New constructions of gender inclusive engineering curriculum

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Abstract*: Starting from a demonstration of the need for gender inclusive curricula in engineering this paper outlines the theoretical framework to support this development. It proceeds to discuss the research conducted both by the authors and others on the perceptions and understandings of gender inclusive curriculum by engineering faculty and students at three institutions in Australia, UK and USA. In analysing the responses we find broad agreement in many areas between the differently located engineering students and faculty, suggesting a degree of cultural similarity between them, along with some interesting differences. The approach taken in this investigation is valuable in making students and faculty more aware of the issues of inclusiveness in their teaching and learning and in providing direction for curriculum change.*

Introduction

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. 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 (NSF, 2003; Clewell & Campbell, 2002). This suggests that the traditional orientation of established engineering education curriculum has not responded to calls for improving equity. Although curriculum is not the only issue that discourages women from entering and remaining in engineering study, it is an important and often unrecognised component of the problem. The gender disparity in engineering enrolments is unlikely to diminish unless there is significant change in course promotion and experience (Seymour & Hewitt, 1997; Gill et al, 2005; Gill et al, 2008b). 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 Kramer-Koehler et al ,1995; Fromm, 2003). 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.

Theoretical framework

Curriculum theorists have long established the position that curriculum refers to much more than the delineation of subject content or prescriptions about the method of teaching. The context in which the learning happens is also implicated in the success of the learning endeavour. The idea is that the learner actively builds her/his own learning and this theory – or group of theories – goes under the title constructivism. Constructivism has become the dominant learning paradigm in recent times (Baviskar, Hartle and Whitney, 2009) and has many implications for inclusive curriculum work which we elaborate below.

In line with constructivist theory, curriculum includes 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, which in engineering means male and probably white. Our initial study of the educational experience of practising women engineers revealed consistent gaps in terms of the recognition of their learning needs and their acknowledgement by their peers (Gill et al 2008a, 2008b). Hence we were drawn to investigate gender inclusive engineering education in an attempt to change the ways in which the engineering curriculum functions.

The particular focus of this study is on the ways in which gender operates as one dimension of the socio-cultural environment of teaching and learning in engineering. We do not imply that gender is the only variable that educators need to think about in their teaching, but we do suggest that it is a particularly important one. The reason for this claim arises precisely because gender forms part of the taken for granted assumptions about the world in which we all live and share. This means that all of us carry unexamined gender assumptions, many of which we unconsciously transmit in our social interactions. However when such assumptions become part of the teaching and learning process they can negatively affect those who are made to feel outsiders, not the mainstream student, less able to accommodate the material to be learned, less able to speak out in class and less likely to score high marks in the examinations. The very normality of our assumptions about male and female attributes constitutes this area as one for close scrutiny in the effort to develop an inclusive teaching and learning experience.

Hence we began the research by investigating the range of ways in which a cross section of current engineering faculty and students view the curriculum in terms of its gender inclusivity. Our focus questions were as follows:

- What are the perceptions of engineering faculty members about the gender inclusivity of their current teaching practice and learning environment?
- Do the perceptions of engineering students differ from those of engineering faculty and in what way?
- What are the implications of these findings for improving the awareness and implementation of gender inclusive curriculum practices in engineering education?

To address the first two questions we surveyed students and faculty at two universities, and incorporated the results of a very similar survey at a third university. In our analysis of the responses we suggest answers to the third question above.

Study methodology

The study involved the completion of an anonymous on-line survey by faculty members and students at two institutions. The first survey was conducted in 2007 at a technology based university in Australia (Aus Tech). The second survey was conducted in 2008 at a large US state university (US State). Both institutions are committed to the education of minority and disadvantaged groups and US State has had a strong women and minorities in engineering program for many years. The outcomes of the two on-line surveys above were then compared with a third survey completed in 2008 at the UK institution (UK Tech); using a questionnaire based on that used for the first two surveys (van Zyl, 2008).

There were some slight differences in the survey sampling technique and project extent at each institution due to different constraints on the project duration and context at each place and the extent of direct access that the researchers had to students and faculty. At the UK institution no faculty members were surveyed, only civil engineering students were invited to participate and surveys were distributed in hard copy rather than on-line (van Zyl, 2008). Some additional questions were also incorporated into the UK survey and some minor modifications made to others, so in this paper, only those questions where a direct comparison of responses could be made have been included in the results. Some relevant statistics for each institution at the approximate time of the survey are provided in Table 1.

Table 1: Characteristics of undergraduate students at the surveyed institutions (latest data available at the time of the survey)

Institutional characteristic	**Aus Tech**	**US State**	**UK Tech**
Total no. students on campus	25600	51300	17800
% female students on campus	57.4	52.0	51.0
% international students on campus	17.5	2.3	15.2
Total no. engineering students (approximate)	900	4100	1100
% female engineering students	15.0	17.0	9.0
% international engineering students	26.1	5.5	42.0
Broad engineering program areas offered (those in bold are the programs that were surveyed)	**Civil** **Electrical** **Mechanical**	Biomedical Chemical **Civil** Construction **Electrical** **Industrial** Materials Mechanical & Aerospace	Aeronautical **Civil** Electrical Mechanical

The first section of the survey (Questions 1 to 7) 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 (Jost, 2004) that focussed on benchmarking 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 created 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 (9 to 18) in the student survey (without level descriptors included) were:

9. How are women's interests represented within your program?
10. What kinds of problems are used in your program?
11. Are problems approached in a multi-disciplinary manner?
12. How are non-technical professional skills incorporated into your program?
13. What is the basis of assessment in your program?
14. Is it assumed that you already have some informal knowledge before you start your program?
15. 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?
16. 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?
17. Is prior knowledge of laboratories and equipment used assumed in your program?

18. Have you experienced inappropriate language and images being used in your program?

The questions for faculty were very similar but slightly adjusted to the context of their teaching experience. At Aus Tech and US State respondents were also given the opportunity in a final text response question in the survey to make any further comment regarding their experience of gender inclusive engineering education during their study or teaching.

Findings

Responses were received from all engineering discipline areas surveyed for both male and female students and from faculty members at US State, and Aus Tech. However, 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. Rather, the focus of the study was a comparison between faculty and student perceptions, and between perceptions at different institutions, which 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.

Table 2: Benchmark levels perceived by faculty and students on aspects of gender inclusive curriculum – (Level 5 = highest)

Aspect of inclusive curriculum	Level perceived by Faculty		Level perceived by Students		
	Aus Tech	US State	Aus Tech	US State	UK Tech
How is theory taught?	3.7	3.3	2.9	2.5	2.9
Women's interests?	2.1	1.8	2.3	2.6	2.9
Kinds of problems used?	3.5	2.8	2.7	2.8	3.0
Problems multi-disciplinary?	4.0	3.2	3.1	3.1	3.1
Non-technical skills?	4.0	2.9	3.4	2.9	3.2
Assessment?	3.8	2.7	3.4	2.8	2.7
Informal knowledge assumptions?	2.9	2.5	2.5	2.5	2.4
Learning environment?	3.4	2.8	3.2	2.9	2.9
Discrimination and harassment?	3.9	4.3	3.7	4.2	3.5
Prior knowledge laboratories?	3.6	3.3	3.0	2.9	3.3
Inappropriate language?	4.3	4.4	3.5	4.1	3.4
Average over all aspects	***3.6***	***3.1***	***3.1***	***3.0***	***3.0***
No. of total respondents	N = 21	N = 20	N = 29	N = 43	N = 96
No. female respondents	4	5	17	26	12
% respondents who were female	19.0	25.0	58.6	60.5	12.5
Response rate overall (%)	47.7	20*	21.6	4.0*	NA
Female response rate (%)	66.6	26*	34.0	Unknown	NA
% respondents with English as their second language	43.0	35.0	34.5	18.6	18.8

* Due to access restrictions for the researchers the response rates indicated must be considered approximate at US State, particularly for the student data.

While the responses to the survey have been presented as average scores in Table 2 we do not intend these results to be interpreted as firm measures but rather as indicators of opinion sets held by engineering students and faculty. The striking similarity of the averaged scores from students at three different locations does suggest some generalisable features of the engineering education experience. However, given the earlier caution about gender forming part of most people's unexamined ways of interacting socially it seemed likely that some of our respondents would not necessarily register their own gender assumptions with any degree of accuracy. At the same time there were some interesting differences such as the tendency of the faculty in Aus Tech to see themselves as operating more inclusively than did the students at this same site. While it may be that the faculty who completed the survey were more interested in the inclusion idea and more likely to adopt inclusive teaching practices - the inbuilt bias in the study design – the same differential in favour of faculty was not evident in US State's response.

One positive result from the survey was that the overall response from both faculty and students at all institutions with respect to the questions about discrimination and harassment and the use of inclusive language were amongst the highest ratings, particularly at US State. A Level 3 response to this question stated that "Some staff attempt to deal with discrimination and harassment in the teaching and learning environment but it is not consistent across all courses" whilst Level 5 stated that "The prevention of discrimination and harassment is consistent across all courses in the program. Inappropriate behaviour is dealt with. Policy is reinforced to students by staff." This may be a pleasing indication that years of equal opportunity policy implementation and training at higher education institutions may be bearing some fruit. However, it was notable that text responses asserting no discrimination only came from male students:

> *I have never seen sexual/racial discrimination in my program* (Male student, electrical, Aus Tech).

Whereas a female student noted that:

> *It's hard because not only do I have to understand the subject, it is my job to change their perspectives about women too* (Female student, bioengineering, US State)

The question of women's interests being represented in engineering education was one about which the faculty appeared more dubious than the students, who were more likely to answer more affirmatively. Without more information it is difficult to know what may have caused this discrepancy. Could it be that engineering faculty acknowledge a sense of not doing enough to include women's interests in their teaching? What do they understand by 'women's interests'? However, it was notable in the text responses from several faculty members that the existence of gender in engineering was denied in favour of the neutrality of technical content:

> *Materials that I teach are gender neutral. I teach STUDENTS, not genders.* (Female faculty, industrial, US State)
>
> *Women's issues don't come into systems engineering (nor do men's issues) so it is hard to answer something so hypothetical. Are we supposed to highlight women as being something special?* (Male faculty, electrical, Aus Tech)
>
> *There is little scope for incorporating women's interests (or men's interests for that matter) as the course material is very technically oriented.* (Male faculty, electrical, Aus Tech)

Students also echoed the position that engineering content was technical and therefore gender neutral. It may also be that some of the women students are inclined to reject the 'female as different' position and hence are likely to answer with a 'false positive' in this instance.

> *I don't think that anyone in the department feels a need to stress "women's issues" or "men's issues" because the emphasis is on the technical content not gender* (Female student, bioengineering, US State)

One respondent was quite hostile to the concept of women's interests or the idea of being made to think about them at all:

> *Been [sic] sexist goes both ways whos [sic] catering for the men, stop trying to force feelings on us* (Male student, Civil, Aus Tech)

Despite these concerns the overall conclusion we take from these findings is that the survey did provoke faculty and students to think about their teaching and learning and hence to become a little more self conscious in these areas. Certainly several staff and students noted that the small number of women in engineering caused a chicken and egg conundrum for their teaching and learning experience:

> *After all, 'Women's interests, experiences and achievements' are unlikely to be represented in a class when there aren't any women in the class.* (Male student, electrical, US State)

The fact that the survey encouraged both staff and students to consider inclusive aspects of their engineering education experience is a favourable outcome insofar as it is highly consistent with constructivist learning principles which commend teachers and learners to become more self reflexive.

Recommendations and future research

In learning spaces dedicated to the preparation of engineers, an essentially applied profession, the dominant idea has traditionally been one of supplying knowledge that the learners must acquire and demonstrate in regular examinations. This context has provided limited space for new pedagogical ideas such as active learning wherein students engage in discussion, make mistakes, learn by doing and where teaching and learning are mutually sustainable activities. Working towards a more inclusive education for engineering involves a profound cultural change in the ways in which engineering is taught and learned. The survey investigation described here constitutes one way in which this change may begin.

A further study is planned whereby both engineering disciplines and the non-engineering discipline area of construction management, similarly male dominated in enrolment and faculty membership, will be investigated using the same instrument at three other Australian institutions. However, the fundamental purpose of the benchmarking undertaken to date and proposed in the future is to determine the current context of inclusive practice in engineering education and to use this knowledge to support a range of proposed curriculum strategies to improve gender inclusivity. To this end the authors are currently involved in two major projects involving the gathering of gender inclusive curriculum exemplars and the promulgation of these to engineering faculty members through a range of professional development activities and resources.

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