The Role of Humanities and Social Sciences in Engineering Practice and Engineering Education

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ABSTRACT: *The relatively poor standing of the engineering profession in the context of professional hierarchies in Australia and the inability, in general, for the profession to attract higher proportion of women as well as high caliber of young people has been of concern to both the profession and engineering education. This paper argues that this is due to the perceptions of engineering profession as one that is of "hard hat" technical in nature and which is at odds with the realities of the world of engineering practice which requires application of broad knowledge and understanding of the human dimension of engineering enterprise. These realities are not generally reflected by the engineering curricula at Australia universities. There is an excessive emphasis focused on highly technical matters in engineering curricula which not only excludes greater technical diversity but also skills and knowledge of human affairs necessary in engineering practice. An analysis shows that despite many recommendations, over the past twenty years to expand the allocation of the engineering curriculum, in Australia, to areas of social sciences and humanities, the expansion of the non technical areas, specifically humanities and social sciences, has been slow to take anchor within the schools, departments and faculties of engineering in Australia. It is argued that this is essentially a problem of academic culture, operating within engineering schools and faculties in Australia, that is based on scientific norms derived from science and the idea of cultural change is explored.*

1 INTRODUCTION

The strategic role that the engineering profession occupies in the national well-being has ensured the profession to public and private scrutiny in its professional practice and its education. In proportional terms there has been a decreasing enrolment in engineering education, at Australian universities, over a number of years [1],[2]]. In comparison to the European Union where approximately 16 percent of tertiary students are enrolled in engineering/architecture [3], the corresponding figures for Australia show approximately 7.7 percent [1]. Furthermore the quality of students entering engineering courses in Australia has also been an issue over many years. Yates has pointed to a long tail of students with relatively poor academic achievement in the final year at school entering engineering education [4]. This reflects adversely on engineering profession when compared with the type of academic talent attracted to professional courses such as medicine, law and business.

The relatively low attractiveness for engineering cannot be attributed to an anti-science stance among the young but rather to their perception of the engineering profession. The ratio of student enrolment in engineering to natural sciences is relatively low 0.5 in Australia in comparison to the European Union where it is three times higher [5], [3]. In addition to the poor marketing of the engineering profession in Australia there is ample evidence that the engineering profession and education has not connected well to the worlds of employment and the community. Johnson brings to the attention of a survey, conducted in Australia, which showed that 97 percent of employers felt that engineering graduates adequate diversity of knowledge and skills to meet the future needs of the professional engineering workforce [6].

The gender imbalance, in Australia, in engineering profession and education is of great concern. Whereas in other areas of professional education such as law and medicine the enrolment of girls reached and exceeded the parity with boys, the enrolment of girls in engineering rose slowly. Over the past twenty-five years the proportion of girls in engineering courses increased from 8 percent to approximately 14 percent [7]. One cannot take any consolation from the increased female enrolment in engineering courses at Australian universities because the increase can be easily attributed to the demographic shift of greater female participation in university education. The proportion of girls entering universities and who enroll in engineering courses at Australian universities has remained fairly constant at around 2 percent over the past twenty-five years. It does not reflect the reality of a potential market for engineering education and the profession. In the final year of secondary schooling the ratio of boys to girls undertaking the pre-requisite subjects for engineering course is 1.5:1 which compares poorly in engineering education where this ratio is greater than 7:1. It needs to be pointed out that the composition of female students varies considerably across engineering disciplines. Socially connected engineering disciplines, ones that address social issues such as environment, such as chemical, environmental and civil engineering have highest proportion of girls in their courses [7]. Johnston reported that the highest proportion of girls were found in combined arts/engineering degrees where, as in the case of Monash University, in terms of numbers the girls reached parity with boys[8].

However the notion that increasing humanities content in engineering curriculum to improve the attractiveness of engineering education will not be problematic if knowledge of humanities enhances professional engineering practice.

2 THE ROLE OF HUMANITIES IN ENGINEERING PRACTICE

Professional discourses have been a fertile ground of inquiry by many social theorists who have tried to pin-down the epistemic dimension of professions [9][10][11][12. In professional engineering workplace discourses scientific theory and development play a significant, but not the only, part in the technical dimension of engineering work. Procedural methods, styles of working, historical precedents, rules of thumb, instinct and aesthetics which all constitute the engineering method that takes into cognition other experiences is an essential ingredient in reaching technical outcomes [13].

Drawing on ideas of Dewey on professions' work I will extend it to the engineering profession whose workplace discourses could be defined as productive pragmatism and show a consensus of this view. Dewey associated the work of productive pragmatist to a rational application of a body of knowledge as technoscience which epistemically embodied more than a body of knowledge defined by theories and paradigms[14]. It represents a general intelligence which can be used as a form of critical inquiry to inform as well as a critical application of knowledge which does not view technology as applied science but in it other knowledge, human experience and aesthetics.

The recognition that professional engineering work discourses encompass humanities has been mentioned as early as 1853. These ideas of engineering profession as productive pragmatists which uses the tools of technoscience that is inclusive of humanities and social sciences has widely recognized. In the concluding comments of the Inquiry into engineering profession and education in Britain the need for the inclusion of greater humanities content into engineering curricula has been recognized if the engineering profession was to be transformed from a technical profession into a social profession that reflects the realities of engineering workplaces [15]. A major review into engineering education in Australia in the late 1980's identified human aspects of professional engineering workplace discourses [16]. This was the result of conclusions reached by the Institution of Engineers, Australia task force [17]. A survey of employers, in Australia, clearly showed that employers were concerned with the lack of social literacies and knowledge concerned with human affairs in amongst engineering graduates. They placed high priorities that these issues needed to be addresses through engineering curricula at even the expense of engineering elective subjects as well as some core engineering and fundamental science subjects [18]. This is not surprising given that the destination of graduate engineers is directed into areas that concerned themselves with human affairs [19]. Engineering graduates needed skills and knowledge that was required in the workplace but not acquired in education. Johnson, Solomon and Florman noted that engineering graduates lacked cultural awareness and diversity needed for an effective engineering practice and the enhancement of the profession [6][19][[20].

The acquisition through education of humanities and social sciences cannot be regarded just as an extension of knowledge capital. It provides professional engineers with means of new way of critical thinking and inquiry. Hudson in a study of humanities and engineering graduates found that humanities students had highly developed divergent thinking skills whereas engineering graduates were more convergent thinkers121]. Divergent thinkers were more effective in conceptualizing an issue into a problem which itself could be further conceptualized. Convergent thinkers, on the other hand, were less conceptual but more effective in setting the parameters of the problem and, in a mechanistic way, solving it. In fact combination of convergent and divergent thinking is a good representation of technoscience and what Schon would see as a basis for a reflective practitioner [12].

3 HUMANITIES AND SOCIAL SCIENCES IN ENGINEERING CURRICULUM

The role of humanities in engineering curriculum needs to be observed through two main perspectives, which are:

- The nature of humanities and social science subjects in engineering curriculum; and
- Proportional allocation of engineering curriculum to humanities and social sciences.

The nature of humanities and social sciences, which are to be incorporated into engineering courses, must be relevant to workplace discourses in which the engineering profession is embedded.

Ashby recommended that subjects concerned with ethics, jurisprudence, languages, social and industrial history, and history of technology were relevant to engineering education [23]. A survey, jointly conducted by the faculties of arts and engineering at Monash University, of government, private and multinational companies in Australia revealed that knowledge of languages as a desirable attribute of engineering graduates was placed highly by the respondents [24]. Though language studied broaden cultural awareness and communication skills, the survey results must be placed in the context of 1990 which marked the beginning of globalization processes. There was a concern that Australian engineering graduates would have difficulty competing with their multi-lingual European and Asian counterparts on the international stage.

A report into engineering education in Sweden recommended the inclusion of History in core engineering curriculum [25]. As a subject, History expands cultural references and enhances the understanding of human condition in the context of development of ideas. In interpreting human condition, History draws on theories from political science, economics and sociology and as such the subject is multi-disciplinary. History can also be highly contextual to the technical and scientific part of engineering curricula. History of ideas and technology may insure that engineering graduates will not go through a process of “re-inventing the wheel”. Philosophy must also be an essential contextual subject in the core-engineering curriculum. The study of value systems is essential in the examination of ethics and ethical frameworks so essential to professional engineering judgments.

There is a general international acknowledgement concerning the value of humanities and social sciences in engineering education to enhance workplace discourses and raise the social standing of the profession.

Grinter suggested that 30 percent of engineering curricula in the United States be allocated to core humanities and social science disciplines [26]. Heitmann in his overview of European engineering education felt that 20 percent of allocation to humanities and social sciences was adequate [26]. The Accreditation Board for Engineering and Technology (ABET), a body responsible for accrediting professional engineering courses in the United States, set aside a minimum of 12.5 percent of engineering curriculum that had to be allocated to humanities and social sciences if these course were to be accredited. This figure was exclusive of management and communication studies subjects [28][29].

In response to reviews into engineering education in Australia for greater inclusion of humanities and social sciences, the Institution of Engineers Australia, which accredits engineering courses in Australia, recommended that 9 percent of the curriculum be set aside to subjects concerned with management and ethics and further 15 percent be set aside to other areas which could incorporate humanities and social sciences [6] [16][30]. Theoretically the humanities and social content of engineering curricula could exceed the minimum requirement in the United States. As shown in table 1, it never happened. The manufacturing engineering course had the highest allocation, in Australia, of engineering curriculum to management, humanities and social sciences of 19.8 percent well below the recommended 24 percent of which only 7.8 percent consisted of humanities and social sciences. The courses in civil engineering at University of Melbourne and chemical engineering at University of Sydney could meet the minimum requirement in the United States for the allocation of engineering curricula to humanities and social sciences, and this was optional through choice of appropriate electives by students. In terms of humanities and social sciences the Australian universities were well short of best practice in engineering education found in the United States and the European Community. Also the courses did not satisfy accreditation recommendations set by the Institution of Engineers Australia.

Table 1 Proportion (%) of engineering curriculum, at selected Australian Universities, allocated to humanities, social science and management subjects. Figures in brackets for year 2000 refer to humanities and social sciences, the highest number represents the maximum percentage content allocated to humanities and social sciences. (Economics is classified here as a social science subject)

Name of the Institution	**Engineering Course**	**Percentage Allocation to Humanities, Social Sciences and Management subjects in engineering curriculum**			
		1987	**1992**	**1997**	**2000**
University of Melbourne	Chemical	0.0	3.1	1.1	3.1/9.4* [0/6.3*]
	Civil	8.5	2.7	3.8	10.7/19.9*[0/15.6*]
	Electrical	5.5	5.0	3.5	12.5/15.6*[0]
	Industrial/Manufacturing	5.0	6.0	13.8	12.5/17.9*[0/1.8*]
	Mechanical	5.0	6.0	13.8	4.9/10.3*[3.1/4.9*]
University of Sydney	Chemical	0.0	2.0	2.3	6.3/18.8*[0/12.5*]
	Civil	2.0	0.0	4.7	5.2/11.5* [0/6.3*]
	Electrical	2.0	1.5	1.8	2.1/13.5* [0/11.5*]
	Mechanical	3.0	3.8	7.1	7.8/10.9*[2.1/5.2*]
Monash University (Clayton)	Chemical	2.0	4.5	3.1	4.1/7.3* [0/3.1*]
	Civil	3.5	1.6	1.6	11.4/17.7*[0/9.4*]
	Electrical	3.5	3.0	4.7	6.3 [0]
	Materials	1.5	2.5	1.6	9.4/12.5* [0/6.3*]
	Mechanical	4.5	7.2	6.3	8.3 [2.1]
University of New South Wales (UNSW)	Civil	9.0	9.0	10.2	14.1 [6.3]
	Electrical	3.5	6.5	11.9	10.8 [5.8]
	Industrial/Manufacturing	10.0	12.6	17.6	19.8 [7.8]
	Mechanical	11.0	12.6	14.4	12.8 [7.8]
RMIT University (RMIT)	Aeronautical/Aerospace	9.9	9.6	7.2	5.2/10.4*[2.1/5.2*]
	Chemical	6.0	7.0	8.9	7.3/13.5*[0/6.2*]
	Civil	6.8	11.6	9.4	9.3/18.8*[2.1/3.6*]
	Electrical	8.0	10.4	1.8	6.3 [2.1]
	Manufacturing	11.8	13.4	9.0	15.6 [3.1]
	Mechanical	9.7	10.0	6.9	13.5 [2.1]
Victoria University of Technology (VUT)	Civil	8.3	6.4	5.1	11.0[1.0]
	Electrical	11.4	7.4	5.1	9.0 [1.0]
	Mechanical	8.5	15.1	8.3	9.0[1.0]

* In these cases the social science and the humanities subjects are selected as electives from a range of subjects that include areas such as science, engineering science and management. The figures therefore shown represent the maximum proportion that is allocated to humanities and social sciences.

4 INSTITUTIONAL IMPEDIMENTS

Lyotard declared that the hegemony of science as the grand knowledge narrative was over. Science operated in its own domain and could subjugate other bodies of knowledge, human experiences and aesthetics [31]. In some way Lyotard reflected the ideas of technoscience put forward by Dewey, half a century earlier, whose ideas can be extended into an aesthetic concept by which the work discourse of the engineering profession can be viewed through the prism of productive pragmatism [29]. Technology cannot be seen as just as an applied science but a technoscience which connects to humanities, social sciences, art and human experiences.

Unlike the professional engineering workplace discourses, the notions of science as the grand narrative are, by and large, deeply embedded in the culture of engineering education in Australia. Knowledge is treated, in general, in highly objectified and value-free form. It is thus not surprising, as shown in table 1, that engineering education is reluctant to incorporate into its curricula humanities and social sciences because these knowledge bases engage a conversation within a value-laden framework. The problem of paradigm change in engineering curricula in Australia is a problem of culture change in engineering education and this culture has strong historical connections to the standing of engineering profession in Australia.

For over a hundred years the means of gaining professional engineering academic qualification anh hence professional recognition was achieved through two educational paths.

One path was through university education which led to degree in engineering. Engineering, as an academic discipline, at universities was viewed with suspicion and even alarm by academic disciplines as not a proper area for academic study. To overcome this and to gain acceptance by the university community, engineering at universities in Australia adopted scientific norms of highly codified knowledge. All inquiry followed linear processes.

Another path to professional engineering qualification led through practical and highly vocational education in engineering that led to a diploma in engineering at a technical institutes or colleges. By the mid 1960's the technical institutes and colleges in Australia were elevated in status and sought parity of esteem with universities. The decision, by the Institution of Engineers Australia in the 1970's, to associate professional engineering qualification with a four-year degree in order to raise the social status of the profession played a role in the introduction of degrees at the colleges as the end-point of undergraduate education. Engineering faculties and departments at colleges used their university counterparts as benchmarks for the introduction of new engineering curricula. There was a shift in academic staff recruitment from professional practitioners in engineering to those graduating with higher degrees in engineering from Australian universities. By 1988 when the bifurcation of higher education ended, engineering courses at the "old technical colleges" resembled those of traditional universities with deeply ingrained norms of science. The science hegemony became further entrenched in engineering education when as a result of poor intakes into science in many universities the faculties of science and engineering merged. The scientific view of engineering was further enhanced by government research bodies through research funding and unlike for other professions, such as law, medicine and architecture, where academic recruitment placed value on practitioners, the recruitment of academics into engineering schools was, by and large, through research doctoral degrees which often could have been carried in science faculties (Table 2).

Table 2. Proportion of the academic staff, in various academic disciplines at Australian Universities, who hold doctoral degrees. Figures in brackets indicate the proportion at old (pre 1990) universities. [Department of Education, Training and Youth Affairs, 1997, Table 4.1]

DISCIPLINE	PROPORTION (%) OF ACADEMIC STAFF HOLDING DOCTORATES
Humanities	59.2 (70.3)
Architecture	16.6 (31.6)
Education	38.2 (60.9)
Science	82.1 (92.2)
Law	21.0 (24.4)
Medicine/ Dentistry	52.7 (54.7)
Engineering	68.0 (84.2)
Economics/ Business/ Administration	34.9 (51.9)

The culture of change therefore must be imposed externally. It is not likely to come the Institution of Engineers, Australia which is the accrediting body for engineering education. Increasingly the musings of the accreditation body has been reduced to an advisory role. There are two other possible ways which can change the face engineering education in Australia.

Globalization where Australian employers place preference on overseas engineering graduates when recruiting or where Australian engineering graduates have problems in gaining professional work in the developed world would provide an impetus for a paradigm shift. The second possible mechanism for change in engineering education is more structural. Over the past few years the vocationally oriented Technical and Further Education Colleges (TAFE's) have stake their claim in educating paraprofessionals through two and more advanced three year diplomas. Given that the TAFE colleges place lower demand, on state and federal governments, for student funding it is very likely in the near future that these colleges will be able to offer vocationally oriented engineering degrees. The fledging engineering departments and schools at some universities would need to revise their curricula and become more eclectic in areas of social education. The resultant diversity of engineering educational discourses to match the diversity of professional workplace discourses would thus result.

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