An Analysis of Application Rates to Programs in Information Technology, Science, and Engineering

John F. Roddick and Adrienne L. Nieuwenhuis

***Abstract*—A shift away from generic undergraduate degrees toward an emphasis on vocationally oriented qualifications has been evident in the awards offered by higher education institutions in Australia over the past few years. This has included those in information technology, science, and engineering, where the growth in the number of, and variation in, awards has been particularly evident. The past few years have also seen a general, and in some cases significant, decline in the application rates for some forms of science and engineering. This has prompted many institutions to look at their awards with a view to making them more attractive, both to students and industry, often through the development of more highly specialized awards. In this paper, the authors investigate application trends for information technology, science and engineering awards from a number of perspectives, including the market perceptions of the institution offering the degree. Although the paper focuses on three broad categories of awards—information technology, science, and engineering—some lessons may be appropriate for other disciplines. Moreover, although this study takes advantage of the centralized admissions systems used in Australia, available indicators show that the results may well be applicable in the United States and the U.K. and possibly elsewhere.**

***Index Terms*—Engineering, information technology, science, university undergraduate application rates.**

I. Introduction

OVER the past few years, many Australian universities have shifted their emphasis from broad-based generic undergraduate science degrees toward named specialist or vocationally oriented degrees. This shift is the result of a number of factors, including industry demand, student preference, and an increasingly competitive domestic and international market.

At the same time, overall demand[1] for science and engineering awards has fallen (between 1995 and 1999 preferences for the science and engineering awards covered by this paper fell by 6%). The pattern of that decline, coupled in some cases with high attrition has prompted many institutions to review, in some cases radically, which awards[2] to offer and even which science and engineering disciplines to retain. While this paper does not cover attrition rates, it is important to note that both in the United States (see [1] for a discussion) and in Australia (see [2]) the attrition rates in science and engineering are higher than in other disciplines and add to the problems of weak demand.

The drift away from science and engineering awards has been a source of concern for some time. In the United States, for example, the number of students completing a science, mathematics, engineering and technology degree has notably declined at a time when the total number of degrees conferred has risen [4], [5]. In Australia, between 1995 and 1999, applications for awards in information technology grew 18% whereas awards in the mathematical, chemical and physical science awards fell 20%, and in resource-based engineering by 23%. These trends have been mirrored in the U.K. where, between 1996 and 1999, there was a 39% increase in applications for awards in information technology and a fall of 8% in science and 17% in resource-based engineering oriented courses [3].

Although the demand for places at Australian universities has traditionally been strong, cutoff scores[3] in science and engineering awards at many universities tend to be lower compared with other disciplines, such as business, law and medicine [12], and many universities are experiencing difficulties in recruiting appropriately qualified students to science and engineering awards.

In this paper, we investigate application trends [as opposed to the more commonly studied enrollment trends (cf. [2]] taking advantage of the availability of data through the centralized admissions systems existing in Australia. We believe that this reflects the popularity of disciplines more accurately than that of enrollment data.

This paper focuses on three broad categories of university-based undergraduate-level award—information technology-based awards, including those with a strong management information systems focus; engineering awards; and science awards, including those in the biological sciences but excluding medicine, nursing, and those awards oriented to the health-care professions. Sufficient data applicable to the vocational education and training sector was not available, but many of the conclusions drawn by this study are expected to be equally applicable.

This paper is structured as follows. In Section II, the authors review previous studies in this area including the availability

Manuscript received January 18, 2000; revised May 25, 2001.

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Publisher Item Identifier S 0018-9359(01)06990-4.

[1]For the purposes of this paper, we define demand as the level of first preferences for an award as recorded by a tertiary admissions center or equivalent. In Australia, state-based tertiary admissions centers handle the majority of undergraduate applications to the country's 36 universities.

[2]To avoid any confusion with nomenclature, we use the term *award* to refer to a course of study leading to a Bachelor's degree. This report deals only with Bachelor level qualifications.

[3]Entry to awards in Australia is generally competitive and student selection is based on many criteria. One of the major metrics employed is a rank that indicates their position in the cohort of students finishing High School in that year. This rank is termed the *tertiary entrance rank* (TER). The TER cutoff for an award, which is provided to applicants for information at the time of application, is defined as the lowest TER of the students admitted under that criterion in the previous year.

of government statistics. Section III then discusses the methodology and scope of the study while the results and inferences of the study are discussed in Section IV. Section V then gives some brief conclusions.

II. Previous Studies

A country's future as an industrialized nation and its ability to participate in the emerging global economy will depend on its capabilities in the new and emerging industries of, for example, information technology, biotechnology, and nanotechnology [2], [4], and on having an adequate supply of suitably qualified scientists, technologists, and engineers. However, a number of studies over the past ten years have concluded that the United States, U.K., and Australian education systems are producing far fewer scientists and technologists than will be needed to maintain a technologically advanced economy [2], [4], [6], [8]–[15].

In 1998, the Australian Council of Deans of Science (ACDS) commissioned a study on enrollments in science in response to public concerns about an apparent decline in the number of students undertaking university science awards. This supports earlier studies by both Abbott [12] and the National Institute of Economic and Industry Research [8] who report on the relatively poor position of science compared with many other disciplines. The ACDS study found that enrollments in the DETYA[4] defined broad fields of study of Science, and of Engineering and Surveying which grew 57.9% and 47.6%, respectively, between 1989 and 1997 compared with 67.3% for Business, 55.8% for Health, and 51.8% for Arts. However, the study also found that these figures fail to represent the variation in enrollment patterns within the science-based disciplines as they mask the wide variations within the categories provided by DETYA. When subdivided using other available data, increases in enrollments in biological and computer science based awards of close to 80% become apparent, as do significant declines in the study of mathematics and the physical sciences. A study into the application rates across the sciences and engineering is thus warranted.

These trends in enrollment and demand are also linked to subject choice and preparation at secondary school. The ACDS report [2] noted the marked dependency of university science and engineering awards on direct school leavers. Many students in Australia are leaving school without undertaking or passing the necessary prerequisites for entry to science awards at university [16] and, as reported in the ACDS study [2], of the students who do undertake a combination of subjects best suited for study in science and engineering awards at university, only about one-third of students (based on Victorian Certificate of Education data) actually progress to science and engineering awards.

Similar concerns are voiced in the 1998 NSF report [5] which states that measured educational progress of eighth and 12th grade students indicates a decline over the high school years in the fraction that can perform at least at basic levels of proficiency in mathematics and science. It also indicates that only a small fraction of 12th grade students are fully prepared to undertake college-level studies in mathematics and science. Reference [5] reports that only 7% and 10% of 17-year olds score above the key anchor point of 350 in mathematics and science, respectively, in the National Assessment of Educational Progress (NAEP).

Thus it would appear that, with the exception of information technology and the biological sciences, the expectation of growth and development in new and emerging science and technological industries may be impeded by a lack of student demand in science and engineering disciplines, and as concluded by both the ACDS and the NSF, is a cause for concern.

Although application data is a key determinant in strategic planning by government and award planning by Universities, by and large, prior, publicly available research in this area has concentrated on enrollment rather than application trends (q.v. [17]). While enrollment data is useful, particularly as a predictor for eventual graduate numbers, application data provides a more accurate measure of the popularity of an award as it is a more direct reflection of student demand. It is, therefore, important that a quantitative analysis of the popularity of science and engineering awards based on application data is carried out to determine the magnitude of these changes in student award choice and to predict future trends.

This paper reports on such a study. It should be noted that in Australia, the collection of data needed for such a study is facilitated by the relatively centralized admissions processes. However, there is significant anecdotal evidence, particularly from academics in those disciplines, that similar trends may be occurring in other countries (certainly the data available from UCAS in the U.K. [3] concurs), and thus many of the findings of this study are expected to be more generally applicable.

III. Methodology and Scope of the Study

The data used in the study was supplied by the tertiary admissions centers in South Australia (SATAC), New South Wales (UAC), Queensland (QTAC), and Western Australia (TISC). Data for awards in Tasmania were obtained directly from the University of Tasmania and the Australian Maritime College.[5] By agreement, in accepting the data for the study, state by state comparisons are not reported. For comparison, data was obtained from the University and College Admissions Service in the U.K.

First preference data only have been considered as factors such as the number of awards available, and the total number of preferences allowable differ from state to state and from year to year. The "age" of an award was generally determined by looking at the state-based admission guides to see when the award was first listed. In all, 1035 Bachelor-level awards from 29 of Australia's 36 Universities were considered in this study representing approximately 149 000 applications over the five years of interest (approximately 30 000 each year). As one point of international comparison, UCAS data [3] from the U.K. was

[4]Australian Government Department of Education, Training and Youth Affairs

[5]Data for Universities operating in Victoria could not be obtained due to an agreement with the tertiary admissions center in that state not to release the detailed information. However, aggregate data supplied by VTAC was seen to correlate with the rest of the data. Data for some Victorian universities' awards were available where their admissions were handled through interstate admissions centers.

analyzed and, as far as can be judged from the data alone, generally concurs with the results available from Australia. The UCAS data lists all preferences, and, for the disciplines covered by this report, are listed in Appendix A.

This paper focuses on application rates rather than on admission rates, which were considered to be an indication of the supply of places. Similarly, cutoffs, are not considered as they are a product of supply and demand. It is nevertheless acknowledged that some measure of self-selection occurs when the stated tertiary entrance rank (TER) cutoffs are high and intake quotas are small. Countering this, to some extent, high TER cutoffs attract some first preference applications at the expense of similar awards with lower cutoffs.

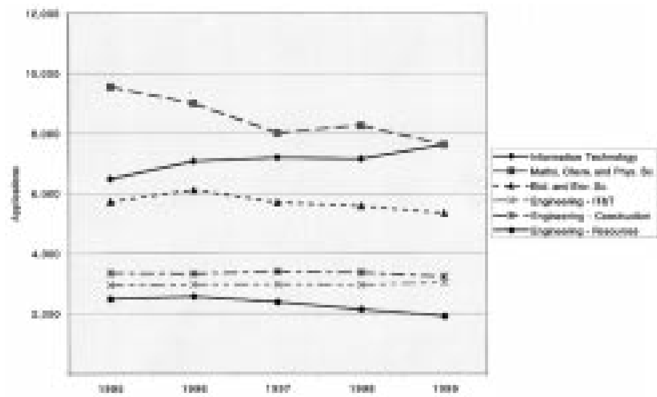

Fig. 1. Application Numbers, 1995–1999.

A. Categorization of Awards

In order to perform the analysis, awards were grouped into one of six categories. Some awards can be considered to fall into multiple categories. For example, an award with significant studies in both mathematics and computing could be considered as both an information technology award and a mathematical science award. In order that the information presented about each discipline can be read independently, where this situation occurs, either the award is explicitly listed as being in one or the other (see below), or the award data is included in both categories in an appropriate proportion, which was estimated from the description of the award in the admissions guides (and thus the totals are still the sum of their parts). For double and dual degrees the application numbers were also listed under all applicable categories (again, using an appropriate proportion). Three and four year bachelor level degree awards and double degree including such awards only were investigated.

The disciplines covered by this paper are categorized as follows:

- **Information Technology**
  This category includes awards covering computer science, (management) information systems, and software engineering. The awards offered do not readily partition into subcategories.
- **Science**
  - *Mathematical, Chemical, and Physical Sciences* include awards covering mathematics, chemistry, and physics as well as closely allied fields such as geo-physics and industrial chemistry. Also included in this category are a small number of awards in which the focus of the study was unclear.
  - *Biological and Environmental Sciences* include awards covering biology, ecology, biochemistry, geology, and biotechnology. However, medically or sports science related awards were excluded. A small number of awards in bioengineering and bioinformatics were also included in this group.
- **Engineering**
  - *Information Technology Engineering* includes awards covering computer engineering, computer systems engineering, telecommunications, and electronic engineering. Software engineering is not included in this category.
  - *Construction Engineering* includes awards covering mechanical, automotive, aeronautical, and electrical engineering.
  - *Resource Engineering* includes awards covering mining, materials, civil, and water engineering. It also includes a number of awards classified as environmental engineering.

This study specifically excludes some awards that might have been expected to have been included such as geomatics, geoinformatics, and spatial information systems. In many cases, these are young areas and, in many cases, the composition of each award was not clear from the descriptions. In addition, awards specifically targeting agriculture, horticulture, and viticulture were not included as the scientific content of some of these awards could not be determined.

IV. Results

Fig. 1 shows the overall variation of applications across the above six categories. (Full data are available in Appendix B).

The figure shows declines in four of the six categories with only Information Technology and IT&T-based engineering showing application growth. Moreover, the 20% reduction in applications for the mathematical, chemical and physical sciences supports the concerns of the Deans of Science raised in [2]. In addition, as discussed later, demand has shifted from existing awards to newer style awards, as well as from single to double degrees.

A. New Awards

Over half of the awards investigated either underwent a name change or are new awards since 1996.[6] A graph showing the growth in applications in awards that did not exist in 1996 is given in Fig. 2.

Note that while some name changes are cosmetic, the vast majority of the new awards represent either a substantial repackaging of existing topics into awards which cover a different spectrum of topics, or entirely new material aimed at developing a new discipline (such as bioinformatics, nanotechnology, etc.).

[6] A small amount of the data for 1995 was extrapolated from 1996 to 1999. *New* awards are thus defined as post 1996.

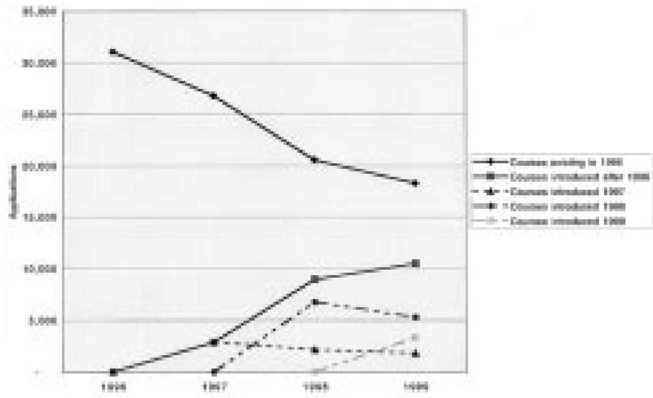

Fig. 2. Growth in Applications for New Awards, 1996–1999.

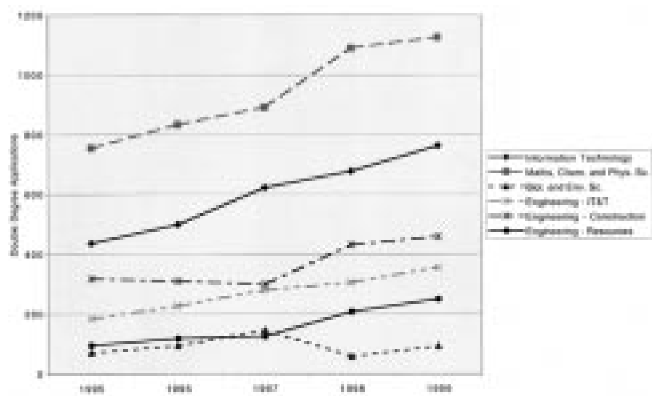

Fig. 3. Growth in Double Degrees, 1995–1999.

The figure also shows that the common profile of a newly introduced award is an initial level of demand followed by an approximate 20% drop in that demand over following years as initial demand is met and more competitive awards are offered.

B. Double Degrees

The development and popularity of various combinations of double degrees are also evident, particular in the mathematical, chemical and physical sciences, and in information technology. Fig. 3 shows the growth in applications for double degree awards for each of the disciplines identified.[7]

In all, double degree applications as a proportion of total applications have grown from 6% in 1995 to 11% in 1999. Two categories of double degree can be identified—those that pair two science or engineering awards and those that pair a science or engineering award with a nonscience/engineering award. Both categories have become remarkably popular lately with the former including over 100 awards in 1999 (less than 40 such awards existed in 1996). For the latter category almost 200 awards were included (up from 62 in 1996) with the common pairings including commerce, international studies, law or management. Each of these two categories represent an approximately equal number of double degree applications recorded for 1999.

[7]For the purposes of this study, in order that each application counted equally, the authors a weighting to each double degree application to account for the proportion of study not in IT, Science and Engineering. For example, for a double degree, B.Sc. with B.A., a figure of 0.5 was applied to each application. For a double degree, B.Sc. with B.Eng., appropriate weightings were applied to each of the subcategories represented in the award, which were estimated from the description of each award in the admissions guides.

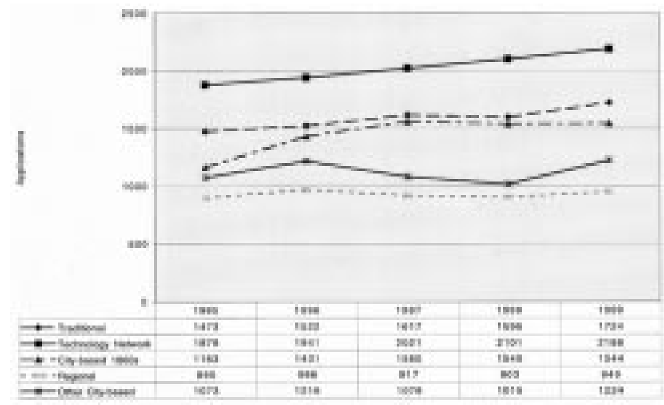

Fig. 4. Applications to Information Technology awards by type of institution, 1995–1999.

C. Perceptions of the Institution

The authors were interested in looking at the diversity of perceptions among applicants toward different types of universities in the sector. For the purposes of the study, institutions were therefore categorized into the five groups listed below.

- *Traditional*, which includes those Universities that existed prior to 1960.
- *City-based 1960s*, which includes the capital city based Universities established in the 1960s.
- *Technology network*, which includes those Universities which grew from the former Institutes of Technology in the late 1980s and early 1990s.
- *Regional*, those universities *primarily* serving noncapital city towns and regions.
- *Other city-based* institutions.

Inevitably, some differences within these groups were apparent, although a remarkable level of correlation was found using these definitions. One of the more surprising results of the study has been the change in application patterns according to this broad categorization of institutions as shown in Figs. 4–9.

The figures show some marked variations in demand across the sector. With respect to applications for information technology awards, for example (Fig. 4), the technology network and the traditional universities have shown a consistent 17% increase in applications over the four years. The highest growth, however, has been in the city-based 1960s institutions, which have attracted a 33% increase in applications.

It is interesting to compare these observations with the IT&T based engineering awards (Fig. 5) which shows relatively flat application levels for all but the traditional universities. Moreover, the decline in applications for regional universities in IT&T based engineering and the relatively static application rate in information technology helps to explain the overall 17% decline in applications in IT, science, and engineering by these institutions.

Mathematical, chemical, and physical science-based awards show that there has been a distinct and dramatic decline in

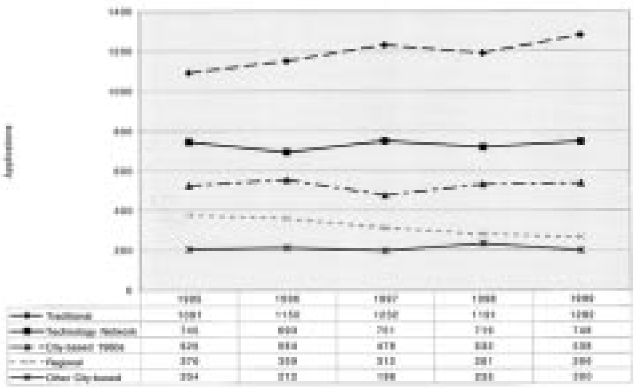

Fig. 5. Applications to IT&T oriented engineering awards by type of institution, 1995–1999.

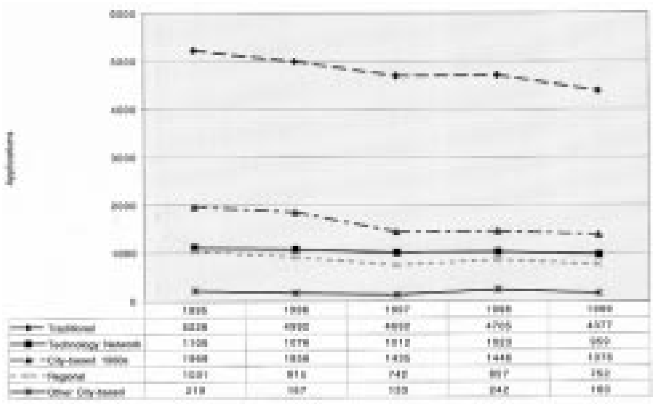

Fig. 6. Applications to Mathematical, Chemical and Physical Science-based awards by type of institution, 1995–1999.

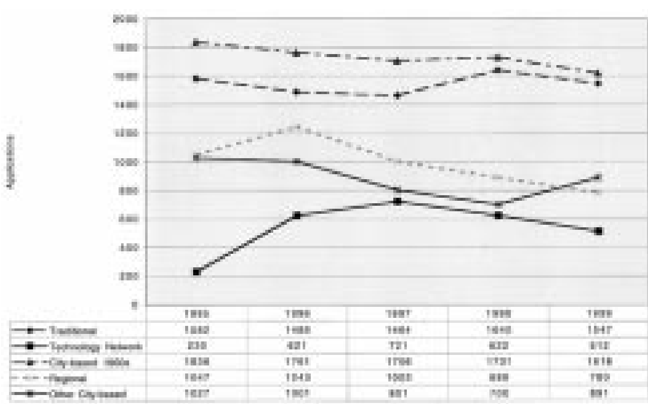

Fig. 7. Applications to Biological and Environmental Science-based awards by type of institution, 1995–1999.

applications for all groups of institution. The decline averages at 20% or almost 2000 applications over the four years, 1995–1999. Because of the manner in which this study was undertaken, this fall could, in part, be explained by the introduction of specialist information technology or biological and environmental based awards separate from the more generic broad-based awards. However, even if all generic science degrees did include these areas in 1995 and did not in 1999, the decline in applications is still of the order of 14–15%. This decline mirrors the data available from UCAS [3].

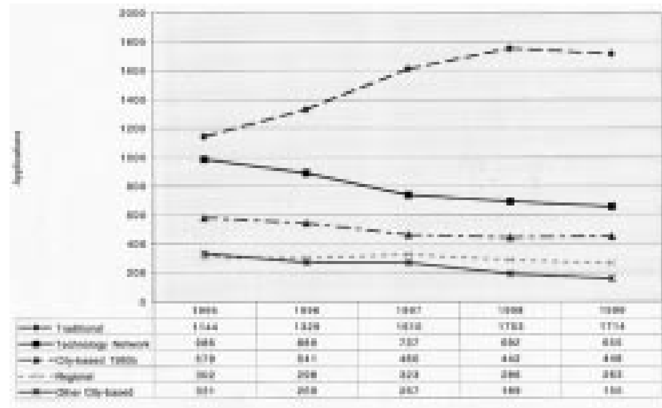

Fig. 8. Applications to Construction-oriented Engineering awards by type of institution, 1995–1999.

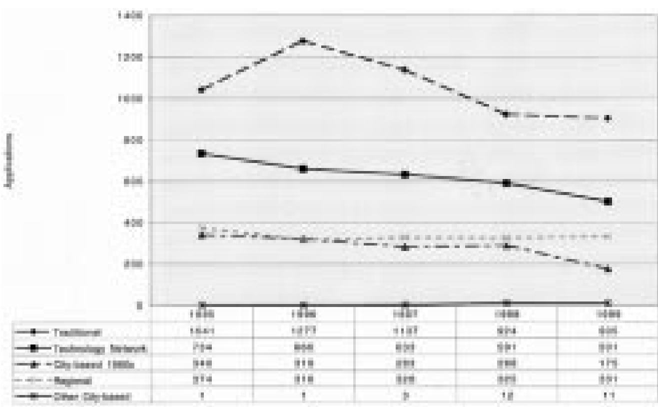

Fig. 9. Applications to Resource-based Engineering awards by type of institution, 1995–1999.

The changes to applications for biological and environmental science-based awards show an interesting trend (Fig. 7). First, it is the only group of awards for which the city-based 1960s universities are consistently the most popular in terms of demand. This is all the more significant when the relatively small size of these universities is considered.

Second, the growth and subsequent decline shown by the technology network and regional universities in biological and environmental science-based awards, indicate an introduction of newer awards in 1996 followed by the subsequent decline experienced by other universities. Overall, applications to biological and environmental science-based awards declined 7% and declined in all categories of institution except the technology network. Again, this is mirrored in the U.K. where a 6% decline between 1996 and 1999 was experienced.

Applications to construction-oriented engineering programs (Fig. 8) show the most dramatic differences in terms of institutional category. While construction-oriented engineering overall has seen a 3% fall in demand, the traditional universities have experienced a 50% rise in demand, while all other categories experienced substantial declines. In particular, the decline in applications to awards offered by the technology network universities (of 34%) is significant and mirrors their 33% decline in resource-based engineering.

Resource-based engineering awards have seen the largest decline in applications since 1995 (Fig. 9). Moreover, since 1996,

Broad Field of Study	1996	1997	1998	1999	Difference 1996-1999
Biology	33921	34269	32171	30801	-9%
Botany	471	478	352	284	-40%
Zoology	6509	6929	6824	6353	-2%
Genetics	3151	3863	3494	3409	8%
Microbiology	3329	3858	3851	3652	10%
Molecular Biology / Biophysics	913	1097	1077	1020	12%
Biochemistry	11565	12600	12460	11726	1%
Other biological sc.	3173	3195	2913	2562	-19%
Bio. sc. combinations	3900	4318	3912	3685	-6%
Chemistry	21918	21956	21479	19558	-11%
Materials science	177	189	38	23	-87%
Physics	16992	18647	18185	16446	-3%
Astronomy	1108	1130	1263	1080	-3%
Geology	7001	7416	8018	7530	8%
Oceanography	1333	1191	1017	1155	-13%
Env. & other physical sc.	14306	13750	11781	10182	-29%
Phys. Sc. combinations	3391	3430	3131	2877	-15%
Mathematics	22845	22387	22628	23063	1%
Statistics	1292	1513	1526	1285	-1%
Computer science	66940	75530	84612	100062	49%
Computer systems eng.	3382	3502	4239	5931	75%
Software engineering	9375	11651	13780	16455	76%
Artificial intelligence	853	1056	962	964	13%
Other math. & info. sc.	902	782	826	756	-16%
Math. Sc. combinations	7821	8170	8753	9152	17%
General engineering	8599	8852	7736	7567	-12%
Civil engineering	22751	20179	18530	16414	-28%
Mechanical engineering	31574	30779	30563	27402	-13%
Aeronautical engineering	9243	9527	9947	10430	13%
Electrical engineering	1783	1615	1366	1212	-32%
Electronic engineering	21088	20513	19589	17720	-16%
Production and/or manuf. eng.	7225	7061	6585	6610	-9%
Chemical engineering	7393	7186	6695	6148	-17%
Engineering combinations	22340	20138	16863	15521	-31%
Metallurgy	136	140	124	87	-36%
Ceramics and glass	10	57	16	41	310%
Polymers and textiles	1840	2627	2976	2876	56%
Other materials tech.	1340	1292	1481	976	-27%
Maritime technology	1861	1979	1809	1555	-16%
Biotechnology	1047	1059	874	899	-14%
Other eng. & tech.	1444	1286	1259	1171	-19%

Fig. 10. Applications in the U.K. as reported by UCAS, 1996–1999.

which saw a rise in demand, the figure shows that there has been a subsequent drop in application demand of over 25% in the past three years.

V. Conclusion and Future Research

The analysis presented in this paper has shown that despite a relatively modest drop in applications across the studied disciplines as a whole, significant changes have occurred in some areas of science and engineering. In particular, there has been a significant decline in the popularity of resource-oriented engineering, while substantial increases in applications have been apparent in information technology. The increase in double degree applications masks, to some extent, the magnitude of these changes. Moreover, as can be seen from the figures, the changes experienced by the different types of institutions have not been uniform and even within these categories, one institution may have a particular profile of change which may be of significance in individual award planning.

The figures provide support to assertions (such as those outlined by the ACDS [2]) that shifts in demand for, and enrollment in, information technology, science, and engineering have been substantial over recent years. This at a time when the Australian higher education sector is experiencing other major financial and competitive pressures.

Because of the data available to the researchers of this project, the identification of finer grain changes to discipline demand was not possible with sufficient accuracy. Nevertheless, it is clear that, even within a broad categorization of disciplines such as mathematical, chemical and physical sciences, the impact on mathematics-based awards has been lower than that on the chemical and physical sciences. The data available from UCAS indicates that the change in popularity of mathematics-based awards is largely unchanged while the changes to chemistry have been marked. Further research could be envisaged to refine this data and allow more accurate inferences to be made.

Given that there is little unmet demand for places in many science and engineering awards at present, the trends in some disciplines are cause for considerable concern. In particular, the decline in interest for resource-based engineering and in the chemical and physical sciences has been steady and is showing no signs of improvement. Thus, despite healthy levels of graduate

University Type	Broad Field	1995			1996			1997			1998			1999		
		P-UT	P-DC	Count	P-UT	P-DC	Count	P-UT	P-DC	Count	P-UT	P-DC	Count	P-UT	P-DC	Count
Traditional	Information Technology	13%	23%	(1470)	13%	22%	(1520)	14%	22%	(1620)	14%	22%	(1600)	15%	23%	(1720)
	Maths, Chem. & Phys. Sc.	45%	55%	(5230)	42%	55%	(4990)	40%	59%	(4690)	40%	57%	(4700)	38%	57%	(4380)
	Biol. & Env. Sc.	14%	28%	(1580)	13%	24%	(1490)	12%	26%	(1460)	14%	29%	(1640)	13%	29%	(1550)
	Engineering - IT&T	9%	37%	(1090)	10%	39%	(1150)	10%	41%	(1230)	10%	40%	(1190)	11%	42%	(1280)
	Engineering - Construction	10%	34%	(1140)	11%	40%	(1330)	14%	47%	(1610)	15%	52%	(1750)	15%	53%	(1710)
	Engineering - Resources	9%	42%	(1040)	11%	50%	(1280)	10%	48%	(1140)	8%	43%	(920)	8%	47%	(900)
City-based 1960s	Information Technology	18%	18%	(1160)	22%	20%	(1430)	26%	22%	(1560)	26%	22%	(1540)	27%	20%	(1540)
	Maths, Chem. & Phys. Sc.	31%	21%	(1970)	29%	21%	(1860)	24%	18%	(1440)	24%	17%	(1450)	24%	18%	(1380)
	Biol. & Env. Sc.	29%	32%	(1840)	27%	29%	(1760)	29%	30%	(1710)	29%	31%	(1730)	28%	30%	(1620)
	Engineering - IT&T	8%	18%	(530)	9%	19%	(550)	8%	16%	(480)	9%	18%	(530)	9%	18%	(540)
	Engineering - Construction	9%	17%	(580)	8%	16%	(540)	8%	14%	(460)	7%	13%	(440)	8%	14%	(450)
	Engineering - Resources	5%	14%	(340)	5%	12%	(320)	5%	12%	(280)	5%	13%	(290)	3%	9%	(170)
Technology Network	Information Technology	33%	29%	(1880)	33%	27%	(1940)	34%	28%	(2020)	37%	29%	(2100)	39%	29%	(2190)
	Maths, Chem. & Phys. Sc.	19%	12%	(1100)	18%	12%	(1080)	17%	13%	(1010)	18%	12%	(1020)	17%	13%	(960)
	Biol. & Env. Sc.	4%	4%	(230)	11%	10%	(620)	12%	13%	(720)	11%	11%	(620)	9%	10%	(510)
	Engineering - IT&T	13%	25%	(740)	12%	23%	(690)	13%	25%	(750)	13%	24%	(720)	13%	25%	(750)
	Engineering - Construction	17%	29%	(990)	15%	27%	(890)	13%	22%	(740)	12%	21%	(690)	12%	20%	(650)
	Engineering - Resources	13%	29%	(730)	11%	26%	(660)	11%	27%	(630)	10%	28%	(590)	9%	26%	(500)
Regional	Information Technology	22%	14%	(900)	24%	14%	(970)	25%	13%	(920)	26%	13%	(900)	28%	12%	(950)
	Maths, Chem. & Phys. Sc.	26%	11%	(1030)	22%	10%	(910)	20%	9%	(740)	24%	10%	(860)	23%	10%	(750)
	Biol. & Env. Sc.	26%	18%	(1050)	30%	20%	(1240)	28%	18%	(1000)	25%	16%	(890)	23%	15%	(780)
	Engineering - IT&T	9%	13%	(380)	9%	12%	(360)	9%	10%	(310)	8%	10%	(280)	8%	9%	(270)
	Engineering - Construction	8%	9%	(300)	7%	9%	(300)	9%	10%	(320)	8%	9%	(290)	8%	8%	(260)
	Engineering - Resources	9%	15%	(370)	8%	12%	(320)	9%	14%	(330)	9%	15%	(320)	10%	17%	(330)
Other City-based	Information Technology	38%	17%	(1070)	42%	17%	(1220)	43%	15%	(1080)	42%	14%	(1010)	46%	16%	(1220)
	Maths, Chem. & Phys. Sc.	8%	2%	(220)	6%	2%	(170)	5%	2%	(130)	10%	3%	(240)	6%	2%	(160)
	Biol. & Env. Sc.	36%	18%	(1030)	35%	16%	(1000)	32%	14%	(800)	29%	13%	(700)	34%	17%	(890)
	Engineering - IT&T	7%	7%	(200)	7%	7%	(210)	8%	7%	(200)	10%	8%	(230)	8%	7%	(200)
	Engineering - Construction	12%	10%	(330)	9%	8%	(270)	11%	8%	(270)	8%	6%	(190)	6%	5%	(150)
	Engineering - Resources	0%	0%	(0)	0%	0%	(0)	0%	0%	(0)	1%	1%	(10)	0%	1%	(10)

Fig. 11. Applications in each area of information technology, science and engineering—(1) as a proportion of those received for that type of university, (P-UT), (2) as a proportion of those received for that discipline category, (P-DC), and (3) as a count of applications, 1995–1999.

demand, such trends, if continued, are likely to result in unfilled places in some awards, and ultimately a reduction in graduate numbers and the associated recruitment problems for industry.

One particular area of concern is the decline in demand for science and engineering across almost all identified categories for those universities in regional and rural areas. With the exception of the high growth area of information technology (which showed a modest growth of just 5% compared with the national average of 18%) all other disciplines' categories exhibited a fall in demand of up to 29%. In part, this decline has been attributed to the low number of adequately prepared applicants for these courses [2], [5]; however, despite this there are a number of qualified students who are choosing not to continue with science and engineering at university.

Equity issues in science and engineering awards, including the low participation rate in some awards, are also a significant issue, and a number of papers have investigated the reasons for this inequity and outlined some solutions. For example, Frize [18] reports on the rise in the participation of women in undergraduate science and engineering programs in Canada over the period 1989 to 1999, and Hill, in an NSF report, looks at similar issues as they apply to black students in the U.S. [20]. The data were not available to see the equivalent application trends in engineering in Australia during that period although the ACDS [2] reports a 3% increase in women entering science awards over that period. Further data on the enrollment, retention, and satisfaction rates between the genders in the U.S. can be found in [19]. Further research in this area would be interesting.

Appendix A

Fig. 10 shows the changing applications for the discipline categories defined by U.K. universities and college admissions body, UCAS. The data was obtained from their website [3].

Appendix B

Fig. 11 shows Australian data for the changing proportion and application numbers for each of the six sub-divisions adopted in this paper by university type. The proportion given is the proportion of each category against the total applications in information technology science and engineering for that university type and for that discipline category.

Acknowledgment

The authors are grateful to the tertiary admissions centers in South Australia (SATAC), New South Wales (UAC), Queensland (QTAC) and Western Australia (TISC) and to the University of Tasmania and the Australian Maritime College for making both their data and their time available to us for this study. Thanks are also due to UCAS in the U.K. for making their data available for comparison and for the useful comments received from Myles Boylan of the Division of Undergraduate Education at the NSF in the United States. Finally, the authors would also like to thank B. Bowden and the anonymous referees for their constructive comments on early versions of this paper.

References

[1] E. Seymour and N. Hewitt, *Talking about Leaving: Factors Contributing to High Attrition Rates among Science, Mathematics and Engineering Undergraduate Majors*: Univ. Colorado, Boulder, Bureau Sociological Res., 1994.

[2] "Who is Studying Science?," Australian Council of Deans of Science (ACDS), Tech. Rep. ACDS Occasional Paper 1, Sept. 1999.

[3] Applications and Acceptances Ratios, by Subject 1994–1999 [Online]. Available: http://www.ucas.ac.uk/figures/archive/subject/index.html

[4] "Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology," NSF Division of Undergraduate Education, National Science Foundation, Arlington, VA, Rep. NSF96-139, 1996.

[5] "Shaping the Future II," NSF Division of Undergraduate Education, National Science Foundation, Arlington, VA, Rep. NSF96-128, 1998.

[6] (1983, Apr.) A Nation at Risk: The Imperative for Educational Reform. National Commission on Excellence in Education. [Online]. Available: http://www.goalline.org/Goal%20Line/NatAtRisk.html

[7] "Degrees and Other Awards Conferred by Title IV Eligible, Degree-Granting Institutions: 1996–97," Dept. Educ., Nat. Center Educ. Statist., Washington, DC, 1999.

[8] "The Demand and Supply of Scientists and Engineers in Australia," National Institute of Economic and Industry Research, Occasional Paper 16, Canberra: AGPS, 1991.

[9] "Physics: A Vision for the Future," Australian Research Council Discipline Research Strategies, Canberra: NBEET, AGPS, Working Party of the National Committee for Physics of the Australian Academy of Science, 1993.
[10] "Developing Australian ideas—The white paper on science and technology," *Higher Education News, DEET*, pp. 14–15, 1992.
[11] S. Oliver and G. Wittenhall, "What will work consist of in the future," *Australian J Career Development*, pp. 40–44, 1992.
[12] T. Abbott, "Scores measure the market," *The Australian*, p. 8, Feb. 14, 1990.
[13] J. Delaeter, Higher education's role in the promotion of science and technology: An Australian view, in Higher Education and Social Goals in Australia and New Zealand, W. Toombs and G. Harman, Eds., pp. 67–83, 1988.
[14] G. Moodie, "The debates about higher education quality in Britain and the USA," *Studies in Higher Education*, vol. 13, no. 1, pp. 5–13, 1988.
[15] "The freshman year in science and engineering. Old problems, new perspectives for research universities," *J. College Sci. Teaching*, vol. 20, pp. 277–287, 1991.
[16] B. Fraser, J. Malone, and P. Taylor, "Tertiary bridging courses in science and mathematics for second chance students in Australia," *Higher Educ. Res. Development*, vol. 9, no. 2, pp. 85–100, 1990.
[17] C. Clotfelter, "Demand for undergraduate education," in *Economic Challenges in Higher Education. Part I*. Chicago, IL: US Nat. Bureau Economic Res., Univ. Chicago Press, 1991, pp. 19–139.
[18] M. Frize, "Canada doubles enrollments of women in engineering in a decade," in *Proc. Int. Symp. Technol. Society—Women and Technology: Historical, Societal, and Professional Perspectives*, 1999, pp. 315–319.
[19] L. J. Sax, "Graduate Education in Science, Math and Engineering: Gender Differences in Enrollment, Persistence and Satisfaction," Higher Education Res. Inst., UCLA, Los Angeles, CA, Rep. Alfred P. Sloan Foundation, 1998.
[20] S. T. Hill, "Blacks in Undergraduate Science and Eng. Educ.," Nat. Sci. Foundation, Washington, DC, Special Rep. NSF92-305, 1992.

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