist. Such a situation, wherein the providers of content are totally removed from experts in pedagogy, is counterproductive for educating new primary, secondary and tertiary level teachers. To some extent, this divide can be attributed to faculties trying to protect their funding base in a tight monetary climate. An opportunity also exists to more fully reap the benefits of the expertise that exists in research institutes that are found both within and outside a university. If we are to truly embrace the concept of learning being research orientated and based on an enquiry approach then mechanisms to encourage research institutes to collaborate more fully in undergraduate education need to the found. Science could also benefit from collaborative learning programs with the faculties of Business and Law, especially if we are to promote an entrepreneurial approach to science (e.g. in the emerging biotechnology sector). This spirit of institutionalized co-operation will require a quantum shift in operational and organizational thinking, as well as for staff to pro-actively embrace the new idea of cross-disciplinary education for undergraduates. However, vast opportunities are being missed at present by not facilitating the linkage between different capabilities on the same campus and closely associated institutes, and as part of teaching and learning reform, universities and governments must now devote resources to achieving this, particularly in terms of incorporating research into teaching, as a matter of course.

Recommendation 4

Foster strategic interactions between science faculties and research institutes by making 100 special "researcher-teacher" positions available (at 30% of a Level C appointment) to facilitate institute staff participation in undergraduate education.

Instead of accentuating the gulf between Research Institutes and Schools and Departments there is an enormous opportunity for co-operation and inclusiveness between the different groups in terms of joint appointments, guest lectures, integration of programs, interdisciplinary material and equipment, joint supervision of postgraduates and providing research experience to undergraduates. This is also an effective way of integrating teaching and research. Such co-operation should be initiated at the level of Institute Director, in conjunction with the Deans of Science and School Heads. The relationship should be formalized in the sense of assigning credit to the Institutes for their teaching component so the relationships are seen as mutually beneficial.

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Foster strategic interactions between science and education faculties to elevate the development of science education; especially for the training of primary and secondary science teachers by funding 100 special cross appointments nationally between science and education faculties to promote instruction in the combined programs with a science and education component.

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Establish a Federal Government endorsed "Science Council" to advise on best practice reform in the integration of science teaching and research in higher education. The Science Council should have representatives from Deans of Science, CSIRO, Australian Academy of Science, Institute Directors and the Business Council of Australia and be in close contact with major funding bodies.

Within the Australian higher education sector there is a general consensus that the type of science reforms outlined in the first part of this document are welcome and long overdue. Most institutions would be willing to make an attempt at improving science education and strengthening the nexus with research but each institution should not have to work through this process in isolation. The Science Council should monitor programs and set guidelines for standards along the lines of those used for professional accreditation, which would look at both content and process in relation to the way science is taught in universities. In this way, Australian resources could be maximized in a spirit of co-operation and thereby enhance outputs across the board.

Recommendation 7

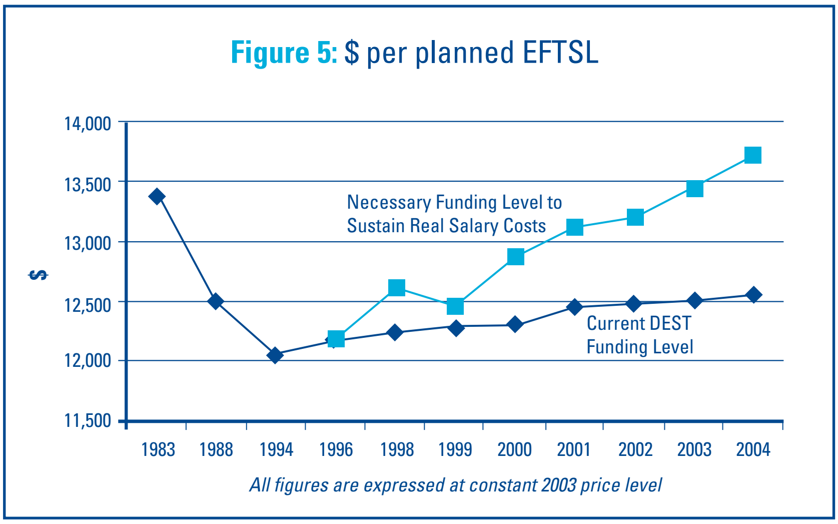
Utilize the full potential of university academics as teachers, researchers and entrepreneurs by ensuring that the costs associated with research and research infrastructure are fully covered in grants and that these areas are not subsidized from university allocations for undergraduate education. The Science Council should meet annually with federal granting agencies (ARC and NH&MRC) to discuss the effect of research funding on science education at the tertiary level, focusing on extending successful US initiatives in tying educational commitments to research grants.

The exodus of outstanding researchers to research institutes where they do not have an undergraduate teaching load is causing an imbalance in the traditional "Faculties," which take the major teaching load but must compete with the institutes for research funding.

This situation is compounded by several problems. The first is that over the last ten years, Commonwealth funding in 2003-dollar terms per Effective Full Time Student Load (EFTSL) has decreased by 6.2% (Fig. 5, dark blue line —◆— ;24). This has happened in an era when advances in genomics, proteomics, biotechnology, super computing and nanotechnology are demanding new teaching methods and require the use of sophisticated costly equipment. Decreases in funding are making it impossible for university staff to maintain this state-of-the-art teaching equipment and infrastructure much less improve teaching practices in order that students be given a true research experience during their undergraduate degrees.

Figure 5.

Commonwealth Funding (Base Operating Grant) Available to Higher Education Institutions per Planned Equivalent Full-time Student Load (EFTSL), 1993 – 2004 (24). The dark blue line —◆— indicates actual EFTSL funding expressed at the constant 2003 price level; this outcome does not fully account for salary increases from1996-2004. The light blue line —■— was calculated taking into consideration the full effect of salary increases.



The ability to charge 25% on top of the Higher Education Contribution Scheme (HECS) (3) will alleviate some of the difficulty confronting a science faculty. However, such an amount, when fully implemented, will only bring funding in real terms roughly back in line with 1983 levels (Figure 5. Dark blue line —◆—). The light blue line —■— in Figure 5 indicates where the level of EFTSL funding should be if salary increases had been fully funded from 1996 onwards. Another way of interpreting the data is that the 25% increase on HECS will enable the retention of the existing workforce but will have minimal effect on addressing high student: staff ratios.

This brings us to the second issue that is causing a systemic problem to improving overall standards of teaching and learning in the sciences – the fact that expensive infrastructure required to both conduct research, and to teach research-based courses, is continually being subsidized from the teaching budget. If research was properly funded to include infrastructure costs this would alleviate the insidious drain of money away from teaching. Australia is currently affording 1.5% of Gross domestic Product (GDP) to Research and Development (R&D) (Table 1).

Country/economy	Percent	Country/economy	Percent
Total OECD (2000)	2.24	Italy (2000)	1.07
European Union (2000)	1.88	New Zealand (1999)	1.03
Sweden (1999)	3.78	Spain (2001)	0.97
Finland (2000)	3.37	Brazil (1999)	0.87
Japan (2000)	2.98	Cuba (2000)	0.82
Iceland (2001)	2.90	Hungary (2000)	0.80
United States (2001)	2.71	Portugal (1999)	0.76
South Korea (2000)	2.65	Greece (1999)	0.67
Switzerland (2000)	2.64	Poland (2001)	0.67
Germany (2001)	2.53	Slovak Republic (2001)	0.65
France (2001)	2.20	Turkey (2000)	0.64
Singapore (2001)	2.11	Chile (2000)	0.54
Denmark (1999)	2.09	Mexico (1999)	0.43
Netherlands (2000)	1.97	Romania (2001)	0.40
Belgium (1999)	1.96	Panama (1999)	0.35
Canada (2001)	1.94	Bolivia (2000)	0.28
Austria (2001)	1.91	Costa Rica (1998)	0.27
United Kingdom (2000)	1.85	Uruguay (1999)	0.26
Australia (2000)	1.53	Colombia (2000)	0.24
Slovenia (2000)	1.52	Trinidad and Tobago (1997)	0.14
Norway (2001)	1.46	Nicaragua (1997)	0.13
Czech Republic (2001)	1.31	Ecuador (1998)	0.08
Ireland (1999)	1.21	El Salvador (1998)	0.08
Russian Federation (2001)	1.16	Peru (1999)	0.08

Table 1.

R&D share of gross domestic product, by country/economy: 1997–2001.)

Notes:

Data are presented for the latest available year, in parentheses.

Sources:

OECD, Main Science and Technology Indicators database, 2002; and Iberomerican Network of Science and Technology Indicators, (25)

The OECD average is 2.3% and countries such as the USA and Germany are contributing 2.7% and 2.5% respectively (25). In 2004, the Australian Vice Chancellor's Committee (AVCC) urged the government to increase GDP spending on R&D to 2% in order for Australia to remain internationally competitive. By 2010, the European Union (EU) is aiming to increase the R&D expenditure of all EU countries to 3% (26) so this is a critical issue for the Australian Government and industry to tackle with some urgency.

"70% of the growth of the American Gross Domestic Product, since World War II, can be directly attributed to the exploitation of new technologies"

Alan Greenspan, Federal Reserve Chairman (4)

Recommendation 8

Establish close contacts with industry and business, through the proposed Science Council, to increase funding from these sources for both research and teaching and monitor whether universities are producing the right balance of graduates for industry.

One vexing question in terms of university research funding is the lack of monetary resources contributed by business and industry in Australia, compared to other OECD countries (8). Whilst it is a fully endorsed aim for universities to foster closer links with industry and business for the purposes of research and development funding, because 95% of Australian businesses are classified as "small"

(8), we may not be in the position of countries with larger populations, and a high proportion of multinational companies, to look to short term improvement of the type we are expecting in terms of financial support, afforded by Australian businesses and industry.

The benefits of establishing good working relationships are nevertheless tangible as evidenced by the 51% success rate of ARC Linkage applications in the 2005 granting round compared to the 20-30% success rate of Discovery scheme funds.

Aside from financial support, the other advantages of developing close links with business and industry are related to mutually beneficial outcomes of work placements for students. The Science Council should facilitate a national internship fund that would enable science schools/departments/faculties to facilitate a selection of undergraduate students to be placed into industrial/business/government agencies (e.g. CSIRO). This would result in improved student perception, feedback from industry to university on student qualities and possible pre-placement in jobs prior to graduation. It would also facilitate good "matches" with industry partners.

Recommendation 9

Foster the importance of pedagogical training in academic science, especially in mathematics, chemistry, physics and biology, by funding 75 special category "teacher scholars" at a minimum of $650,000 per award, distributed over five years.

Recommendation 10

Increase the number of ARC Professorial Fellowships 10-fold to enable full time academics to upgrade their research skills and make a proportion of these Fellowships renewable. Fellowship applications should include details of how the research would lead to better undergraduate teaching at the end of the award period.

To improve the standards of both teaching and research, two inter-related initiatives need to be put in place: (i) enhance the pedagogical skills of university staff engaged primarily in research and (ii) afford opportunities for staff who, as part of their university commitments take a large undergraduate teaching role, to upgrade their research skills. In this way the overall standards of both will be raised and inter-disciplinarity fostered.

At present, the three main obstacles to integration of teaching and research in Australian universities are: (i) academic researchers have little or no formal teacher training in terms of communication skills and presentation strategies that will give the students the best possible learning experience; (ii) a reward system is in place which is effectively a disincentive for researchers to devote time to teaching in a climate of highly competitive research funding and the need to develop research groups and train graduate students and (iii) the frustration of faculty staff with respect to the lack of recognition given to their commitment to teaching, which is often at the expense of research productivity.

Ways in which these obstacles could be removed include: (i) the US National Science Foundation idea of embedding a teaching component in research grant funding - this could be linked with other initiatives which increase the time available for researchers to participate in undergraduate classes; (ii) making competitive grants available for teaching departments; (iii) linking funding of postdoctoral fellows to teaching to create incentives and professional development opportunities; (iv) formulating a set of criteria for allocation of teaching excellence funds that would be available through the university sector; (v) raising the profile of teaching and learning conferences in each discipline by making travel funds available and rewarding participation at these conferences by serious consideration in promotion.

Within this structure, the Science Council should lobby government to make a particular commitment to developing the skills of teacher-scholars in the enabling sciences (mathematics, chemistry, physics and biology) and also prioritize the development of programs that encourage student enrolments in these areas.

Recommendation 11

Provide 2000 undergraduate scholarships at $8,000-$10,000 per year for outstanding undergraduate science students to access the best programs in Australian universities.

An often cited limitation of the Australian Higher Education system is that it is the parochial, with most students attending university in their home location. This is in contrast to the United States and the United Kingdom, where students relocate geographically in pursuit of the best and most appropriate course for their career aspirations. It was reported that only around 10% of Australian students move interstate for study at undergraduate level, and those students tended to choose universities based on prestige, not for the appropriateness of the course in meeting their goals (27). This parochial focus and elitist behavior is not necessarily a good thing for the pursuit of excellence in Australian universities. The recent Overseas Study Help scheme outlined in "Our Universities – Backing Australia's Future (3)" was seen as a very positive step forward and could be adapted to promote mobility within Australia. Such a scheme is essential for Australia to gain a return on its investment in specialized universities, as students should be encouraged to access high quality programs in their area of interest, regardless of the geographical location. This can only be achieved by offering substantial studentships on a competitive basis.

Recommendation 12

Establish a strategic planning group to progress the outcomes of the conference within a prescribed timeframe. The working group should be comprised of 2-3 international experts (preferably those who attended the conference), 1-2 representatives from the Australian Council of Deans of Science, 1-2 representatives from Research Institutes, 1-2 representatives from industry, a Vice Chancellor and a representative from DEST.

Conclusion

The recurring theme that there is a "flight from science" is a phenomenon that is not restricted to Australia. The exact reason for this phenomenon is not overly clear but some conference participants postulated that students see their most important life goal of "being very well-off financially," not being achievable by studying science. However, a recent survey of science graduates by the Australian Council of Deans of Science would suggest this is not the case (28). It is even more remarkable that this "flight from science" has happened when Australian university enrolments have increased from 420,850 in 1989 to 896,621 in 2002 (21) and we are in an era of unparalleled gains in scientific knowledge. In many ways universities have wandered in to a continued state of expansion to cope with such change and the outcomes have not always been to the benefit of underpinning a strong SET base. Add to this the fact that many professional programs such as medicine, pharmacy and physiotherapy have moved to an educational model of "just-in-time knowledge" – that is, the skills necessary for the job at hand, rather than the basic underlying skills (29). This has diminished the critical role science faculties have played in professional education.

Change is now a constant and with the recent fee changes the notion that higher education is a public good, which primarily benefits society and deserves taxpayer's support, has been put to rest. It is increasingly being seen as a private good and, therefore, benefits the individual who should bear the cost. These changes in direction are nothing new to Higher Education and were experienced back in the 1980s in the American system (30). However, it is becoming increasingly apparent that we are in an era where more and more students are seeking professional health orientated degrees, and business related programs continue to be popular. It may however be dangerous for the SET sector in Australia not to embrace a "public good model" for science education. Such a position saw many participants suggesting that the student contribution level (HECS) for science should be substantially reduced, and that it should be added to the same Commonwealth Course Contribution Schedule as agriculture (3).

If one looks critically at the composition of a science quota in most research universities, it is made up of three major cohorts: (i) those students seeking a general education; (ii) those seeking to transfer into a professional health degree and; (iii) the "true believers" who will probably go on to Honours and higher degrees. While one may wish to see the latter cohort become more dominant, it may be unwise to re-engineer such a quota as students require nurturing and time before seeing science as a life-long commitment. In many ways the fundamental problem of the lack of awareness of science and its importance to the community is contributing to students not seeing a career in science as either financially worthwhile or intellectually appealing. This leads to the leaking of science places to professional programs at universities and helps explain why science at the secondary school level is failing to capture the interest of our brightest students.

Universities have a responsibility to help turn this problem around by: (i) providing high-level education for graduate science teachers who will then be equipped to inspire, teach and encourage scientists of the future, (ii) providing outreach programs such as scientist in residence, enrichment programs and professional development programs for continuing teacher education and; (iii) running special "frontier in science lectures" that are designed to highlight the achievements of world class scientists and put into perspective the importance of their work in terms of the national economy and societal progress. However, it is important to appreciate that points (ii) and (iii) above are forms of training or "just in-time knowledge," that should not be confused with science education. Further, while recent web sites and science shows have helped raise the profile of science in the community, it is highly unlikely that an "edutainment" approach is the answer to turning around the current state of Australian science.

There is a call for a renewed focus on undergraduate education, which has been diminished in recent times by an over emphasis on research, particularly in the sciences. Having said that, research funding in Australia is still well below the OECD average (5) and is subsidized by teaching budgets. This has been more broadly recognised across all disciplines at the Commonwealth Government level by the establishment of the Learning and Teaching and Performance Fund and the Carrick Institute for Learning and Teaching in Higher Education (19). As pointed out, a similar position in the United States led to the Boyer Report being published in 1995. Concerns were raised during the conference that the drive to improve undergraduate education may be compromised if the Department of Education Science and Training (DEST) initiates a full blown United Kingdom style Research Assessment Exercise (RAE) as such an approach has the potential to dominate everything - thinking, process, practice, whether real or imaginary. Academics, for survival reasons, may use it as an excuse to abrogate duties in other areas, including undergraduate education. This again highlights the need for the teaching and research areas to be treated con-jointly. The gains from significantly improving the undergraduate experience cannot be underestimated. In the sciences this is particularly the case, and as a community we need to find new pathways to ensure that our students can access the unparalleled wealth in intellectual resources that exists within our institutions. An inquiry-based learning model embraces the idea that students provide the lubrication for the “accidental collision of ideas” that makes staff learn from students as students learn from staff (14). The challenge to inspire students to pursue a career in science has never been greater!

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Additional Papers

The following additional papers were prepared prior to the conference and distributed as background reading material. We wish to acknowledge the intellectual contribution of all authors and thank them for their participation.

These background papers can be accessed at: http://www.brightminds.uq.edu.au/TRC/papers.htm

Title: The teacher/scholar/researcher in a contemporary Australian Science Faculty.

Authors: *Michael E. McManus & Louise E. Mattick*
Faculty of Biological & Chemical Sciences,
The University of Queensland, Brisbane, Australia, 4072

Title: Excellence and international competitiveness in research and research-informed education in Australian universities.

Author: *John S Mattick Institute for Molecular Bioscience,*
The University of Queensland, Brisbane, Australia 4072

Title: The BSc in Australian universities: is it providing the best education for our future scientists?

Author: *Susan Hamilton Faculty of Biological and Chemical Sciences,*
The University of Queensland Brisbane, Australia, 4072

Title: Teaching science scientifically.

Author: *Peter O'Donoghue School of Molecular and Microbial Sciences,*
Faculty of Biological and Chemical Sciences,
The University of Queensland, Brisbane 4072

Title: From single strand to beautiful tapestry - science teaching in universities.

Author: *Tim Brown Faculty of Science*
The Australian National University, Canberra, Australia, 0200

BOYER REPORT AND NSF INITIATIVES

A detailed summary of the Boyer Report recommendations, and examples of the innovative programs run by the US National Science Foundation are available by request from the authors, or can be accessed at: http://notes.cc.sunysb.edu/Pres/boyer.nsf and http://www.nsf.gov

Appendix A

The Science Teaching and Research conference was attended by one hundred and fifty delegates from universities, business and government and addressed by the following national and international experts in science education.

LIST OF CONFERENCE INVITED SPEAKERS

Dr Bahram Bekhradnia
Director, Higher Education Policy Institute, Oxford

Dr Carol Colbeck
Director of the Centre for the Study of Higher Education, Pennsylvania State University.

Dr Rita Colwell
Former Director of the US National Science Foundation and current Chairman of Canon US Life Sciences Inc.

Dr Shirley Kenny
President, State University of New York, Stony Brook

Professor Lily Kong
Vice Provost (Education), National University of Singapore

Dr Don Thornhill
Chairman, Higher Education Authority, Ireland

Professor Peter Andrews
Queensland Chief Scientist

Professor Perry Bartlett
Director, Queensland Brain Institute, University of Queensland

Mr Ian Dobson
Senior Research Fellow, Centre for Population & Urban Research, Monash University

Professor John Hay
Vice Chancellor of the University of Queensland and Chairman of The Carrick Institute for Learning and Teaching in Higher Education

Professor Peter Høj
CEO, Australian Research Council

Professor Craig McInnis
Director of the Centre for Higher Education, University of Melbourne

Professor John McKenzie
Dean of the Faculty of Science University of Melbourne

Professor John Mattick
Director, Institute for Molecular Bioscience University of Queensland

Associate Professor Peter O'Donoghue
School of Molecular & Microbial Sciences, University of Queensland

Professor Brian Stoddart
Deputy Vice Chancellor (Research), La Trobe University