

Engineering Education - undergraduate and masters: China and Down Under

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***Abstract:** This paper started with describing first degree in engineering programs in Australia and China. It was found that the number of first degree in engineering awards per capita for Australia and China was at par. Post-graduate programs in engineering in the two countries were also mentioned and compared. For master's degree in engineering, the number of graduates for Australia to China per capita is 1 to 4.22. It was also discovered that most of the master's degree in engineering in both countries were by coursework. There was no master's degree in engineering by research program on offer in China similar to that offered in Australia.*

Introduction

China is one of the largest sources of migrants of Australia from non-English speaking country. A large number of migrant engineers move here from China, which is also the largest trading partner with this country, if her Special Administration Region, Hong Kong is also taken into account. Australia's recent mining boom is also mainly created by China. Mining is concerned with engineering and it can be argued that comparing and contrasting engineering education in China and Australia is a critical investigation to see if engineers from China can really help to tackle the skills shortages in engineering workforce in this country.

In Australia, the higher education (university) sector currently has sole responsibility for the education of professional engineers and engineering technologists through 4-year (or equivalent) Bachelor of Engineering (BEng), and 3-year Bachelor of Engineering Technology (BEngTech) awards respectively. The university sector shares responsibility with the vocational education and training sector (VET) for providing award programs for engineering officers or technicians, through 2-year Associate Degrees and Advanced Diplomas in universities and TAFE (Technical and Further Education Colleges) respectively; however TAFE and VET sector trains most of the technicians (King, 2008). Down Under, there are 39 universities, of which 37 are public institutions and 2 are private. Only 32 of the public universities offer engineering programs. The first engineering degree program was offered by the University of Melbourne in 1861 (Melbourne school of engineering, n/a).

The first engineering degree program offered by two oldest Chinese universities was 47 years later than its counterpart in Australia. Of the 1080 institutions in China, there are 96 national key universities including 53 polytechnic universities. The development of higher education in engineering in China was originally influenced by the USA; after the communists took power in 1949, engineering education was modelled according to the former Soviet Union; they were mono-disciplinary and multi-disciplinary colleges of engineering; they were very specialized and geared towards the demand of a particular industry. After the 'open door' policy in 1978, China's universities had borrowed and drawn much experience from worldwide engineering education by forging ties with prestigious universities in the world, which has facilitated the reform and development of China's engineering education. The curriculum was also changed to suit the current market economy (Li et al, 1996). With the exception of the 53 polytechnic universities, most institutions offer also three-year Bachelor of Engineering Technology (BEngTech) and two-year Associate Degree as in the case of Australian regional and newer universities.

Universities

In Australia, universities are mainly funded by the Federal Government; fees are charged to international and domestic students. In addition to educating and training professional engineers and engineering technologists, universities train advanced and research-orientated professional engineers by offering master's and doctorate degrees.

Bachelor's Degree

Australia's current pattern of professional engineering education, established around 1980, may be insufficient for the initial education of future professional engineer; industry and the Engineers Australia College boards, asserted that moves towards a five-year award are either desirable or inevitable. Several signatories of the Washington Accord have committed to extend the duration of their professional engineering programs within the next two decades. The Engineering Council of UK requires a Master of Engineering (MEng) qualification, normally awarded after four years of study in England and Wales, and five years in Scotland to qualify as a graduate professional engineer (King, 2008). In continental Europe, engineering education is rapidly adopting the bachelor-masters-doctoral system. Engineers Ireland, has declared that an accredited engineering program will require five years post-secondary education for graduates from 2013. Australia is already moving towards this direction slowly. A good example of this model is the 5-year BEng/MBioMed Eng engineering program at the University of New South Wales. The 'new generation' 3+2 year University of Melbourne model is a variant on this pattern, with the first component being one of three-year bachelor awards, none explicitly in engineering. Students wishing to progress to the two-year MEng take appropriate major studies within their bachelor program. In this latter model it is the 3+2 year program sequence that ultimately delivers the accredited, professional engineering outcome (King, 2008).

So far programs leading to professional engineers have been discussed, but it is understood that many jobs in this country are at technologist level. Some employers do not know the existence of BEngTech program and feel obliged to employ BEng graduates to perform the tasks of engineering technologists because they have to pay more. Another reason for employer emphasis on the professional engineering qualification is the perceived need for graduates to progress to the Stage 2 competencies and to acquire registration on the National Professional Engineers Register. Under state and federal legislation, registration is required for the conduct of defined engineering functions whose outcomes have inherent and potential risks to the public (King, 2008). Other than that, there is no reason to recruit BEng graduates to perform the duties that can be done by technologists. This is particularly true when the supply of professional engineers in this country is far from enough. The society has to spend more time and money to train professional engineers.

King (2008) claimed that most of the industry participants and professional groups recognised a need for workers at levels between VET trained and professional graduate. However, academic groups were much less enthusiastic, and even strongly opposed to their schools responding to the 3-year

qualification concept, unless they had built such a program successfully to satisfy local needs, such as at the University of Ballarat, University of Southern Queensland, and Central Queensland University. A common view was to leave technologists and technicians to the VET sector. This view exhibits a lack of understanding of the graduate level required of technologists, and the opportunities that exist to offer programs at Associate Degree level. USQ needs the two programs because these graduates will usually enrol in USQ BEng program later in their life.

In China, there are mainly two types of bachelor degrees, the four-year professional degree and the three-year sub-professional degree. The number of engineering graduate has increased dramatically in recent years due to two interacting factors: the supply of engineers graduating from universities and a rapid increase in the demand for engineers in this market economy. China started its transition from 'elite education' to 'mass education' in 1999. The number of first degree graduates in China is compared with that of Australia and is shown in Figure 1. The increase for China was from 176,000 to 572,000; an increase of 225% in the last ten years. The increase was sharp from 2000 onwards; this was because of the effect of 'mass education'. On the other hand, the increase for Australia was modest. The number is from 6,200 to 8,800 in the same period. Australia's 'mass education' in higher education sector started in the 80s of last century, more than a decade earlier than that of China. In 2006, China produced 65 times as much bachelor's degree engineering graduates as Australia. It is worth noting that China's population (1.31 billion) is 62.3 times to that (21 million) of Australia. This means that the number of bachelor's engineering graduates in China and Australia per capita is almost at par. It can be argued that China needs to move to five-year engineering programs in the coming two decades.

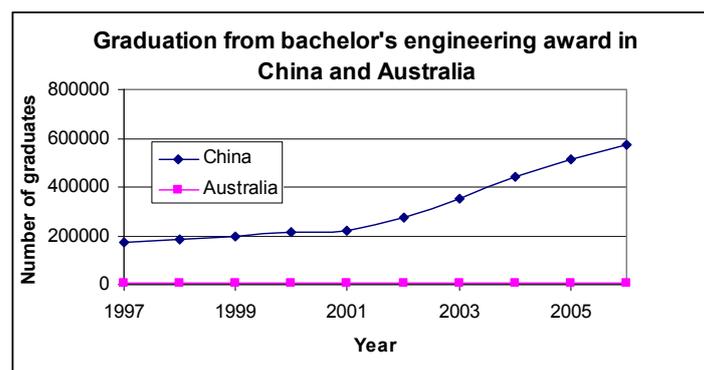


Figure 1: Graduation from bachelor's engineering award programs in China and Australia

Year	China	Australia
1997	176000	6225
1998	183000	6505
1999	197000	6709
2000	213000	6677
2001	220000	6742
2002	274000	8016
2003	352000	7988
2004	441000	8283
2005	516000	8838
2006	572000	8457

Table 1: Graduation from bachelor's engineering award programs in China and Australia

The increase in number of graduates in China is often at the expense of quality. As a result, there is an oversupply of all engineers, while an undersupply for globally competitive engineers (Gereffi et al,

2008). Farrell et al. (2005) found that only 10 percent of engineers graduating from China is globally employable as compared to 80.7 % of those of the USA. It can be argued that the employability of engineering graduates in Australia will be at par with that of the USA because the quality of engineers produced is high as the programs are accredited by Engineers Australia, which is a signatory member of the Washington Accord. In addition, the universities offering these programs are publicly funded and a certain standard will to be maintained. China's professional engineering societies may need considering to join the Washington Accord to improve the quality of her engineering education so that more globally employable engineers can be graduated from her universities. There is a very acute shortage of professional engineers in this country, which have to be met by migrants from China, India and some other countries. Table 1 shows the number of first degree graduates of China and Australia from 1997 – 2006 and is used to supplement information in Figure 1.

Master's degrees

Most Australian universities award master's degrees after three semesters of full-time study for graduates of 3-year bachelor's degrees but these degrees are not necessarily recognised by Engineers Australia for Stage 1 competencies for professional engineer because Engineers Australia does not accredit stand-alone master's degree. Such awards are regarded to provide a professional development pathway for existing graduates, rather than upgrading their professionalism (King, 2008).

There are 117 engineering master's coursework programs, varying in duration from 2 to 4 academic semesters equivalent full-time coursework. Many programs are nested with graduate certificates and graduate diploma awards. The programs are provided by a range of delivery methods, including by distance-education, and some are operated in collaboration with internationally-based universities. Most of the programs incorporate project work, in some case up to 50% of the total program time. Many programs also allow for students to take undergraduate courses, as part of their master's program. Most of these are conversion programs, either for engineering graduates to change to another branch of engineering or for graduates without an accredited professional engineering degree to gain a qualification that would be recognised by Engineers Australia at professional engineering entry level. The graduate attribute outcomes may be closer to a first degree. However, some are discipline specialisation, focussing on in-depth technical material, and possibly oriented towards postgraduate research studies, with normal entry qualification being a four-year engineering degree (King, 2008).

International students dominate many of Australia's postgraduate programs, having a sixfold increase in numbers from 1996 to 2006. Many of these students have the expectation that their programs will assist their immigration into Australia, ultimate employment in the engineering profession. Many international students are surprised, however, by the absence of program accreditation at the professional engineering level for some of the master's programs described earlier (King, 2008). The recognition is by individual circumstances. Fortunately, most Master of Engineering Technology (MEngTech) graduates with project option of the University of Southern Queensland had their qualification recognised by Engineers Australia. It is good to hear that Engineers Australia has declared its commitment to examining program accreditation of master's awards. However, the typical stand-alone three-semester masters program tends to focus on technical content, rather than these broader attributes as required by the four-year BEng program for professional engineers. Their recognition is in doubt unless the first degree of the international student is included as part of the evaluation; this becomes recognition by individual case as in the case of MEngTech of USQ graduates.

Regarding research student numbers, it was found that Australia has fewer BEng graduates progressing to research degrees than is desirable or comparable with international institutions. Domestic graduate progression rate is 5 – 7% in recent years. This figure is highly tentative, and assumes that initial research candidature is at master's level, which may not be the case across the system (King, 2008). One reason for the lack of attractiveness to research engineering degrees by domestic candidates is the tremendous drop in the stipend of the scholarship; it had dropped from 75% to only 40% of a first year engineering graduate salary in the last two decades (Ku & Ross, n/a).

Looking at total research degree enrolments, the figure of 5,413 in 2006 is small for a potential supervision complement of 2,831 teaching and research academics. Having more research degree students of adequate quality would undoubtedly strengthen Australia's engineering research (King, 2008).

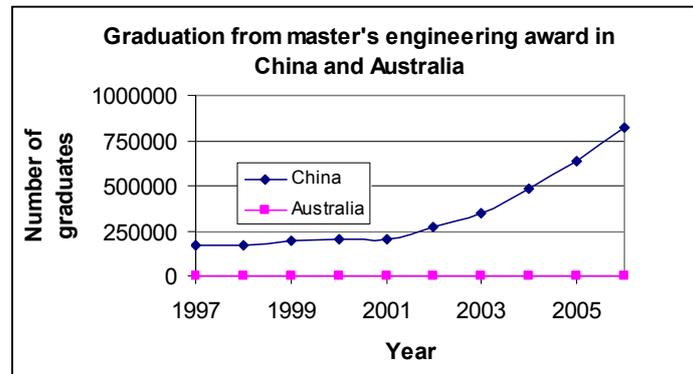


Figure 2: Graduation from master's engineering award programs in China and Australia

In China, the master's degrees are usually by coursework and in making comparison, the coursework and research master's degrees of this country have to be combined. Figure 2 illustrates the number of master's degree graduates in China and Australia from 1996 to 2006. In China, the number of master's awards increased from 169,000 to 825,000 from 1997 to 2006; an increase of 388 % in a decade. With only 572,000 bachelor's degree graduates in 2006, there were 825,000 master's degree graduates in the same year; this can be attributed to the fact that the master's degrees are by coursework and many of previous year's graduates returned to universities to pursue master's degree programs. It is also a glory for the family to have someone qualified in engineering at master's level because most Chinese believe that engineering and technology can help to modernize their country. While that in Australia, the number increased only from 1,068 to 3,142; an increase of 195%. The increase was mainly in coursework master's degree and was driven by international students. The research master's degree actually dropped from 230 to 208 (King, 2008). China graduated 263 times as many masters' engineering awards as that of Australia. The number of master's degree engineering graduates of China to Australia is 4.22 to 1 per capita. This means that China will have an oversupply of master level qualified engineers, while Australia has an undersupply of such workforce given the recent mining and infrastructure boom in this country.

Industry Participation

All engineering schools with accredited programs have instituted industry advisory mechanisms, as required by Engineers Australia, and indeed, by many universities themselves; the willingness of busy members of industry to get involved with engineering schools is highly noteworthy. In many instances, of course, their close industry engagement with the engineering schools allows more direct industry involvement with student projects, work placements and graduate recruitment. Some of the industry members consulted also taught part-time, so had direct involvement with students' learning. The industry groups were particularly valuable with respect to assessment of graduates' attributes (King, 2008). Some special activities were also held to increase the interest of industries in universities, e.g. community research evening held in USQ in November 2008. Similar activities by industries are not well-documented in China.

In addition to developing curriculum, industries in Australia are also relatively keen in supporting research and development in universities by co-funding research programs, e.g. Australian Research Council (ARC) Linkage Projects Grants. Their participation and funding commitment are, of course, less than those of the USA. It can be argued that technology transfer from universities to industry does happen in Australia but it is not well-documented. In China, technology transfer from higher educational institutions to industries has just started, e.g. Tsinghua University (Liu & Jiang, 2001).

Industries in Australia also helped to solve the skills shortage problem by funding universities to train graduate engineers in areas of their needs.

In China, higher education is supervised by two-level supervisory system, the Central and local governments under leadership by the Central Government. The national Education Commission is the highest government agency responsible for education affairs which formulates the general and specific policies of education, control the development rate of education at all levels macroscopically and directs the management of education in ministries, provinces, municipalities and autonomous regions (Du & Jiang, 1990). It can be argued that engineering institutions or societies have no say in the accreditation process of engineering degree programs. There are some participation in engineering education by industries but they are very limited.

Discussion

The current 4-year professional engineering program here is praised by many employers because of its strong focus on design and project work (King, 2008). This is indeed higher than most overseas engineering programs, e.g. four-year program in the USA (Yeargan & Hernaut, 2001). It can be argued that the quality of these programs is better than its counterpart in China. These graduates also have generic qualities such as problem solving, project management, communication and teamwork skills expected by the business community. Most engineering schools have intensified their industry advisory systems in relation to program and course development. This is a key issue in the revised engineering accreditation process.

King's (2008) review of discussed the merits of having fewer large schools, and expressed doubts about the viability of some of the smallest regional schools unless they address niche markets. This is true and USQ tried to offer BEng and BEngTech in small number of disciplines using its expertise in e-learning and distance education. The number of external students has been increasing in double digits in the past three years with the number of day students remained unchanged. The BEng had been offered totally external by employing innovative residential schools (Morgan et al, 1999). This will be further developed to include remote access laboratories to cut costs for students, hence increasing the competitiveness of USQ engineering programs (Goh et al, 2008).

The four-year full-time course equivalent must remain the minimum requirement, but diversity must be encouraged. Many universities have, as proposed, facilitated entry of students from non-traditional backgrounds through relaxation of prerequisite subjects, with bridging programs and flexible entry paths, and do provide articulation and credit transfer arrangements with industry, the VET sector, and other engineering program providers (King, 2008). USQ is such an institution in this country.

Undergraduate teaching dominates the effort of engineering schools, being 78% of all student enrolments in 2006. Since 1996, undergraduate enrolment growth of 25.5% was overshadowed by postgraduate coursework growth of 128%, most of which is from international enrolments. In fact the number of domestic postgraduate coursework students has changed very little, from 4,029 to 4,430 over that period. Almost all of the growth in undergraduate commencements since 1996 has been in international students: from 1,650 to 4,156, compared with domestic undergraduate commencements increasing from 10,944 to 11,140 (King, 2008).

The most notable change in staffing for the decade to 2006 is the high growth of research-only staff numbers, with this category being 40% of the total academic staffing complement in engineering in 2006; many of the originally teaching and research positions have been changed to contract position rather than continuing after a probationary period. The decline in the number of support staff has been mostly from workshop and laboratory technical support functions; this jeopardises the teaching in the practical side of the program. The decreasing proportion of engineering graduates seeking to progress to higher degree research and towards academic careers, thereby weakening prospective staffing in engineering schools (King, 2008). This problem can be relieved by attracting migrant engineers, provided Australia remains a prosperous country and can attract engineers from all over the world, e.g. China and India.

It was reported that many universities offering the 3-year programs at the engineering technologist level have experienced very low demand from school leavers because there is a clear perception that the 3-year engineering program is in some way an inferior outcome, in some cases a fallback exit point for students not coping with the Bachelor of Engineering. However, the program is an opportunity for some trades people and technicians; they want to progress in the ladder of career in engineering profession but do not have the mathematics skills and science knowledge to challenge the BEng program and BEngTech program will be their initial and only choice. USQ have enrolled a large number of such candidates and those holding Advanced Diplomas from TAFE colleges to her BEng program and they will be given advanced standing. Depending on the courses studied in the previous programs, they will get at around 12 courses of exemption and will need only to study 12 courses for the award of BEngTech. Those with Associate Degrees from universities will usually need to study 8 courses for the award of BEngTech. This is not to discriminate TAFE graduates because exemption is granted on a course-to-course basis and Associate Degrees are usually the subset of BEngTech. If the courses studied by TAFE Advanced Diploma holders can match the 16 course of BEngTech offered, there is no reason why they cannot study 8 courses and be qualified for the award of BEngTech. In general, it was not agreed to design BEngTech program as the first three years of a four year BEng program because they are for different occupation category in engineering workforce (King, 2008).

Another point worth mentioning is the contribution by students towards their engineering degree education has increased from \$ 2000+ per eight courses to \$ 8000+ in the period of 1996 to 2008, a fourfold increase. This is unfair to students as they and their parents have paid heavy income tax and goods and services tax (GST) to the Federal Government. It is hoped that the current government should do something reduce the burden of the students and their parents.

The rapid growth of undergraduate engineering degree programs in China had been curbed by the Ministry of Education, China since 2006 due to unemployment, reduction in salary and quality concern. Another problem of the engineering graduates from China is English language proficiency. Many of the graduates from the 53 elite universities are unable to speak English fluently (King, 2008). It can be argued that their written English is still acceptable for employment in English speaking countries like Australia. However, out of the 572,000 engineering first degree graduates, only 10 % were globally employable (Gereffi et al, 2008). Ninety percent of them can only seek employment in China which is unlikely to absorb all of them given that China is still in the process of her industrialization. On account of globalization of engineering profession, it can be argued that China needs to upgrade the English language proficiency of her graduates.

On the other hand, the number of first degree engineering graduates in China per capita is low and is at par with Australia. It can be argued that when China becomes fully developed, there will be not enough engineers in the country. By that time more bachelor's degree holders have to be graduated. At the moment, the best thing for the Chinese government to do is to put more resources into training professional engineers to improve the quality of the graduates as well as their English language proficiency, and make more contact with industries locally and abroad to make the courses more practical.

The master's degree engineering graduates are also too many at this point in time; many of them have to go overseas to seek satisfying jobs. Many of them received PhD scholarships from overseas universities; the case is very common in Australia. This keeps the number of Australian PhD engineering candidates stable over the past ten years despite the economic golden age of this country. Many of the PhD graduates eventually work as academics in Australia. In the Faculty of Engineering and Surveying of USQ, 20 % of the academics are from China. Many more are coming from other developing countries, e.g. Sri Lanka and India. It appears that the Chinese government can offer short term, high pay contracts to these ethnic Chinese academics to teach and work in universities in China. This will certainly improve the quality of engineering education at undergraduate and post-graduate levels in China.

The participation by industries in university education in Australia is highly commended but it can be argued that more has to be done, particularly in technology transfer which will bring about large

economic development in this country. It can be argued that enterprises in China should also support universities there to develop programs for cater for their needs.

Conclusion

China higher education, including engineering education, is now in its ‘mass education’ state as it was in Australia 2 decades ago. However, China’s industrialization is still far from its peak and as many as 60% of the graduates cannot find employment with ease. It can therefore be argued that improving quality of education is more urgent than producing more engineering graduates. On the other hand, Australia does not produce enough engineers to take up jobs in her mining, engineering services, automobile industries and, research and development sectors. Australia has to start training more engineers by introducing incentives to school leavers to take engineering as a profession rather than taking the cream in engineering graduates from developing nations as migrants. Conversely, Australia could help the developing nations, e.g. India and China to improve the quality of their engineering education.

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