Perceptions and understanding of gender inclusive curriculum in engineering education

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Abstract
The scarcity of qualified engineers is a frequently registered concern across the English speaking world. Despite numerous efforts to broaden the entry, the overwhelming majority of Engineering enrolments continues to be male, reflecting the gender demographic of the established profession. The capacity of current University engineering departments to attract a more diverse student body appears extremely limited. Given the urgent needs of the developed and developing world for more innovative engineering solutions to social and industrial problems, this situation is becoming critical. This paper examines one potential solution to this issue. By making the curriculum in engineering undergraduate education more gender inclusive there is demonstrable potential to attract and retain more women in the profession. Beginning with an overview of previous analyses of gender inclusive curriculum in engineering, the paper proceeds to detail a case study of an inclusive curriculum project conducted at one university and the perceptions of current engineering students and faculty about the status of inclusive practice ten years on at the same University. Ultimately the paper argues that ongoing attention to questions of inclusive education must be maintained in order to enrich the educational experience of all students.

Keywords: gender, inclusivity, curriculum, engineering education

1. INTRODUCTION

Engineering is a profession that is essential for the sustainable development of modern society. However, for the past two decades there has been widespread concern about the decreasing student numbers in engineering and science related disciplines in many western countries. At the same time, industry has an increasing need for new professionals with the necessary skills in these areas, and in many countries faces difficulties in finding such graduates. In the current climate of globalisation and the knowledge economy, engineering stands out as one field that has maintained a reliance, in the western world, on males to fill its student places and subsequently gain entry to the engineering workforce. Consequently engineering will have even more difficulty in overcoming current and predicted skills shortages than will other professions. Retention at both tertiary level and within the workforce is also a critical issue. One step towards solving these issues would be to increase the number of females in the engineering profession, although this is clearly not the only reason that it is desirable to redress the gender imbalance. However, numerous national and international reports and studies have shown that there are significant problems in recruitment and retention of women in engineering ([1] to [7]).

Across the English speaking world there have been numerous initiatives over the past 25 years to attract and retain more women in engineering and yet they continue to be a small minority in engineering education and employment. Not only are the current numbers unacceptably small but recent statistics indicate that both the number and percentage of women entering university to study engineering have actually decreased in recent years in Australia, UK, USA and Canada for example. Engineering continues to have the lowest female share of any broad field of education in Australian universities with only 15.4% of total student enrolments and 14.1% of commencing students in 2005, and these figures have been in decline since peaking in 2001[8]. The Australian statistics compare with 19.3% of total undergraduate engineering degree completions who were female in the USA in 2005-6 – the lowest percentage since 1998 [9]. In Canada, the female enrolment in undergraduate engineering degrees decreased from 20.6% in 2001 to 18.5% in 2004 [10]. The percentage of female graduations in engineering in the UK is even worse than in Australia at 9.5% in 2005/6, and has been decreasing steadily from a peak of 12.2% in 1995/6 [11]. In the European Union the percentage of women in engineering varies widely between member states but aggregated across the EU, 29% of employed Scientists and Engineers were female in 2004 [12], although this figure obscures the engineering component, since it incorporates life and health sciences. However the participation rate of women grew much more slowly than the rate for men in the period 1998-2002 indicating that if this persists "women's participation in the field of science and engineering will decrease in relative terms." [12, p. 17] Another report indicates that women comprise 25% of engineering graduates in Europe [13], although again this varies widely between different countries in the union.

There are a few engineering specialisations that do have higher percentages of female students. Chemical and environmental engineering are often cited as disciplines where the percentage of female students exceeds 25% and sometimes approaches 50%, even in western countries. For example in the USA in 2005-6, 36.0% of Chemical engineering and 44.2% of environmental engineering bachelor degrees were awarded to women. However, the total number of degrees awarded in these fields represented only 6.0% and 0.6% respectively of all engineering bachelor degrees awarded in the US that year [14]; hence in overall terms this does little to alter the situation for engineering as a whole.

These statistics suggest that the traditional orientation of established engineering education curriculum has not responded to calls for improving equity and that the gender disparity in engineering enrolments is unlikely to diminish unless there is significant change in course promotion and experience [15], [16], [17]. While some programs to increase women's enrolments have been moderately successful, their success has typically been short lived and tied to short term funding and specific champions, rather than delivering a strategy for long-term change that is embedded within the curriculum [18], [19].

Undergraduate education is the 'gatekeeper' for professional careers in these fields and hence it is a critical site for intervention [20]. The undergraduate engineering curriculum has been identified as typically catering to a narrow range of student interest and prior experience. Hence it has been proposed that the traditional orientation of established engineering education curriculum must become 'inclusive' by taking more account of the interests and needs of individuals from all groups in our society [21], [22]. International studies have clearly shown that inclusive curriculum strategies have improved student engagement for all students, not just women, along with significantly improved retention and success (for example [23], [24]). However, there is little specific guidance about gender inclusivity available for educators in engineering, and related sciences and this formed the background for the current project.

2. UNDERSTANDINGS OF GENDER INCLUSIVE CURRICULUM

Curriculum theorists have long established the position that curriculum refers to much more than the delineation of subject content or even including prescriptions about the method of teaching. The constructivist theory of learning developed from the work of Vygotsky proposes that all learning necessarily builds on prior learning and teaching must therefore take account of the attitudes, previous learning and associations learners bring to the learning task. In addition constructivism implies the necessity for learners to be able to reflect on their learning, to try out new ideas and to make mistakes as they engage in the intellectual work of assimilating new knowledge to their previous understandings. Hence the term curriculum has been used here in its broadest sense, that is, covering all aspects of the teaching and learning experience to include assumptions about the prior experience and interests of the students, the syllabus (or content), the methods used, management of the classroom environment and the ways in which students are assessed. Research has indicated that any of these aspects tend to become tailored to the interests and perspectives of either the teacher or the dominant social or cultural group of students in the class, or both [25], [26]. Since the majority of engineering faculty and students are male, female students may feel uncomfortable or excluded in class, with the result that they withdraw or are not as successful in their studies as they might otherwise be.

A 'gender-inclusive' curriculum is one which has been consciously designed to recognise and acknowledge the evidence that males and females are likely to bring different cultural baggage to their learning experience. Such baggage will include their interests, approaches to learning, and strengths in types of assessment tasks. In an applied area such as engineering, an inclusive curriculum would recognise that student experience of the applications of engineering in daily lives would vary according to gender, race, culture and class. If, as constructivist learning theory suggests, all new knowledge must be linked to the old, it is imperative that teaching and learning makes reference to the different elements of cultural baggage that students bring.

Otherwise the student learning will not be effective. In addition all students have been seen to gain from a flexible approach to teaching and learning in terms of improved motivation and success - not only of female students, but male students as well. Making the engineering curriculum more inclusive should not be seen as a process of remediation but rather as a means whereby the latest advances in understanding the processes of teaching and learning are brought to bear on this particular area in ways that will resonate with the sociocultural context of the current student body.

The following section will address the idea of a gender inclusive curriculum in terms of content, teaching and learning processes and assessment practices. In all of these particular but related areas there are several different understandings of a gender-inclusive curriculum. Authors such as Willis [27], Rosser [28] and Barnett [29] have scaled these along a progressive spectrum so that they range from there being a need for remediation to assist students who are 'disadvantaged', to encouraging students to actively challenge a curriculum which 'constructs disadvantage to maintain the status quo' [27]. Rosser [28] has identified six 'stages' of inclusive curriculum development as typically occurring in universities committed to improving the representation of women in their science programs, though she doesn't claim that all institutions achieve the most advanced stage. Rosser's stages are equally applicable in an engineering context, and to all 'non-traditional' students, and in a previous work [21] we have paraphrased and summarised her discussion and formulated it into tabular form for ease of reference. This is reproduced in Table 1.

Stage	**Title**	**Characteristics**	**Strategies to achieve change**
1	Absence of women is not noted	Assumption that the objectivity of engineering renders it immune to gender considerations	Acknowledge gender influences, and seek ways to incorporate them appropriately in the curriculum
2	Recognition that most engineers are male and that engineering may reflect a masculine perspective	Engineering views the world from a male perspective	- explore issues of social concern - set open-ended investigative-type problems
3	Identification of barriers that prevent women from entering engineering	Exploring why women are not attracted to studying engineering; how to attract them and how to reduce barriers at entry	Consider the learning environment as well as entry issues; remove the "chilly climate" experienced by many women students
4	Search for women engineers and their unique contributions	Include the contributions of women engineers, and discuss why they have often been 'lost'.	- teach in cooperative and interdisciplinary ways - discuss the social benefits of technological progress
5	Engineering done by feminists and women	Accepting and incorporating women's different perspectives and 'ways of knowing' in the study of engineering.	- encourage development of theories and hypotheses that are relational, interdependent, and multicausal - use qualitative and quantitative methods in data gathering
6	Engineering redefined and reconstructed to include us all	Incorporating all of the above into a transformed inclusive mainstream curriculum	The philosophy, aims, objectives and content of the curriculum must be based on the principles of inclusivity, as well as the way the curriculum is delivered

TABLE 1. Stages of engineering curriculum transformation (adapted from Rosser [28], pp. 4-17)

Although research in this field has collated these various understandings of inclusive curricula into a consistent framework, the authors have found that their engineering colleagues are rarely aware of this conceptual integration. Consequently undeclared, incomplete or conflicting perspectives tend to inhibit the acceptance of the concept of an inclusive curriculum and hence its implementation in the engineering curriculum. If and when some consensus is reached as to its desirability and applicability in engineering, a second difficulty arises: How can the characteristics of an inclusive curriculum be incorporated into engineering programs?

The authors have re-interpreted the more theoretical discussion about stages of transformation into a practical framework for practitioners to introduce a gender-inclusive curriculum. The framework uses the following structure:

- Organising the classroom to ensure that female students are not overlooked or 'excluded'
- Designing teaching, learning and assessment processes which acknowledge that all individuals learn in different ways
- Being aware of the social construction of knowledge when deciding on the curriculum content
- Ensuring that students benefit from their socially and culturally mixed learning environment to develop intercultural cooperative working skills, and respect for colleagues from all backgrounds.

The progressive nature of this structure is useful in encouraging practitioners to introduce an inclusive curriculum gradually, allowing trial and error. This framework was used in a major project for inclusive curriculum at the University of South Australia, which was carried out in 1997-8. The remainder of this paper will explore that case study and then consider the results of a follow-up study undertaken 10 years later to assess whether there has been a lasting impact from the original project.

3. AN INCLUSIVE CURRICULUM CASE STUDY

3.1 The inclusive curriculum project at the University of South Australia 1997-8

In 1997-8 the University of South Australia conducted an eighteen-month inclusive curriculum project across all programs in the university. The project aimed to develop inclusive curricula by improving the understanding and practice of faculty and developing guidelines to assist them in restructuring their courses to become more inclusive. The project was intended to raise awareness of the issues and influence institutional and departmental policy, rather than to conduct formal research. Its objectives were to produce guidelines, to provide faculty development and to develop and collect resources to assist the growth and extension of inclusive curricula after the formal project ended.

Whilst guidelines are valuable for implementing curriculum transformation, there must first be faculty and departmental commitment to making the changes. The support of departmental heads in engineering was particularly strong and the authors were asked to provide additional assistance in developing inclusive curricula within those departments. Following an audit to assess the extent of inclusive curriculum practice amongst faculty, workshops were developed on topics such as 'Towards an Inclusive Curriculum', 'Developing an Inclusive Curriculum' and 'Learning Styles and their implications for students' success'. Attendance at workshops was not compulsory, but was strongly encouraged by most Heads of Departments. As expected, most attendees were those faculty who were already identified as having a strong interest in teaching, but this included the vast majority of those who taught large, early year classes and approximately 30% of engineering faculty participated in one or more of the workshops.

At the conclusion of the project the principles of developing inclusive curriculum were formally incorporated into the "*Policy for Development, Amendment and Approval of Programs and Courses*" [30] and the *"Code of Good Practice: University Teaching"* [31] and thus mainstreamed within the university. It was then required when planning the development or amendment of programs that faculty should:

> *"…indicate in what way advice has been sought on issues of inclusivity, how that advice is acted upon in the planning and delivery of the program, and what mechanisms will be adopted to evaluate the level of success of such program components."*

The project was funded for an 18-month period and clearly within that timeframe it would be unlikely that major impacts of the faculty education process could be evaluated in terms of improved participation, success or retention figures for female students. It was also not within the scope of the project to conduct such evaluations. However, these and other project outcomes have been discussed in greater detail in previous publications [22], [32], [33].

3.2 What has changed over the last ten years?

As is probably the case with many universities, the University of South Australia has undergone continual change since the inclusive curriculum project was undertaken. With respect to engineering at the university and the way in which it is taught and administered, some of these changes have been structural and some have come full circle. In 1997 when the original project commenced, all engineering programs and all engineering students and faculty members belonged to a single School of Engineering and the first year of the program was common to all engineering students. By the time the funded project was completed the single school had been split into three, in the broad areas of Civil and Mining engineering, Electrical engineering and Mechanical engineering, and whilst some programs continued to share common courses in the first year, each school gradually moved to redevelop much of their program curriculum, with variable emphasis on areas such as project-based learning. Mining engineering was subsequently closed and the Civil engineering area moved into a multi-disciplinary School of Natural & Built Environments, whilst Mechanical and Electrical engineering have retained their own schools. Then in late 2007 a common first year for all engineering programs was suddenly reinstated by direction of university senior management. This has commenced in 2008 and will lead to concomitant changes in the subsequent years of all engineering programs again. Maintaining curriculum advances such as those achieved during the original inclusive curriculum project could therefore be considered to be problematic in such an environment.

Some of the structural changes achieved in the original project have been maintained. Most notably the amendments to the approval processes for the development of new programs and courses that require the consideration of inclusivity have been maintained, although the requirement for evaluation has been removed. The equivalent 2008 guidelines [34] read:

> *"Identify how the curriculum of the program has been developed to take account of the perspectives of non-dominant groups. This should include consultation with staff of the University. See ideas and examples of Educational strategies for improving inclusivity in curricula, teaching, learning and assessment at…"*

The document links to a university web resource on *Inclusivity* [35] which includes guidelines for educational strategies for improving inclusivity in curricula, teaching, learning and assessment that were developed during the original project.

Over the same time period Australia has continued to have a conservative government that has steadily reduced spending on higher education. This has led to the closure or discontinuation of many initiatives with respect to equity in general, but particularly to the discontinuation of Women in Engineering programs with dedicated program officers, which previously existed in the majority of universities but now remain in only one university.

3.3 Access, retention and success statistics for women in engineering

In Australia there are several groups of students in higher education that are designated as equity priorities, among which are students from non-English speaking backgrounds or low socio-economic status. All universities are required to report annually on the access, participation, retention and success rates for these groups of students; based on the enrolments of domestic students (i.e. the statistics do not consider international students). One of these equity groups is Women in Non-Traditional Studies (WINS), which includes women in engineering. Access and participation statistics are presented in Table 2 for 1996 (the year before the inclusive curriculum project commenced), 2000 and 2005 (latest national data available). Access refers to the percentage of commencing domestic students in engineering who are female and participation refers to the percentage of total enrolled domestic students who are female. The statistics below are for undergraduate study at bachelor degree level.

Year	**Access (%)**		**Participation (%)**	
	University of SA	National	University of SA	National
1996	12.5	14.6 (1998)	10.1	13.8
2000	12.6	15.2	12.5	15.0
2005	12.2	14.1	11.0	14.7

TABLE 2. Access and participation statistics for women in engineering (domestic students at undergraduate level only), [8] and [36]

When considering the figures in Table 2 it should be noted that the percentage of female enrolments in engineering varies widely between different fields of engineering and that the University of South Australia does not offer any of the fields that traditionally have more women, such as chemical, environmental or industrial engineering, but does have a large proportion of engineering students enrolled in mechanical and electrical engineering, which traditionally have the lowest percentage of female enrolments. It should also be pointed out that it would not be possible to attribute any improvement or success in statistics solely to curriculum improvements that encompass inclusivity (or vice-versa), as many other factors and initiatives are involved, both internal and external to the departments. However, it can be seen that the access rate at the University of South Australia has remained basically the same, while the national rate has declined.

Retention is defined as the proportion of students enrolled in the institution in a given year who re-enrol in the following year, less the students who completed their program and *Success* as the study load passed by a student as a proportion of the load for which the student enrolled in a given year. Retention and success rates are sometimes expressed as a ratio compared with the student population as a whole. For example a retention rate of 1.05 indicates that retention for that student group is 105% of the rate for other students. Statistics published by Postle et al. (cited in [37]) indicated that, in Australia in the mid 1990s, female *retention* was above the reference value of 1 in all the non-traditional fields of study and the *success* rate was 1.04 for women in engineering. It appeared to be the case that, once women gained access to non-traditional courses, success and retention were not a particular problem [37]. However, more recent data indicates that this situation has changed considerably and currently "only 52% of men and 60% of women starting engineering will complete their programs" [38]. Table 3 provides retention statistics from the University of South Australia for 2000 and 2006, and success data for 2006. This indicates that retention data is apparently better than national averages, but also shows that female retention and success rates have changed from higher to lower than males in engineering between 2000 and 2006. They have also slipped below university averages, which was not the case in 2000.

Year	**Retention (%)**						**Success (%)**					
	Engineering			University			Engineering			University		
	F	M	Tot	F	M	Tot	F	M	Tot	F	M	Tot
2000	82.2	77.4	77.9	80.1	77.2	78.9	NA	NA	NA	NA	NA	NA
2006	78.1	78.5	78.5	83.0	80.0	81.8	82.5	84.1	83.9	89.7	84.7	87.8

TABLE 3. Retention and success statistics for females and males in engineering compared with university averages at the University of South Australia (domestic, undergraduate students only) [36]

4. PERCEPTIONS OF INCLUSIVE CURRICULUM 10 YEARS ON

In 2007 the authors undertook a small follow-up study to evaluate faculty and student perceptions and understandings of gender inclusive engineering education at the university nearly 10 years after the completion of the original inclusive curriculum project. The study involved on-line surveys and a small number of interviews with female students, final year male students and faculty members in the three engineering schools.

4.1 Study methodology

An anonymous on-line survey was developed for faculty members and students. The first section of the survey gathered base data from the respondent regarding gender, age, engineering discipline area, whether English was their first language and which year of their degree they were completing if they were a student. The remaining questions were based on a document previously developed at the University of Newcastle in Australia [39] titled *Benchmarks for cultural change in engineering education*. Respondents were asked to indicate at which Level (from 1 to 5) they perceived that their program or course operated, in a variety of aspects related to inclusive education. In all cases Level 1 was at the lowest level and Level 5 the highest. A description of Levels 1, 3 and 5 was provided for each question to assist them to make their decision. Only one question explicitly mentioned gender, the remainder were more general but taken together create a picture of the inclusivity of the culture of the program. An example question with level descriptors was:

> Question 8: How is theory taught within your program?
> Level 1 – Theory is taught largely in isolation
> Level 2
> Level 3 – Theory is presented in terms of specific industry related problems
> Level 4
> Level 5 – Social effects are considered and debated wherever possible.

The remaining questions in the student survey (without level descriptors included) were:

- How are women's interests represented within your program?
- What kinds of problems are used in your program?
- Are problems approached in a multi-disciplinary manner?
- How are non-technical professional skills incorporated into your program?
- What is the basis of assessment in your program?
- Is it assumed that you already have some informal knowledge before you start your program?

- A learning environment includes all aspects of physical and social spaces experienced by students in their study. How would you describe the learning environment you have experienced?
- Discrimination may be defined as not receiving equal access to opportunity, based on characteristics such as gender, race, age, disability, marital status or pregnancy, for example. Sexual harassment may be defined as any unwanted sexual advances or unwelcome conduct of a sexual nature. How are discrimination and harassment dealt with within your program?
- Is prior knowledge of laboratories and equipment used assumed in your program?
- Have you experienced inappropriate language and images being used in your program?
- Is there any further comment you would like to make regarding your experience of gender inclusive engineering education during your study …?

The questions for faculty were very similar but slightly adjusted to the context of their teaching experience. The invitation to participate in the survey including the hyperlink to the survey instrument was emailed to all female engineering students, all final year male engineering students (to attempt to get similar male and female response numbers) and to all engineering faculty members who were involved in undergraduate teaching.

Included with the invitation to complete the survey was a request for volunteers to be interviewed for the project. This elicited only a small number of respondents: interviews were subsequently conducted with two female students, one male student, one male faculty member and the Dean of Teaching and Learning responsible for engineering programs at the university. Interview questions expanded on the themes of the survey and specifically sought examples from the interviewees of good or bad practice that they had experienced or used with respect to inclusive curriculum in engineering.

4.2 Findings

Survey responses were received from 17 (34% response rate) female students, 12 (14.3%) final year male students and 21 (47.7%) engineering faculty members. Thirty four percent of the students in total and 43% of the faculty responded that English was not their first language, or 38% of overall participants. The distribution of female student respondents with respect to engineering discipline area generally reflected the actual distribution at the university, with the majority of females studying civil engineering (10 of 17) and lower numbers in the other fields (4 in electrical and 3 in mechanical). Responses were received from all discipline areas for both male students and faculty members. Due to the small overall sample, no attempt was made to differentiate between responses from the various discipline areas, or between male and female responses in either group. A comparison of faculty and student perceptions has been summarised in Table 2. The comparison has been made using the average 'level of inclusivity' perceived by each group to the various questions. As illustrated in the sample question detailed above, the higher the level number, the closer that aspect of the curriculum or environment is to the ideal for an inclusive curriculum.

Aspect of inclusive curriculum	**Level perceived by Faculty**	**Level perceived by Students**
How is theory taught?	3.7	2.9
Are women's interests represented?	2.1	2.3
What kinds of problems are used?	3.5	2.7
Are problems approached in a multi-disciplinary manner?	4.0	3.1
How are non-technical professional skills incorporated?	4.0	3.4
What is the basis of assessment?	3.8	3.4
Do you assume that students already have some informal knowledge before commencing?	2.9	2.5
How would you describe the learning environment?	3.4	3.2
How is discrimination and harassment dealt with if it occurs?	3.9	3.7
Is prior knowledge of laboratories and equipment used assumed?	3.6	3.0
Have you experienced inappropriate language and images being used?	4.3	3.5
Average over all aspects	*3.6*	*3.1*
Sample size	N = 21	N = 29

TABLE 4 Benchmark levels perceived by faculty and students on aspects of inclusive curriculum (Level 5 = highest)

Interestingly, in all but one area, faculty perceived that their practice was more inclusive than students perceived to be the case for their program. It should be recognised that faculty were responding with respect to their own teaching practices or environments, whereas students were responding on the basis of their overall program. Hence it could be that the faculty who responded to the survey were those who were 'converted' to the idea of an inclusive curriculum and did put more of these aspects into practice in the courses they taught. The greatest perception gaps between faculty and students were related to how theory is taught, the type of problems used and their multi-disciplinarity. All of these areas were a significant focus of the original inclusive curriculum project, so it appears that there is significant work to do again in this area. One step towards this has been the redevelopment of the programs due to the re-introduction of the common first year. This has enabled the development of courses that are all required to be multi-disciplinary, and the introduction of two courses in particular that are very focussed on the social contexts of engineering.

5. DISCUSSION AND CONCLUSIONS

The striking and consistent difference between faculty perceptions of their teaching in terms of style and content and that of their students was the clearest feature to emerge from the study. While this finding is somewhat disappointing in terms of the previous groundwork that had been laid relating to both course structures and faculty willingness to be involved, at another level this result comes as no surprise. This difference between teacher and student perceptions is a fairly common experience in educational research – signalled in the commonly heard teachers' cry "I taught them but they didn't learn!" [40]. The important consequence here is to render faculty more aware of the need for checking student perceptions continually as part of ongoing teaching practice, especially when the concept at issue relates to the students' sense of belonging to the group as a whole. This result also signals the need for faculty to model inclusivity in their practice as well as in the stated goals for their courses.

Perhaps the most significant feature to emerge from the study was the finding that gender inclusivity has to be thought of as a continuous process rather than a feature that can be dealt with once and for all by the incorporation of appropriate curriculum content. Gender inclusivity involves continual reflection on the teaching and learning interaction and a constant alertness to the potential of the style and content of teaching to create situations where some may not feel included and consequently may choose to exclude themselves from further study. The work on critical mass has clearly shown that minority students fare best when they are above roughly one fifth of the total class numbers and that they become likely to drop out when the proportion drops below that level. With the women engineers already at a critically low proportion it is important to acknowledge their presence and to sustain their studies by adopting the gender inclusive principles outlined above. Only through measures such as this will the worrying decline in numbers of engineers be overcome.

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