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Guidelines for the design of inclusive engineering education programs

By Julie E. Mills, Mary Ayre, Judith Gill

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These Guidelines are an outcome of a project undertaken by the authors with the support of the Australian Learning and Teaching Council, with project team members from the University of South Australia, University of Newcastle, University of Technology Sydney and the University of Melbourne. Particular acknowledgement is made of the contributions to this document from Emeritus Professor Robin King, Ms Pam Roberts, ANU and Ms Bronwyn Holland, UTS.

These Guidelines are intended for distribution to university academics and administrators who are involved in the design, delivery and accreditation of Engineering programs and courses. Additional electronic copies of the document may be downloaded from the project website at: http://resource.unisa.edu.au/course/view.php?id=568 or at the Australian Learning and Teaching Council website for the project: http://www.altc.edu.au/project-gender-inclusive-curriculum-unisa-2008

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Guidelines for the design of inclusive engineering education programs

These guidelines have been developed as part of the project *Gender inclusive curriculum for engineering and construction management,* funded by the Australian Learning and Teaching Council (ALTC) from 2008-2010. The project was initiated by a team from the University of South Australia led by Associate Professor Julie Mills (Engineering) with Associate Professor Judith Gill (Education) and Ms Virginia Mehrtens (Construction Management). External team members comprised Engineering and Construction Management academics at the University of Melbourne, University of Newcastle and University of Technology Sydney. The guidelines are intended for use by university faculties and individual academics to assist them to develop inclusive engineering programs and courses, in accordance with the accreditation requirements of Engineers Australia.

Why do we need inclusive engineering education?

Despite many campaigns and initiatives over the past 30 years, women continue to be a small minority in the engineering profession and in entrants to engineering degrees. Many books and reports have been written on improving engineering education and addressing the skills shortage in fields such as the construction industry, but most do not acknowledge the gendered and culturally-bound nature of the curriculum. King (2008, p.72) states that "students and others have observed that engineering curricula (and physical science texts) tend to be crafted with over-use of masculine stereotypes and examples, such as automobiles, rockets and weapons" and a US National Science Foundation report observes that the engineering curriculum and culture are "at odds with the value systems of most young women and minorities, and...probably at odds with many talented students of any race and gender" (NSF, 2005: 36)

Engineering is essential for the sustainable development of modern society. Increasing the number of women and others from minority cultural groups in engineering is an issue of social justice, as it directly relates to ensuring that a wider range of citizens play an active and informed part in the control and use of social assets. It will also increase the pool of talent available to the profession. King (2008) recommends that the profession should "address shortages by increasing diversity in engineering workplaces supported by engineering education programs." (p. 111) One suggested way to do this is to "define and implement inclusive curriculum for engineering: reducing male stereotypes within the curriculum, and revitalising the best of the Women in Engineering programs" (p. 107)

What do we mean by an "inclusive curriculum"?

Our focus is on curriculum because it is through the curriculum that engineering students encounter the knowledge, skills and professional attributes that they need to become professional engineers. Our work is based on a constructivist view of learning which argues that students construct their own meanings from information and experiences that they encounter, and so their learning is influenced by their prior experiences and understandings. Learning is also a social activity which occurs through discussion and interactions where ways of thinking, of defining and solving problems and professional attributes and behaviours are modelled. These ideas are critical to our project for creating an inclusive engineering curriculum which supports the equal participation of women and men.

The notion of the engineering curriculum as being gendered or masculine may seem ridiculous or contrary to many who think that engineering programs are about teaching students an objective body of knowledge and skills. However, curriculum involves choices not only about the knowledge and theories students learn, but the language, examples and problems used, the design of teaching and learning activities, the learning environment and mode of delivery, assessment, and more. All of these choices involve assumptions about how students learn and what will be interesting and relevant to them. Some of the differences which previous research has found to be significant for women's participation, retention and success in engineering are:

- women and men typically have different prior knowledge and experiences with technology and science which impacts on how accessible new areas of knowledge are to them
- many women prefer theory to be presented in context, and in particular to understand the social relevance and value of technology
- many women prefer collaborative learning environments

An inclusive curriculum is one in which the subject content covered, the way in which it is taught and the learning methods promoted take into account the diversity of perspectives, attitudes and learning styles brought to the subject by students from different gender, cultural and social groups. Existing undergraduate engineering curricula tend to reflect male cognitive styles and interests. A gender-inclusive curriculum will incorporate a range of teaching, learning and assessment approaches that are more accessible to women. However, this will in no way disadvantage male students as international studies have clearly shown that inclusive curriculum strategies improve student engagement, retention and success for all students, not just women (Fromm, 2003).

In summary the aims of an inclusive curriculum are to:

- Respect every student as an individual
- Enable every student to reach his or her potential
- Recognise, acknowledge and respect the diversity of student interests, values, perspectives, prior experiences, ambitions, learning styles and home circumstances and to use these differences to enrich the learning experience of all students.
- Pay attention to student feedback and evaluations of the informal learning environment as well as to formal coursework, and take these into account in reviewing the curriculum.

Guidelines for faculty managers and academic staff to benchmark current and future performance in inclusivity

The tables on the following three pages can be used by engineering faculties to assess the current level of performance of their engineering programs across a range of indicators of inclusivity, and to improve this by using the suggested approaches.

The tables have been adapted from the University of Newcastle, NSW publication *Benchmarks for Cultural Change in Engineering Education* (Jost, 2004). Using the concept of benchmarking, they incorporate several components that make up an overall engineering education program (or degree) and describe the characteristics that indicate performance at a low (Level 1), moderate (Level 3) and high (Level 5) level of inclusivity.

Benchmarking the inclusivity of an engineering program

	Performance Indicators		
	Benchmark Level 1	**Benchmark Level 3**	**Benchmark Level 5**
Curriculum Design			
Content			
Theory	Theory is taught largely in isolation.	Theory is presented in terms of industry related problems but reduced to a model.	Theory is presented in applied contexts; social and environmental implications are canvassed and debated wherever possible.
Women's interests	Not visible, represented negatively, or are represented in a token way.	Acknowledges women's interests and includes women's experiences.	Women's interests, experiences and achievements are fully integrated into the curriculum.
Problems	Usually require focus on technical detail only.	Problems acknowledge societal needs, and require some acknowledgement in the solution.	Problems are open-ended and focus on societal needs rather than on the technical details of one solution.
Approach	Solely technical.	Draws content from other disciplines but this is not integrated with the rest of the content.	Multi-disciplinary and integrated.
Non-technical skills	Programs may include one course that covers some non-technical skills and professional responsibilities, but these elements comprise a small percentage of class content time and overall assessment.	Some courses integrate technical and non-technical professional skills into content and assessment but this is at the initiative of the individual staff member responsible for the course/program.	All courses are required to integrate technical and non-technical professional skills into content and assessment in a non-trivial way wherever possible.
Assessment tasks	Concentrate on technical knowledge.	A range of assessment tasks is used to assess a defined set of skills.	A number of assessment tasks, methods and criteria are used to test a broad range of skills.
Informal assumed knowledge	At the commencement of a course or program, students are expected to have a level of knowledge which is not formally taught in curricula of prerequisite courses.	Curriculum content assumes no knowledge outside prerequisite curricula.	All required content is included in the curriculum which is designed to build on informal experiences with science and technology that will be familiar to a diverse range of students, e.g. household items and technology.

Benchmarking the inclusivity of an engineering program contd.

	Benchmark Level 1	Benchmark Level 3	Benchmark Level 5
Teaching & Learning			
Learning environment	Creating a co-operative and supportive learning environment is not a faculty/school priority although individual staff may work to achieve it.	The faculty/school encourages staff to facilitate a co-operative learning environment.	Faculty/School policy requires and resources staff to facilitate a cooperative learning environment.
Classroom interaction	University has an antidiscrimination policy but this is not applied at the classroom level by individual teachers.	Some staff uphold University anti-discrimination policies in the classroom but this is not consistent and not implemented on a faculty level.	University anti-discrimination policy is applied consistently by all staff. Inappropriate behaviour in the classroom is dealt with according to policy. Policy is clearly communicated to staff and students by senior management and modelled in their conduct.
Laboratory & equipment use	Students are assumed to be competent in the use of equipment, machinery, apparatus, computers etc.	Students receive a basic introduction to equipment, apparatus etc. relevant to the course.	Further assistance is offered for all students who want to build skills or confidence, such as additional familiarisation sessions. Practical sessions are organised to ensure all students are active participants and all tasks, including scribing, are shared.
Language & images	University-wide policy may exist on inclusive language, but there is no consistent approach to ensure its use in teaching and learning by staff. Inappropriate language is used in classrooms, assignments and staff meetings by teachers and students.	Staff are aware they should use inclusive language and images but actual usage is at their discretion. There is no systematic approach to upholding university-wide policy at faculty or school level.	University policy on use of inclusive language for staff and students is clearly communicated and modelled in the conduct of senior managers. Staff take responsibility for addressing inappropriate interactions or comments in the classroom and challenge inappropriate language from colleagues.

Benchmarking the inclusivity of an engineering program contd.

	Benchmark Level 1	Benchmark Level 3	Benchmark Level 5
Staffing			
Staff profile	Female academic staff comprise < 15% of total academic staff numbers in engineering.	Female academic staff comprise 15-20% of total academic staff numbers in engineering.	Female academic staff comprise > 25% of total academic staff numbers in engineering.
	Academic staff from Non-English speaking backgrounds comprise < 20% of total academic staff numbers in engineering.	Academic staff from Non-English speaking backgrounds comprise 20-25% of total academic staff numbers in engineering.	Academic staff from Non-English speaking backgrounds comprise > 25% of total academic staff numbers in engineering.
	Industrially experienced academic staff comprise < 20% of total academic staff numbers in engineering.	Industrially experienced academic staff comprise 25-30% of total academic staff numbers in engineering.	Industrially experienced academic staff comprise >35% of total academic staff numbers in engineering.
Professional development	Professional development for staff on diversity issues is available on request.	University-wide professional development programs cover diversity issues.	Faculty-based professional development program addresses diversity issues and staff are required to attend and engage by senior management.
Systems & processes			
Implementation	The development and implementation of inclusive curriculum is left up to the individual staff member responsible for each course and/or program.	Information, guidelines or checklists on inclusive curriculum design and teaching methods are made available to staff, use is encouraged and training provided.	A systemic approach is taken to ensure inclusive curriculum and teaching practice is implemented consistently by all staff involved in teaching and/or program design across all courses and programs.
Monitoring	Monitoring or evaluation of curriculum content and teaching methods is at the discretion of individual staff members.	Monitoring and evaluation does not seek feedback from students on inclusiveness, gender and cross-cultural issues and experiences.	A systemic approach is taken to ensure that courses and programs are independently monitored and evaluated for inclusive curriculum and teaching methods. Changes are made in consultation where found necessary.
	Student experiences are not directly monitored or are monitored on a University-wide basis only.	Student experiences are surveyed at least annually by faculty or school at program and course levels.	Student views and experiences are effectively monitored and evaluated with specific attention to inclusiveness, gender and cross-cultural issues.
Staffing	Goal of diversity exists but there is no faculty-specific plan to achieve a diverse academic staff profile.	At faculty level, recruitment and staffing policies are being developed and implemented progressively to increase diversity across academic levels.	Faculty policies and systems exist to increase diversity across academic levels. Progress is monitored with annual evaluations and issues arising are addressed.

Guidelines for academic staff to design and implement an inclusive curriculum

The suggestions and examples in the following pages are intended for use by academics who are involved with designing and teaching engineering courses and programs at university level. They are intended to provide some practical guidelines to ensure that such courses and programs become more inclusive for all students, including women.

Designing an inclusive curriculum usually involves considering all of the components of the curriculum listed below, in approximately this order:

- the assumptions made about the perspectives, prior learning experiences, values and backgrounds of the students
- the aims and objectives of the program or course
- the forms of assessment
- the content
- the teaching and learning methods
- teaching practices
- the learning environment, including the resources needed.

Making any of its components more inclusive can help to make a course more inclusive, but ideally all of its curriculum components should be incorporated into this process. Making a program more inclusive requires consideration of its overall assumptions, aims, objectives, and students' learning experiences, in addition to the inclusivity of its individual courses.

The following tables are based on the book *Gender Inclusive Engineering Education* (Mills, Ayre & Gill, 2010) and are used with permission of the publisher. They provide academic staff with some ideas and examples of things to think about and implement in each of the curriculum dimensions above in order to make their courses more inclusive.

Suggestions for designing and implementing an inclusive curriculum

Assumptions about students	
Think about	**Suggestions**
• the different experiences of students from diverse backgrounds • whether all (or any) have "tinkering" experience (such as working with car engines, building electronic circuits etc. or other typically male hobbies) • 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 program 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 rather than being seen as remedial sessions for some students only.
Systems & processes	
Think about	**Suggestions**
• how to integrate technical understanding with society's needs • developing student 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 priorities with technological and professional goals.
Assessment	
Think about	**Suggestions**
• the evidence that certain assessment methods favour some social and cultural groups • assessment modes need to match the teaching and learning approaches employed • matching assessment techniques to the different teaching and learning approaches which develop particular attributes of engineering graduates • whether the context of questions or assignments may advantage some groups of students over others • how individual or cultural differences, or disability, can give rise to different skills and therefore different ways of excelling.	• provide opportunities for students to demonstrate their learning in a variety of ways, including modes which prevail in other cultural environments • require students to reflect on their learning and offer a choice of assessment strategies to optimise their results • use a mixed portfolio of assessment methods • don't overload students with too much assessment • consider the relevance and the appropriateness of the context of your assignments and exam questions • allow students to choose different ways to present their assignments, for example by oral presentation to peers or a written report.

Suggestions for designing and implementing an inclusive curriculum cont.

Content	
Think about	**Suggestions**
• incorporating the diverse interests and experiences of the community at large beyond the classroom • challenging a singular model of the construction of knowledge • developing, in the classroom and the laboratory, cooperative, communicative, creative and critical capabilities as well as technical, logical and analytical skills and competitive motivation • providing students with 'open-ended' opportunities to relate, apply, generalise from, and hypothesise with, the knowledge and skills they are acquiring • how students who withdraw from engineering programs often complain of a lack of creativity and relevance; and of being bored • relating theory to the 'real world' • finding alternatives to conventional examples of the applications of theoretical material (e.g. car engines) that are engaging of all students • finding novel analogies as these are nearly always gender and culturally specific (e.g. sports) • alternatives to the conventional construction of the history of technology which foregrounds individual male heroes of invention and innovation, and can leave female students feeling somewhat alienated and excluded	• include applications of technology in different physical, cultural and social contexts: e.g. 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, e.g. feminist science • give students investigative problems for which they need to devise their own experiments, rather than standard laboratory exercises with an expected outcome (or 'right answers'). • make creativity and innovation an integral part of the program • include some cross-disciplinary study • focus not only on technical solutions to engineering problems, but also on purported social needs and how these might otherwise be met (e.g. by demand management strategies in energy and water) • use examples of general familiarity and interest, e.g. health-related - devices for the disabled, sanitation, diet, domestic applications and musical contexts • use a range of analogies and examples and explain the point you are making • include women's and non-expert contributions to technological development and innovation. Some examples are: Florence Nightingale (sanitation reform, statistics), Ada Lovelace (collaborated with Babbage on the design of the analytical engine), Alice Tredwell (constructed the Bhore Ghaut railway in India), Emily Roebling (Brooklyn Bridge construction).
Teaching and learning methods	
Think about	**Suggestions**
• active learning strategies have been shown to lead to more effective learning • encouraging more interactive student presence, in all settings • making students more aware and reflexive about their own learning • using a variety of teaching methods to accommodate a range of learning styles and 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: 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 and computer simulations as well as exercises with 'closed' expected results.

Suggestions for designing and implementing an inclusive curriculum cont.

Teaching practices	
Think about	**Suggestions**
• the need to build student confidence from the outset • ensuring that confidence building strategies are continued throughout the program • encouraging students to take more responsibility for their own learning • how to ensure that all students receive equal attention and challenge, without over-compensating • options of pre-selecting groups as well as self-selected group formation for different tasks • whether students are experiencing language difficulties • recognising that some students are more comfortable with cooperative learning styles than competitive ones and vice versa.	• check that technical and jargon terms are understood by everyone • be aware of levels of student confidence and include praise and encouragement in feedback wherever warranted • use group activities, and peer and self assessment options to motivate all students to take an active part • move around in laboratories, make sure roles rotate, sometimes mixing-up groups • use a range of media to provide students with essential (program, and administrative) information: e.g. electronic, as well as written notes, and options to enable them to generate new online content. • allow students plenty of time to respond in class - not everyone wants to respond spontaneously, some prefer to compose their response before replying
Learning environment	
Think about	**Suggestions**
• teacher-student gender and cultural dynamics in the classroom and laboratory • student-student dynamics • whether disruptive behaviour by a dominant group inhibits the learning of other students • whether men and women students select different roles in lab sessions. Does this matter? • the atmosphere of the classroom – is it friendly and interpersonal or business-like or formal and remote? • whether teachers emerge as personally involved in the learning process?	• encourage all students to participate in class. Try to find out why some may not be, (for example, students from some non-Anglo cultures view speaking-up as inappropriate behaviour), but also accept that some prefer to remain quiet • ask students from various groups to help you modify learning activities so that they feel more able to participate • never tolerate racist and sexist remarks, even if only meant jokingly • develop ‘rules’ for classroom and laboratory behaviour, so that each student has opportunities, and encouragement, to participate in the learning activities and no groups dominate discussions or claim the major part of your attention.

Inclusive curriculum examples

A number of exemplars of inclusive engineering courses are included in the book *Gender Inclusive Engineering Education* (Mills, Ayre & Gill, 2010), as well as the website for the related ALTC grant. Details of each are given in the reference list at the end of these guidelines.

The examples below are 'snippets' of inclusive practice from a range of existing engineering courses. Some are sourced from the Mills *et al.* book and are used with permission of the publisher. We hope they may be useful in sparking ideas about something you could apply to your course or program to make it more gender inclusive. Many of these snippets are presented as quotations from publications that may also provide other such examples for you to peruse.

First year engineering

'Boise State University has worked on several strategies to integrate math with engineering applications in the freshman year. ... Eight modules have been developed; the one people most frequently request information about is "Peanut Butter Cracker Manufacturing: Overall Design, Testing, and Implementation of All Facets of a Manufacturing Assembly Process" (Plumb and Reis 2007: 27).

A freshman/sophomore class at the University of California at Berkeley called *Designing Technology for Girls and Women* encouraged students to examine gendered perceptions of the design process (Agogino *et al.* 2004). 'The course covered gender issues associated with new product development from a human-centered design perspective. Students worked in multidisciplinary design teams and participated in interactive workshops with target users and industry sponsors. ... Evaluation showed that students developed a strong belief that 'good design' dictates that technology can and should serve all members of the potential user population, including those traditionally underrepresented with technology' (Dym *et al*. 2005: 107-8).

Cross-disciplinary/professional practice and capstone courses

'The Colorado School of Mines has developed a minor in humanitarian engineering. So far, the proportion of women participating in humanitarian-engineering design projects exceeds the proportion of women in the general population of engineering students. Completed designs include an orphanage in Romania, a drip-irrigation system in Senegal, a water-and-sewage system in Honduras, and village lighting in Ecuador. As a result of the program, students sometimes change their career plans. For example, instead of working for a microchip company, one participant wants to use her electrical engineering degree to work on power distribution for people in developing countries' (Plumb and Reis 2007: 27).

The University of Notre Dame also offers undergraduate research experiences in humanitarian and aid projects in developing countries. Nine out of 10 participants are women 'despite physical hardships and lifting requirements' with a similar ratio in subsequent years (Busch-Vishniac and Jarosz 2007: 256). This book chapter by Busch-Vishniac and Jarosz provides many other examples of inclusive curriculum snippets and is well worth reading.

A 'diversity lecture' was incorporated into a fourth year course *Management and Human Factors in Engineering* that was compulsory for all engineering students at the University of Wollongong in Australia. It was presented by a range of guest speakers including a female pro-vice chancellor, the director of equal opportunity at the university, a female engineering lecturer and postgraduate student and three industry based engineers (two female and one male who was married to a female engineer and who talked about juggling two engineering careers with children). Readings and an assignment on the topic was also set. Feedback questionnaire results indicated a significant increase in awareness of diversity and gender issues for most students (Schafer 2006).

Topic specific examples

Dr Neil Abraham of Bryn Mawr College designed a program to keep undergraduate women in science. 'In addition to designing introductory courses with a minimum of prerequisites so that young women who had not taken physics in high school could enrol, he also involved his students in talking and writing about physics, drawing on their verbal as well as quantitative skills (Kahle 2002: 14). He thus took advantage of their verbal skills rather than limiting his approach to traditionally masculine hands-on tinkering and competition, or to memorizing' (Busch-Vishniac and Jarosz 2007: 251).

Workshop Physics is a scheme developed at Dickinson College and Tufts University in the US. 'An unusual feature of WP [Workshop Physics] is its emphasis on kinesthenic experiments. For example, students run after a ball rolling along by itself. Then they repeat the experiment, hitting the ball repeatedly with a stick, finding that the second ball is much harder to keep up with as it goes faster and faster. This experiment clarifies the difference between motion at a constant speed and motion at constant acceleration.' (Whitten and Burciaga 2000: 219).

References/Resources:

The following list provides details for references and resources referred to in the guidelines along with some additional resources that could be useful for engineering academics and university managers to develop and implement inclusive engineering programs and courses.

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Schafer, S. (2006) 'A new approach to increasing diversity in engineering at the example of women in engineering', *European Journal of Engineering Education, 31*(6): 661-71.

Whitten, B.L. and Burciaga, J.R. (2000) 'Feminist and Multicultural Pedagogy in Physics', *Women's Studies Quarterly, 28*(1-2): 213-35.

Additional resources:

ALTC CG8-696 Gender Inclusive Curriculum in Engineering and Construction Management website (2010) http://resource.unisa.edu.au/course/view.php?id=568

Association of American Colleges and Universities (2009) *DiversityWeb*. http://www.diversityweb.org/

EngineeringExamples.org (2009) *EngineeringExamples.org* http://www.engineeringexamples.org

Hermida, J. (2009) 'Inclusive teaching strategies to promote non-traditional student success', *Tomorrow's Professor Mailing List*. Online posting. http://cgi.stanford.edu/~dept-ctl/cgi-bin/tomprof/posting.php?ID=966

What's Gender Got To Do with It? Gender Inclusive Engineering Education (2010) IEEE career webinar presented by Julie Mills, Judith Gill and Mary Ayre. http://www.ieeeusa.org/careers/webinars/2010/webinar-11-02-10.html

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