An Inclusive Engineering Curriculum: How to persuade and assist your colleagues to develop one

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Abstract
Engineering faculty are urged to be 'inclusive' when teaching classes of diverse students. An inclusive approach, it is argued, will not only assist the progress of those students from social and cultural groups, which have not traditionally entered engineering, but it will also broaden the perspectives of all students and thus improve the overall quality of an engineering program.

This paper is written for academic advocates of quality, equity and diversity. It summarises the development of the various meanings of the term 'inclusive curriculum' in Australian and American literature for the purpose of disseminating and promoting the concept amongst engineering colleagues. It also uses the progressive nature of the various understandings of the concept to make practical suggestions for introducing and consolidating an inclusive engineering curriculum at several levels. Although the case study presented in this paper is located within an Australian university, the need for inclusivity within engineering curricula is relevant worldwide and the techniques and strategies described are readily applicable for use in other countries.

Introduction
In common with the rest of the English-speaking world, Australian universities are seeking to increase the diversity of their students. This is partly an equity and social justice issue: to improve the distribution of the benefits accruing to prosperous societies and ensure that a wide range of citizens play an active and informed part in the control and use of the assets of these societies. And it is partly a quality issue: we want to ensure that the best and most able people from all backgrounds are provided with the necessary education to contribute to the further development of knowledge.

Both of these issues are particularly relevant with regard to engineering students. Firstly, there are two sides to the equity and social justice issue. Engineering is a respected profession, and equity demands not only that it should be open to everyone, but also that long-established conventions and attitudes should not impede the professional success of entrants from any social and cultural groups. From another perspective: the engineering profession is responsible for the development and implementation of many of the technologies that are an essential part of developed societies – advanced communication systems, sophisticated infrastructure such as buildings, transport networks, sanitation and water supply systems and the development of industries vital to the economy of these societies. The profession also has a critical role to play in improving the conditions of the less developed and prosperous parts of the world, by providing expertise to implement and develop these same technologies in areas where they are currently at a basic level or completely lacking. Thus it is very important that engineering students develop an understanding of the role they can play in improving the quality of life of all people, not just those who happen to be from the same ethnic or economic background as themselves.

The quality issue is also crucial in engineering. The engineering profession in the western world remains overwhelmingly male dominated and, although the numbers of female students commencing undergraduate engineering studies has improved over the last twenty years, the indications are that they have now reached a plateau [1, 2, 3]. Similarly the representation of minority groups is also low. With the continuing decrease in the number of high school students graduating with mathematics and science backgrounds suitable to enter engineering, it is critical that universities draw from the complete pool of qualified students available, not just the white, anglo-saxon male proportion of it. However, it is not sufficient simply to attract a diverse student population to engineering. There are further challenges: firstly to cater for the interests and backgrounds of these diverse students during their professional education (one focus of this paper) and then to change the culture of the engineering workforce and workplace to ensure that they can be comfortable and succeed in their profession [1, 3, 4].

Why should increasing diversity in the classroom lead to changes in the curriculum?
The most common and persistent concern of engineering departments relating to diversity is to improve the recruitment and retention of women, initially as engineering students, but ultimately for employment in the profession. Increasing the representation of women in the engineering workforce is desirable for the following reasons:

- social justice considerations – women should not be excluded from the advantages and privileges which accrue to the professional engineer [5, 6]
- recognition that diversity in the labour force is to the advantage of the industry – it brings in new talents and provides access to wider markets [3, 5, 7]
- to relieve labour shortages in the profession [8].

It is therefore a matter of concern that women are still severely underrepresented in the engineering profession and that the proportion is growing so very slowly. In Australia, for example, the proportion of women in the engineering workforce has increased from 5% in 1991 to 6.8% in 1996 (the date of the last census) [2]. Women are more strongly represented in the Australian engineering student population (14.8% in 1999) than in the profession, but not only is this figure nowhere near the proportion of women in the population as a whole, it has remained stationary since 1994 [3]. These statistics explain the continuing attention to finding ways to increase the recruitment and retention of women engineering students.

The typical engineering curriculum (i.e. the entire learning experience within a course) has been blamed for the difficulties in recruiting and retaining female engineering students. Beder [9] describes it as showing an

> *"… obsession with the technical, the mathematical, and the scientific, and an almost complete neglect of the social, political and environmental issues…"*

which discourages

> *" … students with broader interests, a different range of talents…; those who want to work with people rather than machines and numbers, those who care about social relations. Too often it is the female students who are put off."* [p. 173].

Lewis [10] remarks that in the engineering curriculum

> *"The research questions, methods, criteria of success, and styles of teaching are male defined, and consequently, the knowledge itself reflects a bias towards a male cognitive style in its practices, theories, and ways of teaching. The science and engineering makers have created disciplines where they are comfortable with the separation of theory from social or environmental context, and where the top-down, expert scientist authority is the dominant paradigm* [p. 270].

Reforms to the curriculum are therefore recommended in order to attract and retain women students. Other social and cultural groups are also under-represented amongst engineering students. In Australia these groups include aboriginal students, students from rural, low socio-economic and some ethnic backgrounds and international students. Similar social and cultural groups are under-represented in higher education in other western countries. Curriculum reform is recommended to improve recruitment and retention of students from all of these groups too.

What is an inclusive curriculum?

Early approaches to teaching diverse students aimed to ensure that 'different' students were included, as opposed to excluded, in lectures and laboratories, giving rise to the term 'inclusive' teaching. Faculty were urged to examine their teaching practices and to ensure that in the assumptions they made about students' backgrounds, in the examples and metaphors they used, and in the attention they gave to individual students, they were not excluding those students who came from cultures which differed from the dominant culture represented in the class (usually young, white and male) [11]. Modifications to the physical environment were often recommended too, for example lowering the level of laboratory equipment so that students other than 6-foot males could reach it! Over time the concept of 'inclusive' has developed further and is now also generally understood to mean that the syllabi as well as the teaching methods employed should acknowledge the interests, attitudes and perspectives of the 'non-traditional' students, as well as the traditional ones [12, 13]. More controversially, some educators argue that an inclusive curriculum also involves encouraging students to challenge the power of the curriculum to support social injustice [12, 14, 15], otherwise they are permanently excluded from the benefits of society.

Rosser [5] has shown that these various interpretations of the inclusive curriculum represent the developmental stages which typically occur in universities committed to improving the representation of women in their science programs, though not all institutions achieve the most advanced stage. The present authors recognise Rosser's six stages as being equally applicable in an engineering context and to all 'non-traditional' students. In a previous work [16] we have paraphrased and summarised her discussion and formulated it into tabular form for ease of reference. We reproduce this in Table 1 below.

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?

Table 1: **Stages of curriculum transformation [adapted from 5, pp. 4-17]**

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

Developing an inclusive curriculum

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, not to conduct formal research. Its objectives (which formed the indicators against which the project was evaluated) were to produce guidelines, to provide staff 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. The authors have discussed details of the project and its impacts on the engineering departments elsewhere [17], but a brief description has also been included here.

Within the engineering departments the implementation of the inclusive curriculum project commenced with an audit to assess the extent of inclusive curriculum practice amongst faculty. This involved both interviews with course co-ordinators and heads of schools as well as an examination of existing course materials, documentation and departmental policies. Based on the outcomes of the audit, 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 Schools. 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.

As well as conducting workshops, a manual was developed [16] (discussed in more detail later in the paper), that gave faculty practical suggestions for developing inclusive curricula within their courses, and incorporating suggestions and examples from the audit and workshops. The manual was made available to all faculty via the project web site and was available in hard copy if desired. In addition, the authors participated in individual discussions with faculty about developments within their courses.

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 access or participation figures for female students or similar statistics. It was also not within the scope of the project to conduct such evaluations. However, statistics do indicate an improving trend in these figures since the project commenced, refer Tables 2 and 3. Until 1999 the figures that were collected were aggregated for all engineering departments. In 2000, figures were separated into school discipline areas. Separate retention and success rate figures were not collated for female students in engineering until 2000, but these have been included in Table 4 (2001 figures are not yet available). These figures indicate that the engineering departments were either close to or above the retention and success rates of female students across the university as a whole and of male engineering students.

It should be pointed out however, that it would not be possible to attribute any improvement or success in statistics solely to curriculum improvements that encompass inclusivity, as many other factors and initiatives are involved, both internal and external to the departments, such as increased outreach activities targeted to girls' high schools, and high schools in low socio-economic areas. In addition, since overall female student numbers remain small in all schools, changes of only a few students in numbers in any given year can significantly effect these percentages. (The percentages of female engineering students at the University of South Australia are around Australian generic average values in Civil engineering, but the remaining degrees offered by the university are in the 'heavy' engineering disciplines of Mechanical, Electrical and Mining engineering, not in Chemical or Environmental engineering that have proven more attractive to female students, hence overall female student percentages at the university are below the generic national average figures).

Table 2: Access of women in engineering at University of South Australia 1996 – 2001 as a percent of all commencing domestic students in each School

	1996	**1997**	**1998**	**1999**	**2000**	**2001**
Engineering (all)	12.5	12.2	8.5	10.5		
Mechanical Engineering					4.5	8.7
Electrical Engineering					12.6	9.0
Civil and Mining Engineering					15.0	12.9

Table 3: Participation of women in engineering at University of South Australia 1996 – 2001 as a percent of all domestic students in each School

	1996	1997	1998	1999	2000	2001
Engineering (all)	10.1	10.8	9.2	10.1		
Mechanical Engineering					5.2	5.5
Electrical Engineering					11.3	10.3
Civil and Mining Engineering					16.5	14.5

Table 4: Retention and success rates of women in engineering at University of South Australia 2000

	Female Retention (%)	Male Retention (%)	Female Success (%)	Male Success (%)
Mechanical Engineering	100.0	78.9	95.1	82.7
Electrical Engineering	77.6	86.1	80.0	72.8
Civil and Mining Engineering	91.7	74.3	87.5	76.9
University in total	80.7	78.2	86.8	84.3

As stated previously the intention of the inclusive curriculum project within both the university as a whole as well as the engineering departments was one of staff and resource development. 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*" [18] and the *"Code of Good Practice: University Teaching"* [19] of the University of South Australia. It is now 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."*

Hence the requirements for developing and teaching inclusive curricula are now mainstreamed within the university. To the authors' knowledge the university has not yet evaluated the success of the inclusive curriculum provisions individually, as they are considered to be just one part of a multi-pronged effort to improve equity and diversity performance at the university.

The remaining discussion in this paper focuses on some of the obstacles the authors have encountered within the engineering departments when advocating and advising an inclusive curriculum, both during and after the project and the devices they have used to overcome objections and impediments. When we first started to promote and develop an inclusive curriculum, it was clear that although most of Rosser's stages were represented amongst our academic colleagues, the majority were at about Stage 2. However, there were some other issues that needed to be addressed before we could progress through the remaining stages of curriculum transformation.

Clarifying the meaning of 'inclusive curriculum' with colleagues

The evolution in the meaning of the term 'inclusive curriculum' described above caused us the first difficulty in trying to encourage our departments to become more inclusive. We found that it cannot be assumed that colleagues are in agreement with all the 'stages' described above, or even that they are aware of the full range of different meanings. Any consensus amongst our colleagues of understandings of the term ‘inclusive curriculum’ seemed to centre around the perception of a curriculum which respects, acknowledges and values the differing backgrounds, interests and perspectives of all the students in a diverse class.

Some colleagues, however, having accepted the ‘earlier’ meanings, such as acknowledging the contributions of women to the progress of engineering, resisted the ‘later’ thinking that inclusivity now requires penetrating more deeply into the curriculum. Resistance was demonstrated for example by a lack of interest or replication in the first author’s practice of setting engineering problems that address a societal need, rather than focusing only on technological solutions. The range of meanings of ‘inclusive’ also caused difficulties with faculty who by some means made their first acquaintance with the concept in its most advanced form: using the curriculum to challenge inequitable power relationships. Perhaps understandably these colleagues were somewhat sceptical about the relevance of this meaning to the engineering curriculum.

We realised that first we must clarify with colleagues the range of meanings and the corresponding purposes of an inclusive curriculum. We used a variety of media and occasions in which to address this objective: informal discussions, more formal workshops and by circulating and recommending materials. Our purpose was to emphasise the progressive nature of these various meanings and encourage colleagues to initially locate themselves at whichever stage they felt comfortable, but to be open to considering the relevance and applicability to the engineering curriculum of the next stage of development of the concept.

Other Key Issues

Having improved understanding of the term ‘inclusive’, we found it useful to expand on some of the main research findings to provide an overall picture of the ways in which engineering curricula can cause problems to minority students and perhaps more importantly, how an inclusive curriculum can benefit all students.

There have been a number of findings that many women experience a ‘chilly climate’ in science, engineering and technology courses and it is likely that other minority groups share similar experiences. Unhappy or uncomfortable students will not achieve as well as they might in a more supportive environment and they may even resign from the course.

Some of the features of the ‘chilly climate’ that have been identified are:

- erroneous assumption by lecturers that all students have prior ‘tinkering’ experience (practical familiarity with mechanical and electronic devices and appliances) [10]
- lack of excitement in the content or presentation of the course [20]
- apparent lack of relevance in the curriculum content [10, 21]
- teaching methods which are appropriate for only a very limited range of learning styles [10, 22]
- disruptive behaviour of majority groups (e.g. male students throwing paper planes!) [21, 22]
- classroom atmosphere uncomfortable for some students because of racism, sexism, or similar attitudes [10, 21, 22, 23].

Once aware of these features of the chilly climate, it is relatively easy to control, or at least limit, their influences. For example, it is not difficult to stop assuming that all students have tinkering experience and to ensure that the knowledge and skills we require are included in the course. For some faculty, however, it is more difficult to address the issues that relate to the curriculum content.

Many engineers and scientists maintain that their curriculum content is based on universal laws and is not therefore subject to cultural or gender bias, but this perspective is being challenged. Rosser is one author who points to alternative views [5]:

> *Some scientists, influenced by scholarship in women's studies, the philosophy and history of science, and psychology, have begun to recognize that gender may influence science. Kuhn and his followers suggested that all scientific theories are the products of individuals living in a particular historical and social milieu.* [p.5]
>
> *In the teaching of science, most instructors underline the importance of the scientist's objectivity in approaching the subject of study. This is thought to be necessary to establish scientific rigor … Feminist critics' [24, 25] as well as practising scientists' [26, 27] have pointed out that the portrayal of the scientist as distant from the object of study masks the creative, interactive relationship many scientist have with their experimental subjects*.[p.7]

Ideally, faculty who are committed to an inclusive curriculum will acknowledge the ideas suggested above. Those who have not yet reached this stage in their perceptions of an inclusive curriculum may prove resistant to the idea that gender and culture can influence scientific thinking. An author who has encountered this resistance in the disciplines of science, mathematics and engineering, which she describes as 'gender resistant', is Warren [28]. Warren suggests considering the curriculum content as comprising two components; the underlying theory and the applications and examples employed, and designating these as the 'primary' and 'secondary' content. When implementing an inclusive curriculum, engineers may find it helpful to consider these two components in stages: first consider how to make the secondary content more inclusive (by including examples and applications from a range of cultures) then later tackle the issues arising in making the primary content inclusive.

Providing help with adapting the curriculum

When urging our colleagues to adapt their curricula to make them more inclusive, typical reactions we have encountered have been: "We don't know how", "This stuff is easy for arts courses but not engineering" and "We haven't got time".

Here we have found that it is helpful to suggest proceeding in small steps. We encourage colleagues to experiment with the concept of inclusivity by applying its principles to individual components of the curriculum, before considering initiating formal curriculum revision.

Normally curricula are designed by considering the components of the curriculum in approximately the order given below:

- the assumptions made about the perspectives, experiences, values and backgrounds of the students

- the aims and objectives of the program or course
- the content
- the teaching and learning methods
- resources used
- how the students are assessed
- the general learning environment.

To begin to introduce an inclusive curriculum, we suggest to colleagues that they should work through this list in reverse order, since the components at the end of the list can be adapted without invoking any formal procedures. If satisfied with the outcomes of these trials, a lecturer may be inspired to apply the principles to the more formal parts of the curriculum. So we recommend: start by considering how to improve the inclusivity of the learning environment, then apply inclusive principles to assessment procedures and work up the list from there. This process echoes the 'stages' of inclusive curriculum development shown in the table above.

To assist with this process, we have developed an internal manual, *"Making engineering more inclusive"* [16], as a resource for use by our engineering colleagues within the university. The manual includes some of the background of what is meant by inclusive curriculum and why we should develop it, but its primary focus is on practical strategies that faculty members can adopt or implement to achieve an inclusive curriculum. For example, it contains sections entitled "Suggestions for designing an inclusive curriculum" and "Suggestions for teaching an inclusive curriculum", where, for each of the components of the curriculum listed above, we summarise the issues and then provide examples and suggestions for addressing these issues in an engineering curriculum. An extract from the section "Suggestions for designing an inclusive curriculum" is included as Appendix A.

Curriculum development using graduate qualities

Another strategy that greatly assisted the development of inclusive curricula for engineering was an approach to curriculum development adopted by our university that focuses on graduate outcomes. The University of South Australia has identified seven generic 'qualities' as desirable in its graduates and the design of each program must now demonstrate how it will enable graduates to acquire these qualities.
The seven qualities are:

1. Graduates will be able to operate effectively with and upon a body of knowledge of sufficient depth to begin professional practice.
2. Graduates will be prepared for life-long learning in pursuit of ongoing personal development and excellence in their professional practice.
3. Graduates will be effective problem solvers, capable of applying logical, critical, and creative thinking to a range of problems.
4. Graduates will be able to work both autonomously and collaboratively as professionals.
5. Graduates will be committed to ethical action and social responsibility as professionals and citizens.
6. Graduates will be able to communicate effectively in professional practice and as members of the community.
7. Graduates will demonstrate an international perspective as professionals and citizens.

To assist program design, the University has provided, for each 'quality', a set of discipline-generic indicators that a student has acquired the quality. As part of the University's mandatory program development process, these generic indicators must be elaborated for application to the particular discipline area and at this stage are comparable with the 'program objectives' required in other universities.

Also, to support its policy for inclusive curricula, the University has extended its table of 'indicators' described above, by matching each one to a new indicator which 'expresses inclusivity', then suggesting appropriate strategies for course design, teaching, learning and assessment, to enable students to demonstrate the inclusive nature of the curriculum they have experienced. For engineering programs, we have extended this framework further by including a series of specific examples from inclusive engineering courses that had already been developed. These tables were made available to engineering faculty as another practical tool to assist them in developing their programs and courses to become more inclusive. Two examples of these tables are included as Appendix B.

Summary

Universities may adopt several strategies to increase the diversity of their students and improve the quality of the education they offer. In this context, an inclusive curriculum is often advocated as not only being appropriate for minorities, but also, by widening the experience of all students, to improve educational quality overall. The authors have found however, that confusion about the meaning of the term 'inclusive curriculum' creates a barrier to faculty acceptance of the concept and that it is essential to address this issue before expecting any real curriculum transformation.

This paper has firstly presented a synopsis of the various understandings of the inclusive curriculum found in the literature and described strategies employed by the authors to clarify these understandings to their colleagues. Rosser's 'stage' theory is adopted, which views these understandings as forming a steady progression from compensating women and minorities for their apparent disadvantage in the engineering classroom, to acknowledging that incorporating an increased range of perspectives in the curriculum will enhance the education of all.

Next, the paper has considered, again using existing research, the ways in which the typical engineering curriculum has been identified as failing to match the objectives of an inclusive curriculum, and suggests how the curriculum can be re-examined to incorporate inclusive features. In particular, it is recommended that faculty initially address the informal aspects of the curriculum, such as ensuring that the learning environment is supportive of women and minorities. If professors find that small changes of this nature are beneficial to the learning of all students, the authors recommend introducing more variety into their forms of assessment, and from there gradually applying the principles of an inclusive curriculum to all the other components of the curriculum, eventually addressing the content as well. Appendix A provides many practical examples drawn from the literature and from the authors' own experience, of introducing more inclusivity into the engineering curriculum. The authors' own university has assisted in this process by providing institution-wide guidelines linking the inclusive curriculum to the graduate attributes the University aims to develop in the course of each student's higher education and extracts from these guidelines are provided in Appendix B.

This paper has presented arguments for the need to develop inclusive curriculum in engineering programs as well as some practical strategies and resources to assist in this process. Whilst there is sometimes resistance to implementing these changes (as with all change), the authors have found that the use of workshops, informal discussions and particularly the provision of practical and easily understood suggestions in a tangible form can be successful in overcoming this resistance. The importance of modelling best practice in this area within the authors' own teaching can also not be understated.

Bibliography:

1. Khazanet, V.L. (1996), Women in Civil Engineering and Science: It's time for Recognition and Promotion, *ASCE Journal of Professional Issues in Engineering Education and Practice,* Vol. 122, No 2, April 1996, pp. 65-68.
2. Australian Bureau of Statistics (1999) *Human Resources in Science and Technology*, Canberra: Australian Bureau of Statistics.
3. Lewis, S., Harris, R., and Cox, B. (2000) *Engineering a Better Workplace: A Diversity Guide for the Engineering Profession.* National Centre for Gender and Cultural Diversity, Swinburne University of Technology.
4. Roberts, P., and Ayre, M., (in press), ' Did she jump or was she pushed? A study of women's retention in the engineering workforce'. *International Journal of Engineering Education*.
5. Rosser, S., 1995, Reaching the Majority: Retaining Women in the Pipeline, in S. Rosser (Ed) *Teaching the Majority: breaking the gender barrier in science, mathematics and engineering,* Columbia University: Teachers College Press, pp. 1-21.
6. Glover, J. (2000) *Women and Scientific Employment*, Basingstoke, UK: MacMillan Press Ltd.
7. Institution of Engineers Australia, 1996, (IEAust), *Changing the Culture: Engineering Education into the Future, Review Report* Canberra: IEAust.
8. European Technology Assessment Network on Woman and Science 2000. European Commission, URL (accessed December 2001) ftp://ftp4.cordis.lu/pub/improving/docs/g_wo_etan_en_199901.pdf
9. Beder, S. (1989) Towards a More Representative Engineering Education. *International Journal of Applied Engineering Education* 5 (2), pp 173 – 182, and URL (accessed December 2001): http://www.uow.edu.au/arts/sts/sbeder/education2.html
10. Lewis, S. (1995) Chilly Courses for Women? Some Engineering and Science Experiences, in *Women, Culture and Universities: A Chilly Climate*? University of Technology, Sydney, pp. 270-276.
11. Fennema, E., and Leder, G. (Des) (1990), *Mathematics and Gender: Influences on Teachers and Students,* New York: Teachers College Press.
12. Willis S., 1996, Gender Justice and the Mathematics Curriculum in (Eds.) L. Parker, L. J. Rennie, and B. J. Fraser, *Gender, Science and the Mathematics Curriculum: Shortening the Shadow,* Dordrecht: Kluwer Academic Publishers, pp. 41-51.
13. Seeman, K., and Talbot, R. (1995) Technacy: Towards a Holistic Understanding of Technology Teaching and Learning among Aboriginal Australians in *Prospects,* Vol XXV, no. 4, December, pp. 761-775.
14. Parsons, D., & Parsons, B. (1997) The aboriginal experience: a case study in engineering values*, Proceedings of the Australasian Association for Engineering Education 9th Annual Convention and Conference*, University of Ballarat, 14-17 December, pp. 272-276.

15. Bianchini, J., Whitney, D., Breton, T., and Hilton-Browne, B. (1999) *Inclusive Science Education: Scientists' Views and Instructional Practices,* URL (accessed December 2001) http://www.educ.sfu.ca/narstsite/conference/bianchinietal/bianchinietal.html

16. Ayre, M.E., Mills, J., Nafalski, A., and Priest, S., *Making Engineering More Inclusive*, (Preview edition 1998, University of South Australia).

17. Ayre, M. E., and Mills, J. M., 1999, Outcomes of a University's Inclusive Curriculum Project in the Engineering Disciplines, *Proceedings of the 11th Annual Convention and Conference: Unfolding Landscapes in Engineering Education: Australasian Association for Engineering Education, 26-29 September.* Adelaide: University of South Australia, pp. 406 – 411.

18. University of South Australia, 2000, *Policy for Development, Amendment and Approval of Programs and Courses.* Internal document.

19. University of South Australia, 2001, *Code of Good Practice: University Teaching.* Internal document. Available at http://www.unisa.edu.au/adminfo/codes/teaching.htm

20. Nair, I., and Majetich, S. (1995) Physics and Engineering in the Classroom in (ed) S. Rosser, Teaching the Majority: Breaking the Gender Barrier in Science, Mathematics and Engineering, New York, Teachers College Press, pp. 25-42.

21. Lintern, S. (1995) *Oh Look …A Girl!*, University of South Australia.

22. Jolly, L. (1996) *The First Year Engineering Ethnographic Project: An Overview,* Department of Anthropology and Sociology, University of Queensland.

23. McLean, C., Lewis, S., Copeland, J., O'Neill, B., and Lintern, S. (1997) Masculinity and The Culture of Engineering in *Australasian Journal of Engineering Education,* Vol 7, No 2, pp. 143-156.

24. Haraway, D. (1978) Animal sociology and a natural economy of the body politic, *Signs*, Vol 4, No 1, pp. 21-60.

25. Keller, E. (1982) Feminism and Science, *Signs,* Vol 7, No 3, pp. 589-602.

26. Bleier, R. (1984) *Science and Gender: a Critique of Biology and its Theories on Women*, Elmsford, New York, Pergamon Press.

27. Hubbard, R. (1990) The Politics of Women's Biology, New Brunswick, New Jersey: Rutgers University Press.

28. Warren, K. (1989), Rewriting the Future: The Feminist Challenge to the Malestream Curriculum, *Feminist Teacher*, Vol 4, No 2/3**.**

29. Armstrong J., and Leder, G., 1995, *Engineering Education: How to Design a Gender-Inclusive Curriculum,* Congress of Engineering Deans

30. George, R.,1997, *Influences on the development of graduate qualities in the Australian context;* unpublished paper, University of South Australia

31. Cartwright, N., 1997, *Assessment and Feedback,* Support Centre for Effective Teaching and Learning, University of Ballarat

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Appendix A

Suggestions for Designing an Inclusive Engineering Curriculum

Use this table if you are designing a course or subject, and want some ideas about how to make it more inclusive.

Note: There is not necessarily a one-to-one correspondence between the points in column 2 ("think about") and Column 3 the "examples and suggestions", since the column 3 items often address several of the column 2 points.

Curriculum Components	Think about	Examples and Suggestions
Assumptions	• whether students from diverse backgrounds have the same experiences and interests as 'traditional' engineering students • whether they all have 'tinkering' experience • students' previous access to computers and their levels of computer literacy	• include introductory 'how-to-use' laboratory and computer sessions as an integral part of the course; for students who have had limited access to computing facilities, or who have never had the sort of experiences often assumed, like playing with mechanical or electronic toys, or dismantling a car engine. • ensure that these sessions are open to *all* students
Aims and Objectives	• how to integrate technical understanding with society's needs • developing students' awareness of international, multicultural, gender, indigenous, and other perspectives in engineering and technology • preparing students for professional practice in a multicultural society and global economy	• include social, environmental and global aims and objectives with the technological and professional ones **Example from the University of South Australia subject "Communication and the Profession"** On completion of this subject, the student should be able to • take account of environmental issues and the human factor in analysing and designing engineering systems; • present a set of logically related ideas in spoken and written form; • plan, draft and edit a range of written assignments; • listen to, read, summarise and reflect critically upon the viewpoints of others; • identify, analyse and discuss the major features of language used in professional and academic contexts, and themes and issues in verbal communication; • realise the importance of sustainable development and professional ethics.
Content: (primary, and some secondary)	• incorporating the interests and experiences of diverse social and cultural groups • challenging a uniform view of knowledge • developing, in the classroom and the laboratory, cooperative, communicative, creative and critical skills as well as technical, logical, analytical, and competitive skills • providing students with 'open-	• include applications of the technology in different physical, cultural and social contexts: eg electrical/electronic appliances where the power supply is unreliable; and bio-medical, as well as military, applications • discuss the ways in which technology has improved peoples' lives • include reference to alternative scientific methodologies, eg feminist science • give students investigative problems for which they need to devise their own experiments, rather than standard laboratory exercises with an expected

Curriculum Components	Think about	Examples and Suggestions
	ended' opportunities to relate, apply, generalise from, and hypothesise with, the knowledge and skills they are acquiring • students who resign from engineering courses often complain of lack of creativity, and relevance; and of being bored	outcome (or 'right answers'). • make creativity and innovation an integral part of the course. For example, the University of South Australia's course "Engineering Innovation and Practice" combines a problem-based approach in engineering education with techniques from the field of educational psychology to develop creativity and innovation in students. • include some cross-disciplinary study
Teaching and Learning	• active learning strategies are generally regarded as leading to more effective learning than passive methods like lecturing • using a variety of teaching methods to - accommodate a range of learning styles - develop a range of skills in all students	• aim to extend the preferred learning styles of all students by employing a variety of teaching methods • teaching and learning arrangements could include, for example: problem-based-learning, mini-projects, peer-assisted learning, case-studies, computer-based-learning • make sure there are opportunities for collaborative learning, as well as learning in competition with others • give open-ended laboratory investigations or computer simulations, as well as exercises with 'closed' expected results
Assessment	• the evidence that some assessment methods favour some social and cultural groups (eg male students tend to perform better than females in multiple-choice tests, women are often better at essay-writing than men) [29] • assessment modes need to reflect the teaching and learning methodologies employed • Matching assessment techniques to the different teaching and learning arrangements which develop particular graduate qualities is an important characteristic of excellence in course and subject delivery [30]	• provide opportunities for students to demonstrate their learning in a variety of ways, including modes which tend to be encouraged and developed in other cultural environments • use a mixed portfolio of assessment methods **Example from the subject Electricity and Electronics**. *Students are assessed by:* • tutorial quizzes held in the first 10 minutes of each tutorial • team reports of practicals • a multi-choice mid-semester test (practice tests available on the internet) • a mixed-mode 2-hour final closed-book exam • Students also have the opportunity to earn a 5% bonus by contributing to the development of the subject with eg: new laboratory tests, software, tutorial questions. See Cartwright [31] for exemplars illustrating the use of a variety of assessment methods in engineering subjects

Appendix B – University of South Australia Inclusive Curriculum Guidelines, Examples from Engineering

QUALITY 2 ***A graduate...is prepared for life-long learning in pursuit of ongoing personal development and excellence in professional practice.***		
INDICATORS EXPRESSING INCLUSIVITY	**EDUCATIONAL STRATEGIES**	**EXAMPLES**
▫ understand the social and cultural dimensions of networks of knowledge and be able to recognise their implications in locating, evaluating, managing and using information ▫ understand the partial and relative nature of their own knowledge and its construction in relation to their historical, social and cultural experiences ▫ recognise the potential for enlarging their repertoire of learning styles to include strategies appropriate in a range of cultural or social groups ▫ maintain a concept of self in relation to, and which is informed by, wider social and cultural perspectives ▫ sustain an intellectual approach which embraces the changing social and cultural professional context	▫ structure and stage information literacy into the requirements of assignments ▫ incorporate into the details and discussion about specific assessment the relevant issues of locating, evaluating, managing and using information ▫ as a part of the curriculum, engage students in an analysis of their own readiness for learning and preferred ways of learning and provide opportunities for these personal styles to be discussed in a group context ▫ use a range of learning and assessment strategies providing learner choice within the curriculum ▫ give opportunities for students to maintain a positive self concept by providing opportunities for all students to affirm and use their previous experiences within the curriculum ▫ use a range of registers, language styles and vocabularies in different media to model communication practices which include rather than exclude ▫ respect and build on diverse prior learning experiences, values and goals ▫ specify assumed knowledge and skills and make provision for students to access these ▫ respect, value and make provision for different kinds of student participation	▫ set open-ended laboratory investigations or computer simulations, as well as exercises with 'closed' expected results ▫ sometimes ask students to reflect on experiences in the classroom or in undertaking assignments, in writing. This provides a 'safe' medium for all students to participate without being too publicly exposed, and also helps develop language skills ▫ be aware of the importance of 'attribute style' - the pattern of causes attributed by people to the events of their lives, and the known gender differences in these, such as women students attributing failure to lack of ability whereas male students may 'blame' bad luck (or even bad teaching) ▫ use a mixed portfolio of assessment methods, eg in *Electricity and Electronics* students are assessed by all of the following: tutorial quizzes held in the first 10 minutes of each tutorial, team reports of practicals, a multi-choice mid-semester test (practice tests are available on the internet), a mixed-mode 2-hour final closed-book exam. Students also have an opportunity to earn a 5% bonus by contributing to the development of the subject with eg: new lab tests, software, tutorial questions.

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QUALITY 4	***A graduate...can work both autonomously and collaboratively as a professional.***	
INDICATORS EXPRESSING INCLUSIVITY	**EDUCATIONAL STRATEGIES**	**EXAMPLES**

▫ recognise that self direction may involve fundamental differences in approach for individuals from different groups
▫ be aware of the social and cultural factors in constructing arguments and negotiating with others
▫ work collaboratively in groups which comprise members form varying social and cultural backgrounds
▫ work in teams which comprise members from varying social and cultural backgrounds
	▫ as a part of involving students in group work, encourage shared responsibility and the recognition and value of differences in opinion and methodology
	▫ encourage both formal and informal collaborative work among students, including peer tutoring or mentoring
	▫ provide opportunities for students to play different roles in groups and teams
	▫ encourage analysis and appraisal of the effectiveness of the group process
		Exs from the *Civil Engineering Design Project* subject:
		▫ class is formed into a single company with work teams and elected managers
		▫ initial work teams are composed by the lecturers who
		  ▹ try to spread the (few) females and the NESB students and international students evenly around groups to ensure differences in approaches, backgrounds, opinions in the group
		  ▹ mix personalities, sometimes deliberately putting dominant personalities together to make them learn to work together
		▫ project is organised and directed by the students with guidance from the lecturers who act as 'clients'
		▫ shared responsibility is essential, class has to pull together, task is too large for just a few to complete it
		▫ peer assessments of individuals and work teams are conducted at each stage and allocated 30% of overall mark (i.e. seen as important); these assessments are now also incorporated by students into their quality management process
		▫ short talks and exercises on teamwork, personality differences, negotiation skills etc. are conducted by the lecturers during the project to assist students' understanding of group dynamics
		
		Exs from the *Mechanics and Structures* subject:
		▫ peer assisted learning sessions or study groups are used (held separately from, and with a different purpose to, lecturer-led tutorials)
		  ▹ led by successful students from previous year interested in participating in this way
		  ▹ current students indicates value the sessions for explaining topics in language they understand, reinforcing concepts etc.
		  ▹ student leaders positive value the mentoring and personal growth experiences the role provides for them