London Engineering Project HEI Guidelines to promote inclusive engineering courses: Towards an Inclusive Engineering Curriculum

These guidelines form part of a body of practical approaches and resources, developed by the London Engineering Project, to assist with achieving its key aim of increasing and widening participation in engineering Higher Education. Informed by research and drawing on existing good practice the aim has been to provide a practical tool for departments to use in reviewing and developing engineering curricula. The guidance responds to concerns raised by a diversity of students, not only those from under-represented groups, hence their application is likely to improve the student experience for all students, equipping them with the necessary skills to become engineers and to reach their potential.

Goal	Rationale	Actions to promote inclusion
1. Place engineering theory within its practical context	A number of studies identify that students of engineering and physical sciences fail to perceive these subjects as relevant to their daily lives and wider goals, and this can influence how, and how well, students learn *(ref. 1,9,10,13,17,24*). Demonstrating the ways that day-to-day engineering practice impacts on some of the great global challenges can make a real difference to the way students engage with that practice. Moreover, an appreciation of context and purpose can make difficult concepts easier to understand, and there is substantial evidence that women, in particular, value an approach that recognises this. Finding effective ways of linking theoretical principles to real life applications requires an understanding of the ways that gender, background and ethnicity shape the perceptions and real life experiences of students *(ref. 11,12,14)*. Links that seem obvious to the lecturer may not appear so to students because of those perceptions and experiences.	▪ Demonstrate how engineering relates to society and to a broad range of social and environmental needs. ▪ Use a broad range of contemporary examples and contexts. ▪ Include problems which consider human, social, environmental and global considerations. ▪ Incorporate opportunities for students to identify applications which reflect their experiences, interests and aspirations. ▪ Ensure the practical applications of theoretical principles are an integral part of teaching practice. ▪ Build inter-disciplinary links and apply them to existing courses and teaching material. ▪ Highlight, showcase and recognise the contributions of a range of cultures to the development of engineering principles, concepts and applications.
2. Provide opportunities for problem-based learning	An approach that uses a specific, real context or problem situation as the organiser for technical learning has been found to be effective in engaging students, and particularly women *(ref.10,13,22,24)*. In problem-based learning, the path to a solution leads to	▪ Provide opportunities for project and laboratory work in which students learn theoretical principles through tackling relevant 'real-world' problems. ▪ Provide students with work placements and projects in industry to enrich theoretical studies by providing

	an appreciation of underlying theory, and for a well formulated problem, an added benefit is that purpose and relevance can be self-evident. There is also consensus within industry and university engineering departments of the need for closer collaboration in order to enable students to gain experience in the application of theoretical understanding to real applications encountered in industry *(ref. 17)*. The opportunity for group work allows the development of more co-operative[1] approaches which can be more attractive to, and inclusive of, women *(ref.19,22)*. Problem-based learning is also helpful to BME students who are more likely to start a degree with non-standard qualifications and who therefore may be relatively disadvantaged by more traditional ('chalk and talk') approaches to learning *(ref. 2)*.	insight, relevance and purpose.
3. Discuss engineering practice in society	Engineering is often presented as the neutral, value free application of technical principles, with engineering education requiring solely the transmission of technical knowledge. In practice, since engineering decisions shape society, the implementation of positive engineering solutions requires engineers to engage with both social and technical implications *(ref.14,17).* A recognition of engineering practice being open to change, being shaped by social and political factors and not necessarily involving a unique, correct answer is likely to lead to increased motivation, particularly amongst female students *(ref. 4)*. For BME students, a crucial factor in their engagement is the extent to which engineering practice takes account of their own communities' values and perspectives *(ref. 21)*.	▪ Include discussion of the social, political, environmental and cultural factors that influence engineering practice and how engineering has affected/shaped world history. ▪ Discuss value conflicts and uncertainties relevant to the subject and build understanding of the role that ethical dimensions have on the implementation of engineering solutions. ▪ Showcase engineering practice from a range of countries, including developing countries.
4. Equip students with	The diverse work of a professional engineer requires a	▪ Build into the curriculum opportunities to develop

[1] Co-operative approaches need not exclude some element of competition, for example, co-operating within a group, whilst competing with other groups.

the full range of skills to become professional engineers	broad set of generic skills to support and enable the effective application of technical principles *(ref. 18).* Recognising these generic skills as a necessary part of an engineering identity, and valuing them as such will encourage students to develop them alongside their technical skills, and in so doing enhance their effectiveness as engineers. Evidence suggests that whilst all students would welcome more training in these generic skills, and realise that employers require them, they are not always clear about how these generic skills relate to their curriculum. BME students, particularly, are less likely to feel that they have improved their generic skills at university and to understand their relevance *(ref. 2,4,7,14,18,16.)*	general skills e.g. communication skills, social skills, problem solving, negotiation, project management, teamwork skills, report writing and presentation skills. ▪ Embed skills development and articulation in programmes, in a consistent way such that students are aware of the direct relevance of a given skill to their future employability. ▪ Develop a structure to embed existing institution-wide skills provision within programmes. ▪ Promote interaction between HEI's and employers at the programme level.
5. Support the transition from education to employment	There is evidence that all students, female, male and BME want a more practical curriculum, and that women, in particular, benefit from opportunities to get experience of 'hands-on' laboratory work *(ref. 1,7,14,16,18).* Industry visits and placements offer significant opportunities for students to experience 'real engineering' and to meet positive real models, however it is vital that this initial contact with industry is well planned to ensure positive experiences that challenge rather than reinforce stereotypes *(ref. 1,2,5,7,24).*	▪ Provide timely links between lecture materials and laboratory activities and make links explicit. ▪ Demonstrate the links between curriculum content and range of potential career opportunities. ▪ Maximise use of visiting lecturers (including via video-conferencing) and exchange programmes to enable learning from a diversity of female, male, and BME lecturers within academia and industry. Video-conferencing[2] can be used to maximise international links, including those from developing countries. ▪ Organise industry visits to enhance students' awareness and to enable contact with a diversity of female, male and BME engineers. ▪ Enable students to undertake industrial placements, whether for a full year or shorter periods, to facilitate the transition from education to work. Evidence shows that the majority of graduates who found a job immediately after graduation had done a placement ▪ Provide BME SET role models through interaction between HEI's and BME Networks and business forums at the programme level.

[2]

6. Develop delivery strategies to include all students	It is reported that many students would like more opportunities for interactive learning, and there is evidence to show that teacher-centred activities and whole-class instruction are more detrimental to learning for women than men *(ref. 10,17,19).* A wide range of studies show that on STEM courses, in particular, male students exert control over discussions, are given more attention by lecturers and are asked more challenging questions *(ref. 4,13)*. A similar picture emerges for BME students, with reports of them being marginalised and becoming 'invisible' in traditional STEM learning situations *(ref. 6,23)*. A learning environment and teaching strategy that take account of a range of learning styles will engage the broadest range of students.	▪ Use a range of teaching methods to accommodate students' varied interests, values, prior experiences, ambitions and learning styles. ▪ Include interactive teaching techniques and questioning methods that enable interaction and reflection e.g. use of white boards; discussion of questions in pairs / small groups; building in individual thinking-time before asking for responses. ▪ Incorporate group work and plan groups to enable all students to participate equally and to increase their ability/confidence in a range of skills e.g. where groups are not self-selected, rotate group roles; provide opportunities for women/BME students to choose to work together. ▪ Define and clarify technical terminology and jargon when it is introduced. ▪ Be aware of student-student interactions and vary teaching strategies to promote inclusion of all students. ▪ Have high expectations of all students with clear feedback mechanisms to praise achievement and enable improvement as required. ▪ Regularly review teaching practice and/or use peer observation to ensure active engagement of all students e.g. monitor who tends to ask questions, answer questions, and lead groupwork. ▪ Enable 'Fast Track' provisions for mathematics, ICT skills and English to be made at an earlier, pre-entry, stage including collaborative provision within FE and sixth forms.
7. Develop a positive learning environment and culture that is inclusive to all students	The culture of an Engineering department the 'how we do things round here' develops, largely unconsciously, around the needs, interests and experiences of the people who teach and learn within it. Alongside technical knowledge, taught through the formal	▪ Participate in staff training/workshops to increase awareness of gender and culture related differences in learning styles, educational experiences and self-confidence of students and to identify strategies to promote inclusion.

	curriculum, students learn the informal rules, beliefs and attitudes, 'the hidden curriculum', from the experience of attending and learning within a specific department *(ref. 14,20)*. Engineering in academia (and as a profession), is white and male-dominated and, unsurprisingly, reflects and reinforces Western male norms *(ref. 4,19).* Curriculum influences culture, as does teaching style and course content, but a range of other taken-for-granted, less-tangible, issues have a significant effect on the extent to which an environment challenges stereotypes of who should or could be engineers, or reinforces them *(ref. 4,24)*. These include the physical environment, the nature of day-to-day conversations and banter, the pictures on the walls, the style and content of notice boards, departmental publications and ease of contact with other women and/or minority ethnic students *(ref. 19).*	▪ Use language and course materials that are inclusive in terms of gender, culture and ethnicity e.g. make reference to a diversity of female, male and BME engineers; ensure that images reflect a diversity of engineers; use examples and analogies that are likely to interest a diversity of students. ▪ Use inclusive language e.g. avoid '*Morning Lads'*; continually referring to engineers as 'he'. ▪ Challenge comments and 'jokes' about female engineers – whilst offence may not be intended, they contribute to a feeling of being unwelcome and not taken seriously as an engineer. ▪ Display current work and achievements of a diversity of students. ▪ Use positive images of a diversity of engineers; promoting the contribution of female, male and BME staff. ▪ Ensure that any materials used by, or on display within the department are inclusive and do not reinforce stereotypes. ▪ Display opportunities for networking, attending conferences and linking with employers that are inclusive to female, male and BME students. ▪ Create a clean, well-organised physical environment. ▪ Provide sufficient women's toilets and facilities.
8. Offer support and networking opportunities	Membership of social and professional networks contribute to a sense of belonging within the engineering community and impact on academic progress, career choice and progression. Whilst all students need support to thrive, being in the minority can be a particularly isolating experience, and seemingly small inequities may have cumulatively large negative effects upon students' confidence and career aspirations *(ref. 4,7,24).* Appropriate support structures and ready networking opportunities help	▪ Conduct induction processes that extend over the first term. Pay attention to students from minority groups in order to be sensitive to their needs and to assist them to build a support network. Involve current students and lecturers from minority groups. ▪ Offer a range of support mechanisms to students e.g. mentoring, support groups, flexible allocation of tutors, access to professional networks. ▪ Ensure that support is structured into industrial placements – this will enable students in the

	prevent this, and will particularly benefit women and BME students, who tend to have limited/less access to informal networking opportunities or role models *(ref.1,19,22).*	minority to develop effective strategies for their transition to employment. ▪ Offer a range of ways for students to mix socially that appeal to a range of interests and backgrounds. ▪ Encourage students to become members of their associated professional body (or bodies). ▪ Promote and encouraging participation in SET activities outside the degree programme. ▪ Make students aware that undertaking a placement provides opportunities to network.
9. Facilitate links between students and lecturers	Clearly, lecturers are a key influence on students' motivation and achievement, hence an environment where contact with lecturers is regular and commonplace is likely to benefit all students.	▪ Enable clear, accessible routes for all students to approach lecturers. ▪ Encourage students to contact lecturers and ask questions. ▪ Offer ongoing student support, pastoral as well as academic, and an effective tutorial system with tutors briefed on, and appropriate to, their role. ▪ Develop openness in departmental management and communication.
10. Promote co-operative working amongst students	There is substantial evidence of women's preference for a co-operative rather than competitive approach to learning and work, and team-working skills are regarded as essential by employers *(ref. 4,13,17).* A curriculum that integrates the social applications of engineering into the learning process and enables discussion of the values implicit in these requires, and also promotes, a more-co-operative style of learning, is generally more attractive to women and does not disadvantage male students *(ref. 4,14,18).*	▪ Encourage co-operation among students e.g. build small-group discussion /problem-solving into lectures ▪ Support the formation of peer study groups. ▪ Provide study areas for students that promote interaction and co-operative[3] working. ▪ Conduct careful timetabling to ensure (part-time) student carers can engage fully. ▪ Combat isolationism through group projects and teamwork.
11. Use a range of assessment methods	In recognition of students' different learning styles, use of a range of assessment methods will avoid disadvantaging certain groups *(ref.4,13,14).*	▪ Use a range of assessment methods to reflect different learning styles in both technical and non-technical aspects. ▪ Make explicit the grading scheme of any assessment method.

[3]

		▪ Include student self-assessment and review. ▪ Implement anonymous marking, where possible, in individual assessments / examinations.
12. Develop mechanisms to make use of student feedback	Mechanisms that allow feedback from students (and industry) to shape the curriculum and the learning environment are key to developing courses which enable a diversity of female, male and BME students to thrive, fulfil their potential and aspire *(ref. 24)*.	▪ Devise a comprehensive, timely and inclusive student feedback procedure. ▪ Evaluate and review curriculum, teaching style and culture based on feedback from a diversity of students. ▪ Take account of student feedback on the informal learning environment as well as the formal parts of the course. ▪ Incorporate opportunities for rapid feedback e.g. '*instant whinge'* systems allow students to give instant feedback electronically to a moderator who will direct comments to the lecturer without revealing the identity of the student. The presence of the moderator provides a degree of anonymity for the student whilst ensuring some accountability for comments made. ▪ Consult widely on course design and research areas including feedback from a diversity of students and from industry.

References

1. Baglihole, B. (2006) *Encounters with engineering: first experiences of women students*, Research Briefing, Loughborough University.

2. K. Booth, H. Takruri-Rizk, L. Welamedage and K. Mansi (2007) *BME participation in Northwest SET*, Final Report, ESF project 061024NW3 (NW BME Entry to SET Careers).

3. Carter, D. J., and Wilson, R. (1997) *Minorities in higher education* Washington DC, American Council on Education.

4. Cronin, Catherine; Foster, Maureen & Lister, Elizabeth (1999) *Set for the future: Working towards inclusive science, engineering and technology curricula in higher education;* Studies in Higher Education, Volume 24, Number 2, June 1999, pp.165-182(18).

5. DfES Research Report 448 (2003) *Minority ethnic students in higher education: Interim Report*, Institute for Employment Studies.

6. Driver, G. (1982) '*Ethnicity and cultural competence: Aspects of interaction in multi-racial classrooms'* in Bagley, C. and Verma, G.K., 'Self-Concept, Achievement and Multicultural Education' London: Macmillan.

7. Faulkner, W. (2006) *Genders in / of engineering, A Research Report,* Science Studies Unit, University of Edinburgh.

8. *The Future of higher education White Paper* (cm 5735) (2003) DfES Race Impact Assessment.

9. *Girls in the physics classroom: a teachers' guide for action* (2006) Institute of Physics.

10. Jones, L. & Teresa, S. (1995) *Confidence and mathematics: a gender issue?* Gender and Education, Vol. 7, No. 2.

11. *Land of Plenty: Diversity as America's competitive edge in science, engineering & technology* (2000) Report of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering & Technology Development.

12. *Mills, J. & Ayre, M. (2003) Implementing an inclusive curriculum for women in engineering education; Journal of Professional Issues in Engineering Education and Practice 129(4): 203-10.*

13. Murphy, P. & Whitelegg, E. (2006) The Open University *Girls in the physics classroom, a review of the research on the participation of girls in physics;* Institute of Physics.

14. Nafalski, Andrew; Ayre, M & Gol, O. (2002) *Inclusive engineering curricula – design considerations;* School of Electrical and Information Engineering, School of Advanced Manufacturing and Mechanical Engineering; University of South Australia.

15. Powell, A; Baglihole, B; Dainty, A. & Neale, R. (2004) *Does the engineering culture in UK higher education advance women's careers?* Equal Opportunities International 23(7/8): 21-38.

16. Read, E. & Wojcik, A. (2007) *Reshaping engineering curriculum to enhance the student experience and reflect changing student profiles,* presented at the Annual Conference of the Society for Research into Higher Education (SRHE) December 2007.

17. Roger, A. & Duffield, J. (2000) *Factors underlying persistent gendered option choices in school science and technology in Scotland,*
Gender and Education, Vol. 12, No. 3, pp. 367-383.

18. Royal Academy of Engineering (2007) *Educating engineers for the 21st Century.*

19. Sagebiel, F. & Dahmen, J. (2005) *Masculinities in organisational cultures in engineering education in Europe: results of the European Project WomEng.* European Journal of Engineering Education, Vol. 31, No.1 March 2006, .5-14

20. Seaton (2002) Reforming the hidden curriculum, Curriculum Perspectives, vol 22, no.1, April pp.9-15.

21. Torkington, N.P.K. (ed.) (1996) *The social construction of knowledge – A case for Black Studies*, Liverpool: Liverpool Hope Press.

22. Viefers, S. Christie, M. & Ferdos, F. (2005) *Gender equity in higher education: why and how? A case study of gender issues in a science faculty*; European Journal of Engineering Education, Vol. 31, No. 1, March 2006, 15–22.

23. Westcott, E. (1996) *Race Matters;* AUT Bulletin, pp12-13

24. Women in North West Engineering (WEWIN) (2006) School of Computing, Science & Engineering, University of Salford.