ROYAL ACADEMY OF ENGINEERING

UCL Centre for Engineering Education

Designing inclusion into engineering education

A fresh, practical look at how diversity impacts on engineering and strategies for change

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www.katalytik.co.uk

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Contents

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This report goes beyond simply proposing ways of increasing the numbers of women or other targeted groups and reframes diversity to be more relevant to engineering.”

Executive summary

Introduction

Educators have a fundamental role to play in addressing the skills gap in engineering, but making the profession more welcoming to everyone is challenging. This report sets out a framework to build an inclusive higher education environment in engineering and technology. Based on work at UCL from 2011 to 2016, which culminated in a symposium, it also includes contributions from experts across the world and is supported by the Royal Academy of Engineering (the Academy).

Many engineering faculties and departments in UK universities participate in outreach programmes, awards and the Athena SWAN charter, but these do not bring about the dramatic change in culture that is needed to ensure underrepresented groups can be their best. Further, it may mean that engineering itself misses out on innovation.

It is possible that diversity or inclusion as topics are not integral parts of engineering curricula because engineering leaders have not considered the benefits of including it in highly technical programmes of study. This report sets out why and how engineering can be enriched by considering diversity and inclusion around a model of four pillars (**Figure 1**).

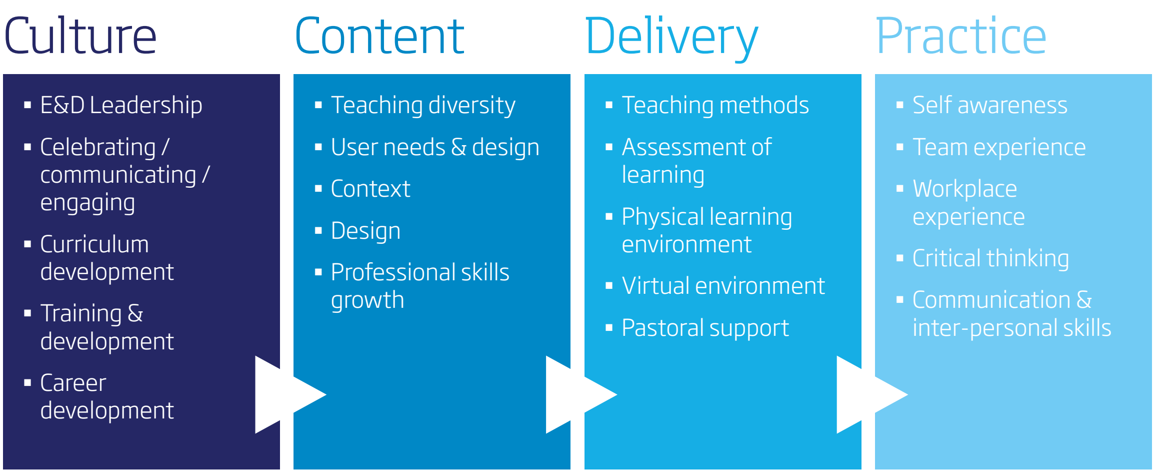


Figure 1: The four pillar model for inclusive engineering education

It draws upon practices from across the world to suggest a change process and actions that will help faculties and departments build an environment that will enable innovation to be driven by diversity (**Figure 2**).

This report also builds on a recent study by the Academy (2017) that focuses on creating cultures where engineers thrive. The aim is to work towards an inclusive graduate engineer who understands that they are not working in a monoculture and not producing products or solutions for a homogenous customer.

Reframing diversity and inclusion for engineering faculties

The 'four pillars' offer a structured approach to enable every department, school and faculty to take a fresh look at how they address diversity. The framework is designed to stimulate discussion and the development of an action plan for change, allowing for incremental changes rather than wholescale redesign in most cases. The authors found that the framework itself can help educators make small adjustments to projects, scenarios, courses and their assessment, to catalyse a shift in thinking.

The four pillars address the following objectives:

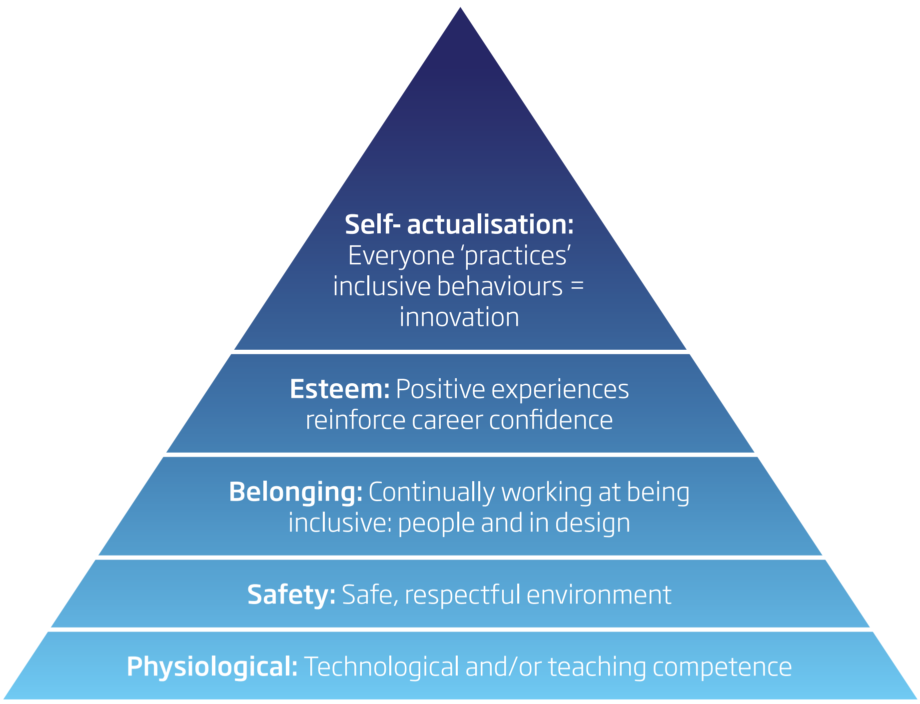
- Extending excellence in teaching of engineering and technology to address diversity and inclusion.
- Creating a safe and welcoming place that meets the diverse needs of students and educators.
- Providing space for students to feel like they belong and can practice professional skills, including inclusive behaviours that will serve them as future managers/leaders.
- Growing career confidence of all students to make the most of the talent within engineering.
- Encouraging innovation and diversity in solutions to problems.

These are framed around Maslow's Hierarchy of Needs (Maslow, 1943)

Roles and responsibilities

The responsibility for ensuring that the engineering profession is fit for the challenges of the 21st century lies not with underrepresented groups but with the whole profession.

Figure 2: Hierarchy of excellence in engineering – innovation is driven by diversity



Conclusions

The aim is to address the three irrefutable facts that engineering:

- has in the past failed to provide solutions for some populations
- is diverse in many ways, but there is no excuse for not providing equal outcomes for students from different backgrounds
- needs to adapt to meet the professional standards expected of engineers for example, in the UK the Standard for Professional Engineering Competence (UKSPEC).

The challenge has been to clarify how diversity and inclusion can be seen to be relevant to engineers and engineering and empower the profession to be both confident and competent in addressing it.

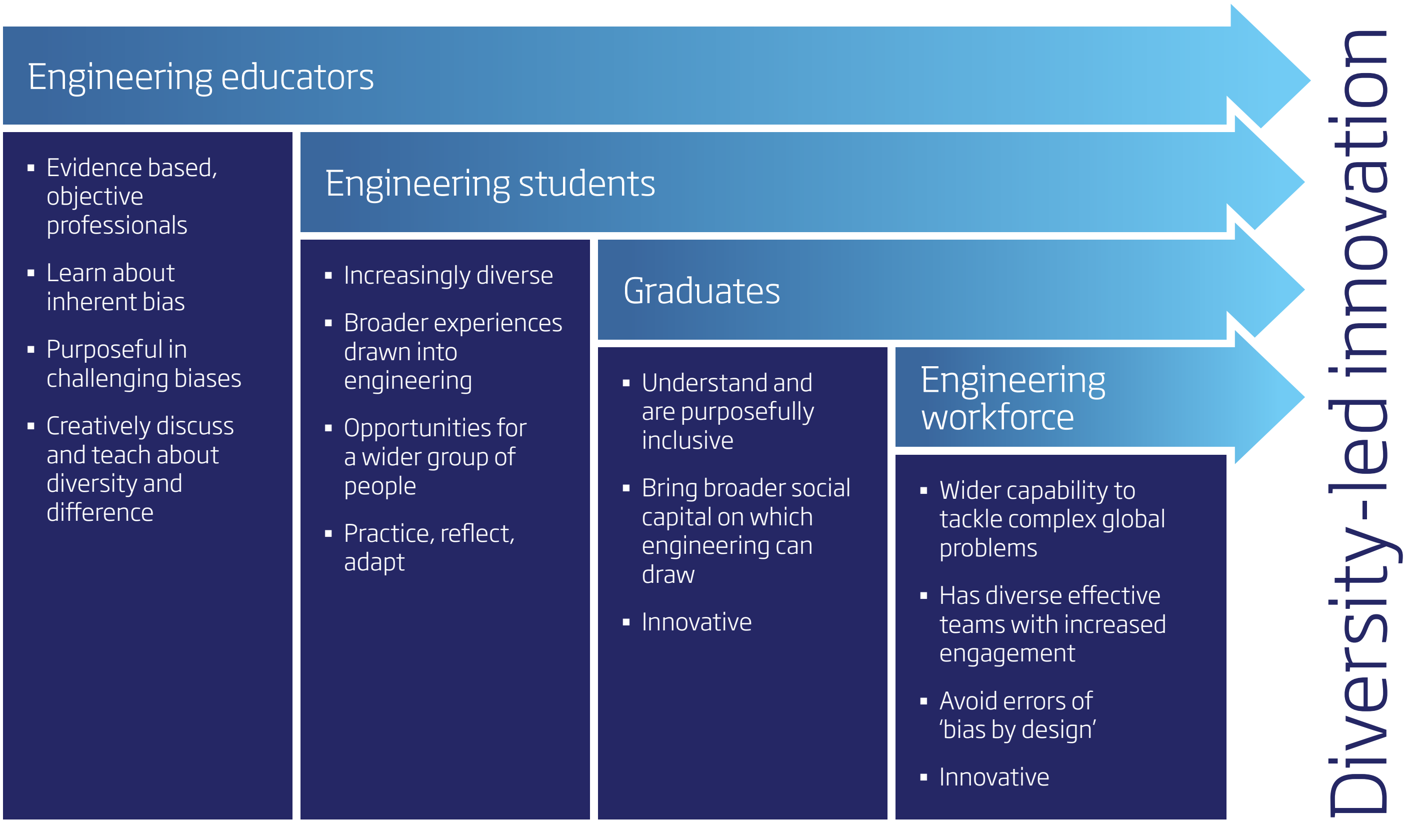
Real-world projects, scenarios and case studies offer an authentic experience that prepares students to face the engineering challenges of the 21st century. They also provide a context to develop the skills that will empower engineering students to be more self-aware, better communicators and/or managers.

Recommendations fall into three categories:

Higher education leaders and educators

Departments, schools and faculties should have a conversation around the four-pillar model with a view to developing an evidence-based five-year plan. By opening the conversation to peer review with fellow institutions and professional bodies, ideas and good practice can contribute to raised standards, co-creation of resources and greater confidence in what works.

Some ideas for action are included within the report under each pillar. These are collated at the end of each chapter.



Professional bodies and learned societies

There are 36 members of the Engineering Council, the regulatory body for the profession in the UK. In contrast, the UK science community, which has discipline-related professional bodies, has undertaken a wide range of studies into careers and gender issues within and across disciplines.

The professional engineering bodies and learned societies could provide greater support and research to address inclusion and diversity within taught courses through the course accreditation process.

Furthermore, this report highlights additional areas where the professional engineering institutions (PEIs) and their members could collaborate across disciplines to build case studies to enrich the professional development of students. Support through professional institutions and sectoral bodies could help:

- define criteria for students to undertake a professional skills-based reflection around inclusion during project evaluations
- create a set of team-based case studies with a diversity slant, sponsored by PEIs, to be used in tutorials, coursework or to enrich challenges given to students
- collate a good practice repository on inclusive teaching and learning, including assessment and design.

Suggestions to support staff creating inclusive materials:

- Illustrations for use in pre-work for modules, images in slides and group or tutorial activities.
- A set of team-based case studies with a diversity slant, to be used in tutorials, coursework or to enrich challenges given to students.
- Case studies and activities that can help course tutors or leaders extend the examples they use to be more inclusive and contextual for distinct groups of users.

Research to gather evidence, provide benchmarks for change and create resources

Suggestions for further work have emerged from discussions with academics around the four-pillar framework. Funding is required for the following cooperative research and discipline related studies:

- A study to mirror the *Planning for Success: Good Practice in University Science Departments* report (Royal Society of Chemistry, 2009) in order to share good practice from undergraduate to dean.
- A review of what and how diversity and inclusion are, or could be, covered within exisiting engineering programmes. A pilot course to be co-created across a number of universities.
- An exploration of how social science research, datasets on society or policy studies could provide valuable insights into global and societal challenges, plus new perpsectives in research for student projects.
- A good practice report about teams and inclusion in engineering that incldues a resource to assimilate university efforts around managing and supporting teams and development of a tool for managing student teams.

1 Introduction

Addressing the skills gap in engineering by increasing diversity demands the attention of engineering educators. This report sets out a framework to build an inclusive and diverse higher education environment in engineering and technology.

Practical actions are suggested for professional bodies, engineering leaders and course tutors to fill gaps in knowledge, raise standards and create engineers who can demonstrate their awareness and competence in valuing diversity as required in the UK by the Engineering Council's UK Professional Standards Specification (UKSPEC).

1.1 Overview

This report builds on an international symposium on inclusive engineering in 2016, follow on conversations and the Academy's recent work on cultures in engineering (Royal Academy of Engineering, 2017), as part of its Diversity and Inclusion Programme. A detailed analysis presents ideas of how engineering education could become more inclusive and lower the barrier to progress. It shows that many of the steps that could be taken are straightforward, but would make a significant difference to individuals.

Imperatives for change:

1. Engineering is unequal. Alongside pedagogical changes in engineering education (EE) and the focus on active learning approaches, research has highlighted that women are marginalised in engineering project work (Seron and Silbey, 2015). The experiences of exclusion by women in engineering extend to other minority groups with career defining consequences:
   - The degree attainment gap has remained nearly static over the last 10 years: In 2012–13, 57.1% of UK-domiciled Black, Asian and minority ethnic (BAME) students received a top degree, compared with 73.2% of White British students – a gap of 16.1%, although this is smaller for STEM subjects (HEFCE, 2015 and Stevenson, 2012).
   - Fewer women and BAME engineering graduates choose to work in engineering after graduation than their white male counterparts (McWhinnie and Peters, 2012).
2. Employers require graduates capable of considering and communicating with different user groups during research or product design, interpreting standards and working with datasets.
3. Initiatives to date have been 'representative', focusing on increasing the numbers filling the pipeline rather than on change to the culture itself. These initiatives are seen to have failed as the number of women has not increased significantly.
4. Engineering has been slow to engage with programmes such as Athena SWAN or Stonewall.

Diversity and inclusion are referred to frequently in this report, the Academy definitions are used:

Diversity considers similarities and differences in terms of age, ethnicity, disability, gender and religion, as well as less visible differences such as sexual orientation, disability, religion, educational background, personality type, nationality etc.

Inclusion is the extent to which an individual feels valued for who they are in terms of personal and professional background, experience and skills, and the extent to which an individual feels they belong or 'fit' in the engineering profession and in their organisation.

1.2 A new approach for engineering education

Historical approaches to change in engineering and technology have focused on filling the pipeline and training women or minorities to fit into a culture. Efforts to bring about culture change by adopting policies and processes (a change approach summarised by Soudien (2010)) seem to have stalled in engineering and technology. During the development phase of this report some engineering department heads asked what to do once the unconscious bias training had been completed. This report translates Soudien's model into a framework that cuts across the policies, processes and practices common within an engineering and technology education environment and provides a structure, ideas of discrete actions as well as recommendations for providing supportive resources and knowledge sharing. This theoretical approach is summarised in **Figure 1**.

Five levels of growth for engineering and technology departments are

Figure 1: A theoretical approach to change: A three-pronged approach to inclusive engineering education (informed by Soudien, 2010)

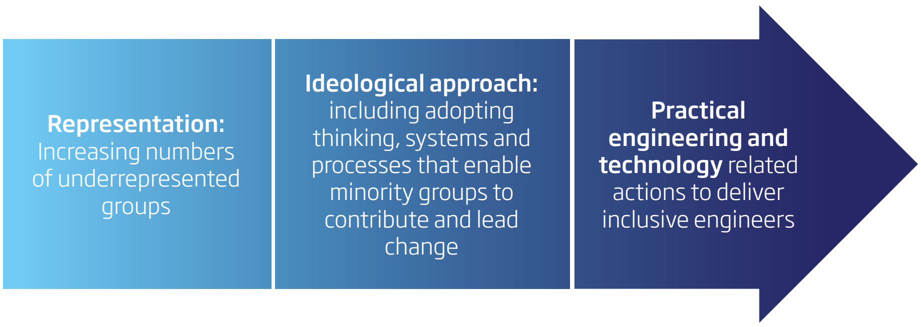
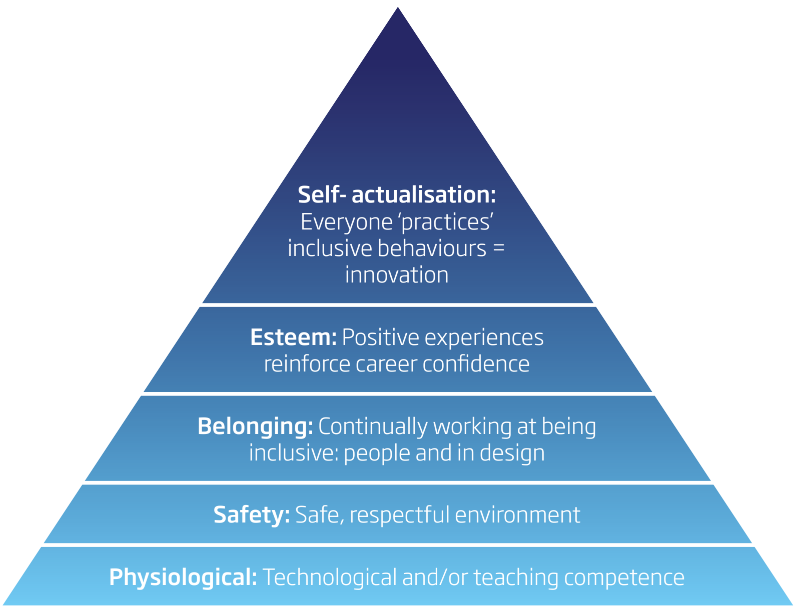


Figure 2: Hierarchy of excellence in engineering – innovation is driven by diversity



identified by adapting Maslow's (Maslow, 1943) hierarchy of needs to engineering education (**Figure 2**). They are as follows:

1. Technological and/or teaching competence.
2. A safe and respectful engineering education environment.
3. Engineers work towards being inclusive and focus on involving and including people, as well as considering inclusion and users in designs.
4. Engineers grow in career confidence.
5. A healthy environment empowers each engineer to be inclusive and confident in discussing and considering difference, and uses data on difference to be innovative and solve problems that previously were not seen. Innovation is driven by diversity.

This report presents a framework for engineering leaders and educators so they can review what they currently do and explore what else they could do to enrich and broaden the education of engineers. The aim is that they appreciate that they are not working in a monoculture and are not producing products for a homogenous user.

Facts

- Engineering is still overwhelmingly male in the UK, with the lowest representation of women engineering undergraduates in Europe at 15.8% (European Commission, 2015).
- According to the UK's Stonewall Workplace Equality Index, less than 0.5% of respondents worked for engineering firms compared to around 20% of all workers in the country. A large UK survey of students showed that male students felt women students are missing out, but the women students denied this. (Peters and McWhinnie, 2012).
- Diary studies of engineering students (Seron et al, 2015) provide conclusive evidence of (openly denied) bullying and harassment of women engineering students.
- Fewer engineering departments are entering or achieving Athena SWAN[1] awards than their science counterparts.
- UKSPEC[2] requires engineers to be aware of diversity.
- Changes to disability support threatens the loss of expertise for students.
- People in a minority have an increased cognitive load that adds a burden to their participation and can make them appear less confident or less present.
- A study of 366 public companies found that those in the top quartile for ethnic and racial diversity in management were 35% more likely to have financial returns above their industry mean, and those in the top quartile for gender diversity were 15% more likely to have returns above the industry mean (McKinsey, 2015).

1.3 Methodology of this report

In 2016, the UCL Centre for Engineering Education hosted an international Inclusive Engineering Education Symposium.

Ahead of the symposium, a three-pillar framework for advancing inclusion in engineering education was proposed by the symposium chair. On reviewing the papers and written contributions, a fourth pillar was added to the model. The discussion was extended beyond the symposium and evidence and evaluated examples have been contributed by global experts from engineering education, social science and diversity from Australia, the US and Europe. This evidence draws upon:

- research
- evaluated interventions

1 www.ecu.ac.uk/equality-charters/athena-swan

2 The UK standard for professional engineers in the UK https://goo.gl/u7urkd

Figure 3: The four pillar model for inclusive engineering education

- strategies to promote a culture of respect among students and educators
- examples from universities, specialist consultants, employers and non-profit organisations.

For example, the development of the Integrated Engineering Programme at UCL, expertise from RWTH Aachen University and shared learning from the Stanford University gender in engineering project, the organisational and management of engineering at the University of South Australia and team working at Purdue University. Additional contributions illustrate the support for minority and underrepresented groups in engineering that can help to enhance their experience and outcomes.

1.4 Objectives

The transformation of engineering through embedding inclusion and diversity in the education and training of engineers has five objectives that relate to **Figure 2**:

1. Extending excellence in teaching of engineering to address diversity and inclusion.
2. Creating a safe and welcoming place that meets the diverse needs of students and educators.
3. Providing space for students to feel like they belong and can practice professional skills, including inclusive behaviours that will serve them as future managers and/or leaders.
4. Growing career confidence of all students to make the most of the talent within engineering.
5. Being more innovative and practising diversity-led innovation in solutions to problems.

1.5 Report structure

This report goes beyond simply proposing ways of increasing the numbers of women or other targeted groups and reframes diversity to be more relevant to engineering.

A structured approach to inclusion and diversity is made around four pillars, **Figure 3**, to enable every department or faculty to embed this approach. The framework is designed to stimulate discussion and action.

In particular, the work of social scientists is translated into practical measures that engineering academics and leaders could implement. Where possible, information is represented diagrammatically to condense large amounts of background knowledge into an accessible format. To this end, the report includes a set of references and an extended bibliography.

Aside from the symposium and written contributions, separate interviews have been undertaken.

The report is structured around the four pillars and future actions are summarised in the final, sixth chapter.

Chapter 2 explores the first pillar – engineering departmental **culture** – and breaks down the areas for a focused discussion into five areas.

Chapter 3 explores the second pillar – course **content –** in an overarching way, so it is relevant to all courses. Resources and methods are indicated.

Chapter 4 examines the third pillar – how the **delivery** of course material can be made inclusive – and brings examples of innovative and effective teaching methods, assessment and classroom management.

Chapter 5 highlights the fourth pillar – **practice** – and outlines five areas that constitute the opportunity for students to gain experience in being inclusive in both the behaviours they exhibit and the work that they produce.

Chapter 6 summarises and explains the approach of creating an inclusive engineer and identifies recommendations for a **sustainable change**.

“

There are examples of women engineering academics taking on the responsibility for Athena SWAN submissions jeopardising their career by losing focus on research and publications while they struggle to manage departmental submissions.”

> “The Athena SWAN gender charter principle provides the rationale for representation: we acknowledge that **academia cannot reach its full potential** unless it can benefit from the talents of all.”
>
> **ECU Gender Charter 2015**

2 Leadership and culture change

The matrix in which you work and deliver your education programmes

Creating an inclusive workplace is to build an engaged, productive and energised workforce. This pillar is referred to as the leadership and culture pillar as, fundamentally, it is the matrix in which engineering education is delivered. The aim is to reinforce the principles of equitable and fulfilled personal growth for both staff and students.

The aim of this report is to work towards an inclusive graduate engineer or technologist who understands that they are not working in a monoculture and not producing products or solutions for a homogenous customer.

All demographic groups of engineers see the engineering culture as a problem-solving one, safety conscious and a place where engineers are proud of the work they do (Royal Academy of Engineering, 2017). This chapter sets out a framework of good practice to build an inclusive teaching and learning culture in departments and faculties, specifically relevant to engineering and technology.

As a discipline, engineering and technology has been involved in many 'girls in' and outreach programmes, yet these have failed to deliver significant changes to the gender make-up of engineering courses (Barnard et al, 2011). While 'Men as Allies' has itself become a campaign, it is frequently women or minorities who organise committees, argue for resources or deliver projects.

Minority employees and students have lower satisfaction, experience exclusion and under achieve.

The pressure to conform and 'be one of the boys' is compounded by the unease with which engineers talk about difference, and their low participation in initiatives such as the Stonewall Survey. The effect of an inhospitable environment is an increased cognitive burden or load and lower job satisfaction for minority employees, such as women in engineering (Mills et al, 2010a) and for LGBT staff (Bilimoria and Stewart, 2009).

Furthermore, exclusion has been reported as a cause of underachievement among LGBT students when compared to other STEM workers, and to LGBT workers in other fields (Cech, 2011; Bilimoria and Stewart, 2009).

In the UK, Athena SWAN awards and Charter have supported elements of an ideological shift towards inclusion and have widespread support from organisations such as the Academy, the Medical Research Council, Royal Society of Chemistry and Institute of Physics. Although engagement from engineering is low. In 2017, no engineering departments had achieved Athena SWAN Gold; few had achieved silver and some had achieved silver and failed to have it renewed.

The finding from the *Creating cultures where all engineers thrive report* (Royal Academy of Engineering, 2017) that male and white engineers are the least likely to include 'more diverse' or 'more inclusive' in the top five changes to culture that would make engineering a better place to work, may in part explain why this problem-solving culture has yet to tackle inclusion and appears resistant to change. For many, inclusion seems to be irrelevant to the technical tasks in engineering.

Universities have diversity and inclusion programmes that deliver staff training and development supported by organisational practices, in some cases stimulated by funding grants from the Higher Education Funding Council for England (HEFCE). Some examples include:

- addressing bullying and harassment for staff and students
- improved facilities and support services to improve accessibility, such as mandatory lecture capture, provision of slide decks in advance of lectures, creation of quiet spaces and in some instances, halls of residences for students with autism spectrum disorders or mental health issues (Department for Education, 2017).

While unconscious bias training is widespread, proactive follow-on training on being an active bystander (such as described by Ashburn-Nardo et al, 2008) or developing an inclusive curriculum is less so. Entrenched attitudes, disinterest or simply a lack of awareness of what could be done prevents progress and the banter or 'playful conversations' persist as a key way in which engineers relate to each other.

Drawing on practice in different universities, this chapter offers a framework for change in engineering beyond usual institutional practices.

2.1 The culture of engineering

Despite the demographic of the engineering workforce in the UK becoming more diverse, the Academy's Diversity and Inclusion Programme[3] found that more needs to be done to increase inclusion. Its 2017 report defines the culture of engineering and the extent to which it is inclusive, based on responses from 7,000 engineers from all backgrounds (Royal Academy of Engineering, 2017).

It found that nine themes describe the culture of engineering. Six of them state what is present in the culture: problem-solving, safety-consciousness, pride, loyalty, flexibility and an appreciation of teamwork, while three describe tensions in the culture that might act as barriers to inclusion. These include: a friendly but not personable atmosphere, solutions having a strong attachment to tradition, and a lack of support and clarity in relation to career development, despite high levels of job satisfaction.

When it comes to the benefits of inclusion, the report found that it boosts the performance of individual engineers, with 80% reporting increased motivation, 68% increased performance and 52% increased commitment to their group. It also says that organisations benefit because the more included engineers feel, the more likely they are to understand business priorities, be confident about speaking up on improvements, mistakes or safety concerns, and see a future for themselves in the profession. It highlights that white male engineers feel that the culture of engineering is more inclusive than women engineers, who in turn feel that it is more inclusive than engineers from black, Asian and minority ethnic (BAME) backgrounds.

These varying perceptions of inclusion lead to what the report describes as the 'inclusion privilege', which means that those who already feel included are least likely to act. The Academy is collaborating with engineering employers to

3 www.raeng.org.uk/policy/diversity-in-engineering

implement recommendations from the report as a means to creating cultures where all engineers thrive.

2.2 Cultural shift

An inclusive engineering education environment needs supportive and visible leadership for long term impact that changes the educational context (Seymour, 2001). This should focus on shaping and managing the environment and culture to embrace difference, creating respect among both staff and students.

Eight building blocks for shaping the culture in engineering are summarised (from Mills et al) in **Figure 4**. But while Mills focused on gender, this report provides a leadership framework that will cut across all aspects of diversity.

An audit of what is already in place will answer the questions:

- What is currently in place in engineering institutions or companies? (under each of the headings as listed in **Figure 4**)
- Are these steps making a useful contribution to developing an inclusive culture?
- Are they properly resourced or could a similar output be achieved differently?

In engineering, what gets measured gets done. Understanding the levels of engagement and inclusion within a department or faculty might be the starting point using a bespoke or commercially available survey. The findings will provide a tool for prioritising action and measuring change.

For successful implementation **all** the following groups must participate to make the necessary changes:

- All students
- All academic and professional staff across all areas of a university
- University leadership
- The profession
- Professional accreditation bodies

The National Science Foundation (NSF) funded TECAID[4] programme is a further source of practical support on culture change in engineering. Five teams of faculty, chairs and staff from mechanical engineering departments in the US worked intensively to give staff the knowledge, skills and strategies relevant to change the complex academic environment. Final reports are not yet available, but the website offers insights and resources that translate to the UK.

Figure 4: Building blocks for an inclusive faculty (Mills, Ayre and Gill, 2010a)

4 Transforming Engineering Culture to Advance Inclusion and Diversity www.wepan.org/mpage/TECAID

> The success of efforts aimed at recruiting and advancing women students and faculty in US science and engineering depends largely on whether university leaders and administrators promote the institutionalisation of change, not quick fixes and rapid implementation."
>
> **National Academy of Science 2006**

Drawing on the collected initiatives presented at the UCL symposium, four strands have been identified that can catalyse changes across the teaching and learning environment. These are summarised in **Figure 5** and described in more detail in the following sections.

It is important that the inclusion work programme is led by the department heads and or dean as part of a change programme. Other personnel will need to help shape and develop the vision and messaging to create shared ownership of the change.

Mills et al note that change can be more effective using shared learning through collaboration and benchmarking, for example:

- collaborating with other departments and institutions to share good practice and support schemes
- undertaking or collaborating in research to inform and assess progress
- formulating a plan to work on the culture, such as through staff surveys and away days and/ or measuring engagement and progress.

2.3 Communicating and celebrating

Professor Paul Walton of the University of York chemistry department described the route to Athena SWAN Gold as: "A complex journey that requires a department to travel around the diversity loop to adapt, prioritise, act and review multiple times until the culture evolves that is right for that department."

Walton's comments on his experience of the 'SWAN' journey (in which the department achieved and renewed its Gold award,) affirm that rapid change doesn't happen. Dialogue is the catalyst that brings engagement and understanding of the issues experienced by a minority group and allows departments to create solutions to challenges. This approach is at the heart of this section.

Departmental leaders should proactively connect with and listen to minority groups. Grassroots employee networks that represent specific interests, for example women, different faiths, LGBTQ colleagues, may already exist but could also be encouraged further. These are an obvious starting point for establishing a dialogue. A benefit of recognising the contribution of such groups is that the groups are legitimised and more likely to sustain and contribute to change (Etzkowitz, 2000).

External organisations such as InterEngineering – a professional network for LGBTQ engineers and straight allies – ASPIeRATIONS' Campaign Campus, which supports talented, able professionals with an

Figure 5: A framework for departmental/faculty and the top-level action plan on inclusion (Mills et al, 2010a)

Communicating, celebrating	▪ Proactively connect with and listen to minority groups ▪ Specifically acknowledge, involve and celebrate those who make up the community
Curriculum development	▪ Define a policy and review process that addresses what is taught ▪ Set out a plan to systemmatically review and adapt all programmes
Training and development	▪ Review and report on the steps to ensure staff can shape and deliver an inclusive curriculum and inclusive research
Career development	▪ Review the departmental plan and set up local support for underrepresented staff – consider mentoring, coaching and advocacy

Autism Spectrum Difference, and the Women's Engineering Society can support local groups by helping to develop a greater understanding and respect at a departmental level for individuals who do not fit the profile of the 'average academic or student engineer'.

Some of the visible changes that might be seen as part of the change programme are:

- a diverse and gender balance of speakers are a part of the seminar programme
- guidance material is available on creating inclusive curriculum and course design that is actively used
- the diversity of the department is evident in the wall art, literature and electronic media.

Consider these ideas for your communication plan:

- Why do this? What is the story behind the message?
- What is the story behind the impact of the engineering the department/school/faculty has created or is teaching?
- How can engineering and the impact it has on society be celebrated to generate excitement and enthusiasm?
- Practice inclusive language at all times.
- Open a dialogue with staff and students from underrepresented/minority groups and offer small grants and administrative support.

Supporting students to achieve their potential through mentoring

The Women in Brunel Engineering and Computing (WiBEC) mentoring scheme is an example of a support group for students that offers an opportunity for external supporting companies to interact and support students as well as enriching students' experiences and confidence.

A programme of events and activities for women students creates valuable opportunities for staff and students to make site visits, for example to Heathrow Airport. The scheme links women STEM students with the engineering industry and helps them build confidence networking with different companies. Students value being part of the programme:

"I have learnt a lot about myself and gained confidence through the programme."

"The scheme sets us as Brunel students apart because we have the advantage of being paired with a mentor from the STEM industries."

The scheme operates with a dedicated manager who not only coordinates a full programme of events, finds and matches mentors with the students but also provides support to the student-led Innovia society. The continuity of a staff member helping to facilitate the programme is at the heart of its success, helping to maintain momentum between years and when students are out on placement.

"I have made connections to industry not only with my mentor but with other mentors through the dinners and networking events she has held."

As well as providing technical site visits, the scheme has a personal development programme offering insights to strengths and mindfulness.

www.brunel.ac.uk/women-in-brunel-engineering-and-computing

2.4 Curriculum policy and development

Student-led campaigns such as 'Why is my curriculum white?' have stimulated greater consideration of what is taught within courses and how diversity is represented. Conversations about how an engineering course might address inclusion within design are easy to dismiss. Persistence is vital so the conversation broadens out beyond considerations of making materials and examples accessible. Chapter 3 and 4 explore two aspects of curriculum change in terms of content and delivery.

Creating a consistent, systematic approach to curriculum change (discussed further in chapter 3) will support the implementation of inclusive principles alongside effective monitoring and evaluation (see, for example, Jost, 2004). This systematic approach might include, for example, a training policy: how many of your teaching and learning staff could access a course? A training and development plan and timetable with structures and processes will enable staff to meet to discuss and exchange ideas, facilitate monitoring, and enable continuous improvement of the training and development system as well as staff competence.

A performance indicator suggesting successful practice (or otherwise) might be the extent to which curriculum documentation shows a consistent approach to inclusive teaching and content across programmes of study. Considerations include:

- Curriculum review frequency.
- Definition of standards.
- Examples of content, delivery and assessment to grow good practice.
- Process for new courses and review of existing courses.

2.5 Staff education and training

Creating an inclusive teaching and learning environment demands raised awareness and knowledge among staff on two levels: individual behaviours and knowledge of how inclusion relates to the curriculum.

Internal biases (Kahnemann, 2011) and the schemas (images) we hold in our heads can affect the behaviours of educators, administrators and technicians. While much of this is covered by institution-wide practices in engineering, entrenched views can mean that traditional views prevail. Research has shown that technicians, for example, have been observed offering extra help and even completing work for women students therefore causing them to gain less from the project or exercise (Powell et al, 2011).

As a leader in engineering you can:

Take a lead by learning how to be an active bystander and help colleagues change the workplace for their daughters, granddaughters and any other person who is present as a minority and carries that as a burden.

The banter talked of in the *Creating cultures where all engineers thrive* report (Royal Academy of Engineering, 2017) describes some of the behaviours that are termed 'micro-aggressions', which in themselves are small inconsequential comments or actions. These phrases – perhaps the questioning of someone's capability or experience – can mean careers stall before they take off.

Consider the following objectives for the education and training aspect of the action plan:

- Staff become confident and conversant talking about all diversity issues as colleagues and in the classroom.
- Seminars on diversity and professionalism are part of continuing professional development.
- All staff, including technicians, are aware of how they might give additional support and help to some groups of students, for example.

A level of training and awareness of good practice and standards might be planned over a five-year programme of review and implementation. This would include capability to review materials and identify opportunities to extend course plans, content and outcomes to be more inclusive against a checklist and set of examples.

Four steps that will make the programme sustainable are:

1. All staff should participate in shaping and delivering the inclusion change programme with responsibility shared and rewarded across all groups.
2. Targets are set in all managers' annual plans.
3. Resources are allocated for projects and support, including staff, resources and external expertise.
4. Consultation with students confirms the inclusion change programme is fit for purpose.

2.6 Career development

Women continue to report disadvantage in engineering compared to men (ECU, 2017). Being an advocate for inclusion should not have a negative impact on someone's career. Career development for staff will specifically offer levelling training and support to minority groups and ensure that the burden of promoting inclusion does not fall solely on their shoulders.

Involvement in diversity initiatives should be seen as the responsibility of every member of staff and goals for each year should be assigned to each and every person and be acknowledged in performance and achievement.

Minority staff at all levels will need to be included, encouraged and supported in developing their career, perhaps through mentoring and coaching.

2.7 Summary

This chapter lays out the steps for building an inclusive engineering culture and embedding the change within the education and learning environment from a leadership and management perspective. Subsequent chapters detail how this change programme can be implemented within curriculum content and its delivery. In summary, it advises that:

- leaders should proactively connect with and listen to minority groups and form sub groups to focus on actions
- teaching methods need to be evolved
- opportunities for practising and reviewing being inclusive must be extended
- participation in the change process consequently needs to be acknowledged and rewarded.

National and collaborative action:

A study into the engagement of inclusion and diversity across engineering departments is needed that to provide a benchmark for change and study of good practice to produce a 'University of Utopia' engineering faculty good practice guide.

The creation of a set of scenarios in engineering teaching courses or faculties can support classroom management and anticipate situations, for example when a male student refuses to work with a woman student on religious grounds.

Professional engineering institutions:

PEIs could specify ways that students can think about different groups of people and consider them during assignments or engineering design projects. They could, for example, address who uses a plant, building or product and how these could be inclusive.

The following chapters look in more detail at ways in which the curriculum itself can be shifted to be inclusive.

> "Developing inclusive engineering education requires a wide range of people at all levels of an institution to take responsibility for its development, implementation and continuation using a wide range of strategies that require long-term leadership, commitment and resources."
>
> **Professor Julie Mills, University of South Australia**

Leaders in engineering:

Leaders should start and sustain a conversation around the four pillars for inclusive engineering and commit their department or faculty to change through an action plan. They could challenge the department to initially do three actions in each pillar.

Some actions that might be in an action plan include:

- specifically acknowledging, involving and celebrating those who make up a community
- defining an inclusive curriculum policy to review and embedding inclusion within the engineering curriculum
- reviewing the departmental plan and setting up local education and training support for underrepresented staff – considering mentoring and coaching
- introducing active bystander training and practice
- conducting a self-audit by reviewing and reporting on the steps to ensure staff can shape and deliver an inclusive curriculum and conduct inclusive research
- assessing progress towards an inclusive engineering education to include monitoring and reviews.

3 Content of the curriculum

Introducing, relevance, context and diversity as taught material

The concept of diversity and inclusion within education is not new and is acknowledged as being important (Kamp 2014; Grasso and Burkins, 2010), but academics and educators are only just beginning to explore how it can be covered within the curriculum. The lack of clarity about what inclusion means is compounded by lack of knowledge of what to do in practice.

This chapter clarifies what is meant by making the curriculum inclusive and provides ideas of how to introduce inclusion through relevance and context, as well as ways of teaching diversity to students. The focus in this chapter is on content and is drawn from some of the presentations at the UCL Inclusive Engineering Education Symposium in 2016. Six aspects to inclusive content are covered as well as a process for creating a departmental shift in approach:

- A process to review and approve curricula.
- Teaching of diversity itself.
- Situating engineering into a holistic context.
- Professional skills.
- Teaching self-awareness and about teams.
- Design and innovation.

3.1 Curriculum development and change

An example of curriculum change is provided by the University of South Australia (UniSA). UniSA implemented and sustained a long-term commitment to inclusive engineering education. Over 40% of UniSA domestic undergraduate students belong to one or more equity groups (primarily low socioeconomic status and culturally and linguistically diverse backgrounds) and this percentage increases to 50% or more in the engineering student cohorts, which also has approximately 30% or more international students.

In 1997, UNiSA undertook an 18-month inclusive curriculum project across all programmes in the university and formulated a policy that requires all courses to be approved for inclusion. The process suggested by the head of school at the School of Natural and Built Environment covers six clear steps, illustrated in **Figure 6**.

Olin College in Massachusetts started with a blank sheet of paper and had a 50:50 female cohort in its initial partner year. However, Deb Chachra of Olin, pointed out that parity doesn't solve all of the issues, saying: "It is still important to consciously address diversity/inclusion in the learning environment and educate students around these issues."

She also said that courses must seek advice and input on how inclusivity might be addressed and define how that advice is acted upon in planning and delivery and must spell out the mechanisms that will be adopted to evaluate the success of the programme components.

Figure 6: A curriculum review and change process, as used by UniSA, created from information from Mills, J.

Thought leaders from Olin College and the University of Illinois took a student-led approach, based around problem-solving in cooperative, collaborative spaces that are inclusive by design. Students helped shape both the curriculum and campus (Goldberg and Somerville, 2014).

UCL designed the Integrated Engineering Programme as a cross-disciplinary programme focused around two challenges with supporting design processes, maths, critical thinking and professional skills. From the outset, inclusion was a prime consideration, for example setting the challenge context in a specific country or socioeconomic setting.

Changing mindsets of existing staff, providing the resources and training for course leaders and teaching staff (see Chapter 2), and embedding a step into the course approval process are crucial aspects for creating these changes. In some cases, recruiting new staff or using external consultants can assist with creating or adapting new materials.

3.2 Teaching diversity and inclusion

A small number of universities explicitly teach students about diversity and what it means. There is no data on whether this occurs in the UK, other than perhaps in relation to user needs within design and a session on unconscious bias.

Universities paying specific attention to inclusion and teaching diversity as a subject for engineers include Purdue University, UniSA and RWTH Aachen. Aachen University embraced teaching diversity within engineering and beneficiaries included:

- society, by making results more responsive to social needs
- business, by developing new ideas, patents and products
- business and society, by enabling peers and colleagues to both be themselves and contribute fully to the enterprise
- team culture, by providing tools to aid communication, respect and understanding
- science and engineering, by ensuring quality outcomes of diversity aware engineers.

Purdue University teaches diversity to first-year students using multiple learning theories and strategies to explore how it could affect their future careers as engineers, with three aims:

1. To explore the concept and definition of diversity so students can reflect on how they differ from others.
2. To consider how diversity might affect engineers in practice.
3. To investigate how diversity might affect problem-solving.

National study and collaboration:

Conduct a study of UK engineering departments to identify how, and how widespread, the teaching of diversity is within engineering programmes.

3.3 Engineering in a holistic context

Many courses are already taught in context and with specific user groups in mind. Some do so without realising it, while others could simply add a small adjustment or perspective to achieve this.

This section presents a model that will embed inclusion and diversity into an engineering programme. Ensuring that a bank of illustrations and case studies is available will raise awareness of the breadth of inclusion and diversity.

The model presented in **Figure 7** places engineering into a contextual framework that demands an approach that is holistic and transdisciplinary. This is vital for the development of future-oriented, sustainable and socially responsible engineers who can produce technical solutions and innovations with societal and economic added value (Leicht-Scholten and Bouffier, 2015).

The consideration of gender and diversity fits into this model and is practised at RWTH Aachen University as an exemplar of progress along with other initiatives, such as the Conceiving – Designing – Implementing – Operating (CDIO[5]) initiative, (Crawley et al, 2007). These are yet, far from standard, but should form part of an audit and advisory process to module and course leaders as part of the training recommended in Chapter 3.

Essential to this is enabling students to become confident in working with gender experts, for example, as well as appreciating and accessing literature from the social sciences and policy bodies. A wider range of literature will aid engineers' learning and understanding of design constraints, users and potentially provide ideas for new projects or products.

Engineering students need to consider a variety of users within

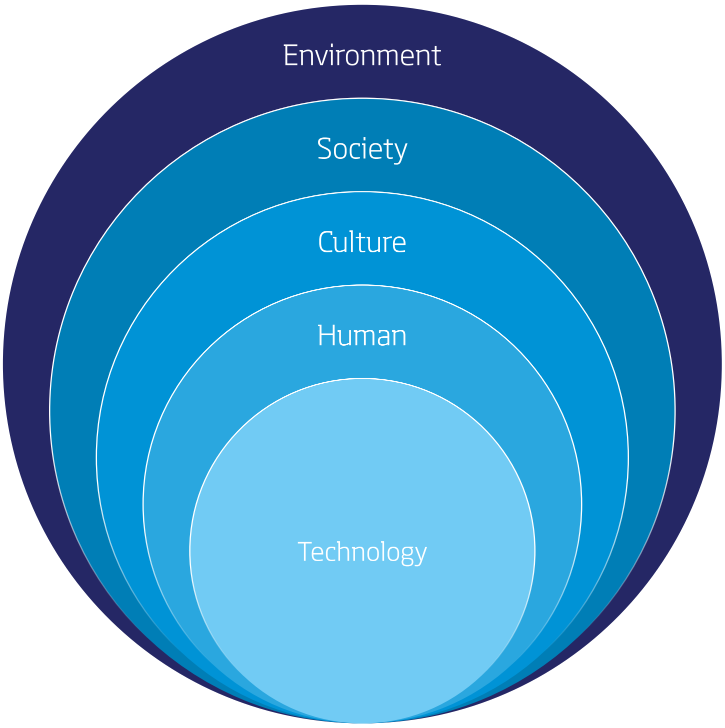


Figure 7: Holistic engineering: technology in its context (Leicht-Scholten and Bouffier, 2015)

5 The CDIO™ INITIATIVE is an innovative educational framework for producing the next generation of engineers. www.cdio.org

Teaching diversity and inclusion to students in year one at Purdue University

In the first-year engineering programme at Purdue University, students are explicitly taught about diversity in relation to teamwork as part of the curriculum. A key learning objective of the course is contributing effectively to team products and discussions.

Students are assessed on their ability to take on alternative perspectives in listening, working and communicating effectively with one another within teams. Developing these skills is easier for students who are alike rather than different, so purposely mixing students up provides a more 'real-life' learning experience.

Students bring with them their prior experiences and attitudes when they walk into the classroom and these differences can cause team conflict. Rather than letting students figure it out on their own, team skills and valuing diversity are essential parts of teaching what it means to be an engineer.

each project or scenario that they work on. At times, they will need to access and interpret data and its context with respect to socioeconomics, gender, disability and so on. Knowing that this data exists and how to obtain and use it should be considered a vital part of the engineer's toolkit and an integral part of engineering design.

Creating confidence in data and methodologies from the social sciences is important. This can be done via project themes, situations or in tutorial or class discussions using examples to show how gender bias, implicit racism or failing to be disability aware can be harmful and expensive with unintended consequences to different groups of users. The model in

National and collaborative action:

Research how student engineers use and perceive social science and policy literature and how it can inform societal engineering challenges.

Collect or create examples of how engineers and student projects have used social science or medical datasets and how confidence can be inculcated in student engineers about this source of knowledge.

Figure 7 illustrates a process to help expand students' appreciation of how, for example, gender can influence a project's scope.

The Gendered Innovations project at Stanford University (Schiebinger et al, 2011) illustrates how engineering has failed many in society through constrained thinking. For example, until the mid-1970s crash test dummies were almost six feet tall and approximately 180 pounds (12.86 stones) consistent with an average adult male body type. In 1976, dummies more representative of the average woman and child were developed. However, it wasn't until 2002 that a pregnant crash test dummy virtual simulation was developed by a woman engineer, Laura Thackery, to understand impact on developing foetuses. This might be viewed as a failure of good engineering practice to not undertake a literature study of the impacts of seatbelts on car occupants. A search would have revealed that car seat belts are a leading cause of foetal death. Using the workflow in **Figure 8** would introduce issues such as gender into the research phase of a design project.

Taking a holistic approach to engineering with the model presented in **Figure 7**, makes diversity applicable to every strand of engineering. While the model was originally developed as part of

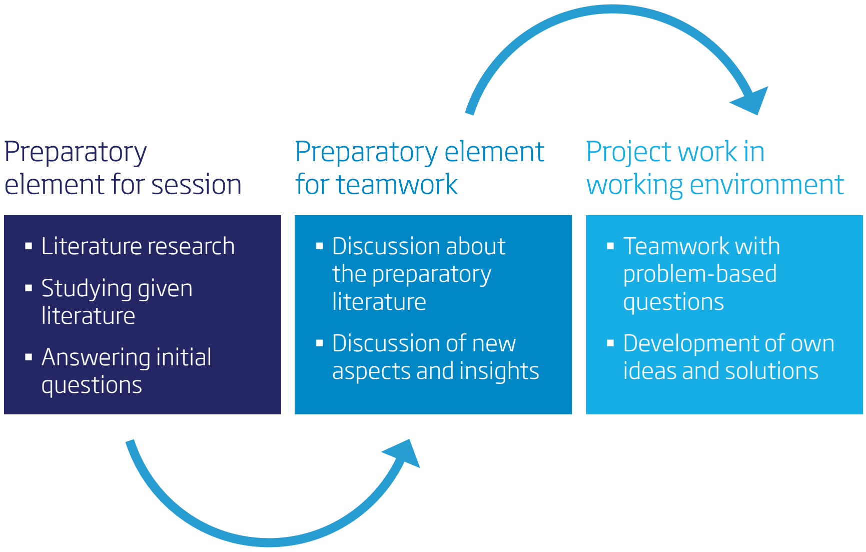


Figure 8: Structure of knowledge transfer in the innovative course Expanding engineering limits: culture, diversity and gender (© GDI 2015)

a gender project, it is relevant to all aspects of diversity. The aim is to consolidate students' diversity knowledge by embedding diversity within processes and practices that are taught.

For example, design and critical thinking asks students to reflect on their own contributions and how their backgrounds or experiences could influence the project. The desired outcome is for students to appreciate differences between each other and value what they bring from their own experiences.

The aim should be to introduce discussions around implicit bias and explore how engineering in the past has failed to cater for specific user groups. Examples of 'racist software' that have shocked the public and engineers include the HP webcam software that could only track white, but not black faces; a soap dispenser that wouldn't dispense soap to a black hand and famously the Google photo app that tagged black faces as gorillas. Other examples are listed on the Gendered Innovations[6] website where gendered or sex differences have meant that men or women have been unable to benefit from technology or have potentially been harmed.

National and collaborative action:

Create a structured resource of case studies and activities that can help course tutors or leaders extend the examples they use to be more inclusive and contextual for different groups of users.

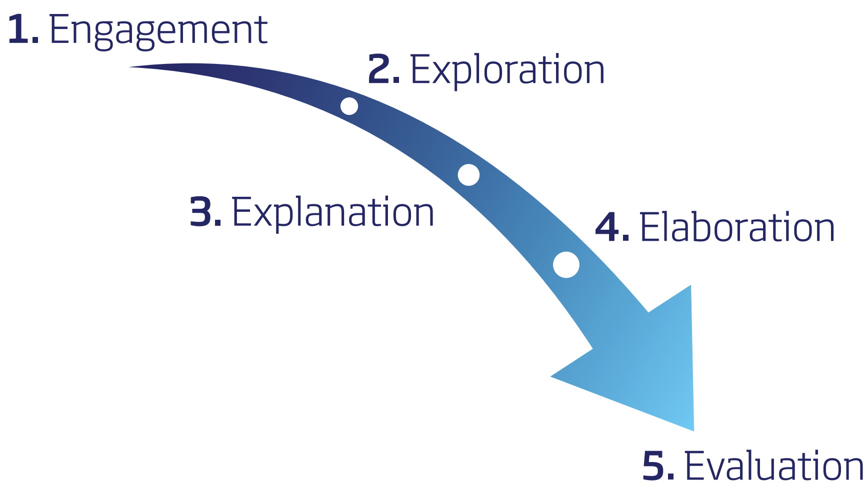
3.4 Professional skills

Engineering employers increasingly understand diversity and inclusion beyond 'doing the right thing' and this extends to:

- encouraging respect among staff, which increases engagement, productivity and profitability
- tapping into employee's talents, which can empower employees to view the business, its processes and environment differently and add value
- meeting the needs of diverse users better, which improves products
- ensuring managers and leaders are confident about diversity and inclusion, reducing the chances of equality laws being infringed and increasing the chances of best practice being adopted.

6 genderedinnovations.stanford.edu

Figure 9: Framework to help course plans provide a context for explaining engineering principles familiar to a wider audience (Atkin and Karplus 1962)



Being diversity and inclusion confident is increasingly a core part of being a professional within engineering (see section 1 and 3.4 for more details). In some sectors this has been precipitated by government policy, for example the public funding of infrastructure projects, such as the London 2012 Olympics, Crossrail and Tideway projects. These projects demand a diverse workforce, close engagement with local communities to promote engineering and construction careers, and finished schemes and structures that meet the needs of diverse user groups.

However, as the demographic profile of the UK engineering workforce becomes more diverse, the Academy's Diversity and Inclusion Programme[7] finds that more needs to be done to increase inclusion. In 2017, it published a report[8] describing the culture of engineering and extent to which it is inclusive, based on responses from 7,000 engineers from all backgrounds.

Having an open dialogue and culture that is respectful of disabilities has helped BAE Systems' employees and managers become a neurodiverse friendly company. Colleagues are able to openly talk about what they need to be fully present at work and contribute to the best of their ability.

Professional engineering institutions:

Define criteria for students to undertake a professional skills-based reflection around inclusion during project evaluations.

Professional skills and work-readiness are covered within degree programmes and yet continue to be the subject of concern (BIS and HEFCE, 2016). These skills include communication and presentation skills as well as adaptability and resilience. Notably lacking though is a reference to an understanding or awareness of diversity (UKSPEC). Engineers need to demonstrate, through example, a situation where they put that awareness of diversity into practice for their professional registration.

An element within employability and/or design projects could provide an opportunity to explore and discuss what diversity means for society and for engineering across the three or four years of a taught course. The aim is to build upon the student's growing professional skills and increase their self-awareness and knowledge (see Chapter 5).

7 www.raeng.org.uk/policy/diversity-in-engineering

8 *Creating cultures where all engineers thrive* www.raeng.org.uk/inclusivecultures

National study and collaboration:

Create a cross-university project to formulate a curriculum in a bid to make a diversity confident student.

Three or four partner universities should pilot and evaluate it. Outputs will include background material, discussion guides and a 'train the trainer' programme. It could be integrated into accreditation by PEIs.

The diversity element of study programmes may be sourced externally or developed and tailored to individual courses, but need to accommodate the following:

- Exploring diversity.
- Practising diversity and being an inclusive colleague or peer.
- Innovating with diversity.

These elements can be embedded within existing project activities with specific user groups defined to extend the activity. For example, in electronics, a sensor-based project could have a

Benefiting from creating an inclusive culture

BAE Systems is committed to creating a culture that supports colleagues who have long-term health conditions, physical or mental impairments. Recruitment processes are continuing to be adapted to be more inclusive with adjustments being made to ensure that people with Autistic Spectrum Disorder (ASD), for example, are not put off at interview. A number of engineering apprentices have now been recruited who have an ASD diagnosis.

Apprentices are encouraged to find business-based development projects to support their learning that could be written up as part of their project dissertation.

Typically, students quickly find a single project. BAE Systems apprentice (in photo), who has both Asperger's and other health conditions, returned with 14 strong project ideas that could improve the business. The training manager was surprised to see how quickly they had picked out real issues that affected the business that no-one else had noticed. Their final chosen project focused on a problem involving the prevention of aircraft damage when placing ground equipment against the aircraft for maintenance access. They developed proximity sensors and organised trials with aircraft teams.

This project provided an opportunity for the apprentice to show their creativity and focus on making a difference. It also demonstrated to colleagues and managers that a more open and inclusive approach to people with disabilities could provide new ideas and be a source of unexpected innovation that BAE Systems could be missing out on. The apprentice went on to win an external prestigious innovation award for their work. They have also become a founding member of the BAE Systems ENabled Steering Board, helping and supporting other disabled employees and raising awareness across the business.

Having an open dialogue and inclusive culture that is respectful of disabilities has helped BAE Systems' employees and managers be supportive and become an ASD friendly company. Colleagues are able to openly talk about what they need to be able to be fully present at work and contribute to the best of their ability.

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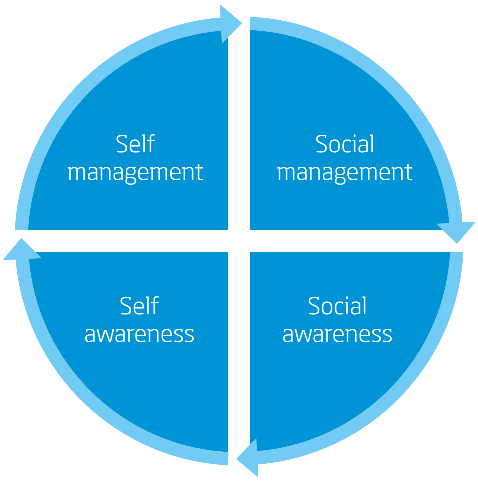


Figure 10: Four stages for developing emotional intelligence (Goleman, 1995)

disability slant, perhaps modelling a pedestrian crossing close to a retirement home, or car safety might focus on pregnant women or elderly people.

3.5 Teaching about teams and leadership

Team-based activities and role play have been used in engineering for many years. However, teaching about teams and leadership has been ad-hoc and rarely draws on a university's management school expertise (McWhinnie and Peters, 2012). There is no consistency across engineering departments or disciplines. It is rare that the models used are those currently in use across the engineering sector.

Frequently, students are organised into self-selecting teams and left to assign a team leader. The implicit expectation is that they will become great team players, future managers or leaders by osmosis. Helping students learn about teams, leadership and inclusion within a framework can offer many opportunities for follow-up conversations and self-reflection.

National study and collaboration:

Conduct a study into leadership and team working for undergraduate engineers, undertaken in conjunction with the PEIs and employers to draw together best practice and a curriculum with supporting material and training.

Emotional intelligence (EI) introduces a cycle of four stages that begin with self-awareness (**Figure 10**) (Goleman, 1995). EI serves as an introduction to modern thinking around leadership and can be built on through the years of a degree. Formally introducing team skills and one or more theories in Year 1 will provide a basis to analyse the experiences gained in projects and group work. Preparation and coursework could involve viewing films, reading management books or analysing scenarios from industry case studies. These case studies might involve situations with challenges catalysed by a difference in thinking, cultural values or bias for example.

Professional engineering institutions:

Create a set of team-based case studies with a diversity slant, sponsored by PEIs, to be used in tutorials, coursework or to enrich challenges given to students.

The model aligns well with active learning approaches and appropriate assessment methodologies that use self-reflective processes to help build inclusive and productive teams. Using a theoretical framework and a widely used tool provides a robust approach to evolving team and leadership insights in students.

One of the greatest difficulties in group working is having difficult conversations with team members. Providing each student with a common vocabulary around differences in behaviours will inevitably help addressing problems between people. Examples of tools widely used in industry to assist with developing self-awareness include: The Four Temperaments, Myers Briggs, DISC personality theory, and CliftonStrengths. This is covered in more detail in section 5.1.

Goleman's EI framework involves four steps for self-reflection and action. Extending and formalising self-reflection as part of student assessment can support self-directed learning when used in conjunction with an active learning approach and one of the aforementioned tools. A more systematic and consistent use within the curriculum would assist tutors in helping students' personal development (for an example of an implementation see Eliot and Turns, 2011).

3.6 Design and innovation

Different users have unique needs that can depend on life stage as much as sex, physical size or disability. In addition, the issues surrounding each dimension of diversity can vary across the globe from the average physical size of a man or woman in a country, to gendering of roles based on cultures or religion. These and other dimensions of diversity can affect design standards and/or specifications and influence a design brief.

Diversity in the context of design covers the design process as well as critical thinking. This includes examining users and their needs as well as the personal experiences and perspectives that each student brings to the design brief and the function of the product, service or environment. Such thinking may result in exciting new inventions and innovations. Students should be challenged to think beyond making a building or structure safe for, say wheelchair users, and consider the user's potential experience. This is illustrated by the way in which BuroHappold designers challenged engineers to consider making the O2 Walkway as much an experience for wheelchair users as fully able bodied people (see image on right). The outcome was fewer lifts, less safety glass and a more thrilling experience for all!

Inclusive design can be introduced as images in slide decks, preparation exercises or discussion topics. Establishing a specific context or set of users for a project, scenario or case study may be all that is required. For examples that could be used of where disability or gender does and should have previously intersected with science and engineering, see the Gendered Innovations project website[9]. Some of these examples are summarised in **Figure 11**, on the next page. For further examples that demonstrate how connecting with specific groups of people has led to innovation, see the BBC series, The Big Life Fix, where engineers tackled life-changing disability with technology.

Integrating inclusive design into buildings and spaces is a legacy of the 2012 London Olympics and has resulted in a cross-industry initiative to make public spaces enjoyable for all[10]. The challenge now is that students build on the approaches developed as part of the legacy. Integrating this into the curriculum as a piece of work that is marked and assessed, rather than a topic of discussion, could make a difference promoting the importance of accessible spaces in all designs. Taking this approach into other disciplines is the next challenge.

BuroHappold has created tools that help designers and engineers explore how real potential users might use or interact with a project – for example by creating tactile maps to help potential users grasp the scale of plans, allowing them to envision what a new space might look and feel like. During the design process, it is also vital for engineers to consider what might be driving a requirement and how this might impact on protected characteristics. These practices can be taught within design classes.

As a leader in engineering you can:

Use a list of specific things for the students to think about during their assignment in engineering design projects that address who uses the plant, building or product, and how.

Typically engineers use codification to define design constraints and requirements. At times, a project will be of so large, or using fast-moving technology, that it isn't possible to fully define the functionality or delivery method in advance. Sometimes a different approach to a tight specification includes a list of specific things that are required to help deliver what is needed for the key users and stakeholders, because the funder doesn't know enough about how to deliver those needs. Public funded projects, put out to tender, are being used to shape an inclusive approach; engineers need to be able to respond to these tenders with ease and innovation. This approach can be used in teaching.

© Attitude is Everything

> "It's about people understanding people and not necessarily following design standards but understanding why those standards are there. The key is about understanding how people use things and helping engineers understand how things will be used and used safely."
>
> **Neil Smith, Head of Inclusive Design at BuroHappold**

9 genderedinnovations.stanford.edu

10 https://goo.gl/nozq77

Figure 11: Examples of how population differences can have an impact on engineering solutions and innovations

1. State-of-the-art machine translation systems such as Google Translate or Systran often default to masculine pronouns, for example 'he' said. The Gendered Innovations project has led to efforts to develop algorithms that determine the gender of each person in a text – a deep 'fix' that enhances the quality of translation and addresses gender bias.

2. As the world's population ages, robust new markets for assistive technologies are emerging. Elderly men and women may have different needs. Designing with these distinctive needs in mind helps engineers develop technologies that may yield broader markets.

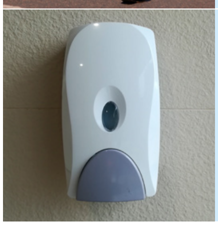
3. In sub-Saharan Africa, women and girls spend some 40 billion hours annually carrying water. Because water procurement is women's work, many women have detailed knowledge of soils and the water they yield – knowledge that is vital to civil engineering, for instance, and could be used to decide where to place wells and water taps.

4. Conventional seatbelts do not fit pregnant women properly and motor vehicle crashes are a leading cause of foetal death related to maternal trauma. Gendered innovations have led to the development of pregnant crash test dummies that enhance safety in automobile testing and design.

5. Public transportation systems with new data-collection techniques to capture the 'mobility of care' (how children and the elderly travel) have led to more efficient systems.

6. A tech company is planning to design a 'wearable' to detect early signs of heart disease. Recognising that men and women have different patterns of heart disease can enhance the usability and uptake of the device.

7. Timing road crossing lights to enable all users more than enough time to cross the road could cause traffic delays. Assistive and adaptive technology[11] is developing all the time from monitoring the speed of pedestrians approaching a crossing to lighting up the road when a pedestrian steps out, giving different users just enough time to cross a road safely, while optimising traffic flow.



8. A soap dispenser by Technical Concepts is one example of a 'racist' technology whose designers have not considered all users' needs. It uses near-infrared technology, which sends out invisible light from an infrared LED bulb for hands to reflect the light back to a sensor. If the reflective object actually absorbs that light instead, then the sensor will never trigger because not enough light gets to it.

Gendered Innovations is a globally accessible, peer-reviewed website that provides 26 examples of gendered innovations and technology at the time of writing.

11 https://goo.gl/gAKyzo

National study and collaboration:

Create a themed repository of inclusion in engineering for background reading, module/lecture preparation, images in slides and group or tutorial activities, scenarios, projects and challenges.

3.7 Summary

Some of the design errors of the past are the result of limited thinking; thinking that hasn't tested a product on a wide range of users (drugs, heights of hand rails or with different skin colours). Diverse teams are more likely to constantly re-examine facts, remain objective and avoid 'group think' (Rock and Grant, 2016). The research tells us that diverse teams are smarter and generate more innovative solutions and products.

Creating and delivering inclusive curriculum content, as with all curriculum developments, takes time. Finding existing examples is a good starting point. It is unlikely that any engineering department will not be able to find some examples and knowledgeable staff who can help to initiate a discussion about inclusion in curriculum content and identify **modest adjustments** to share ideas and reflect diversity in examples and illustrations.

By embedding inclusion into a curriculum, from introducing discussion topics to guiding students to social science and medical literature for evidence of problems that need solving, there are many ways that all engineering and technology students can be encouraged to think more widely, deeply and critically about what they are doing.

A university or organisation's diversity strategy and plan should identify more systematically how and when: courses are reviewed and updated; staff trained, developed and supported; and new courses are approved. This process is covered in Chapter 2.

Figure 12 summarises three main strands that contribute towards a student having a more informed and valuable team working experience. This is based on becoming more confident in understanding diversity and practising inclusion, being more self-aware, and practising considering how to become more inclusive across all elements of a course.

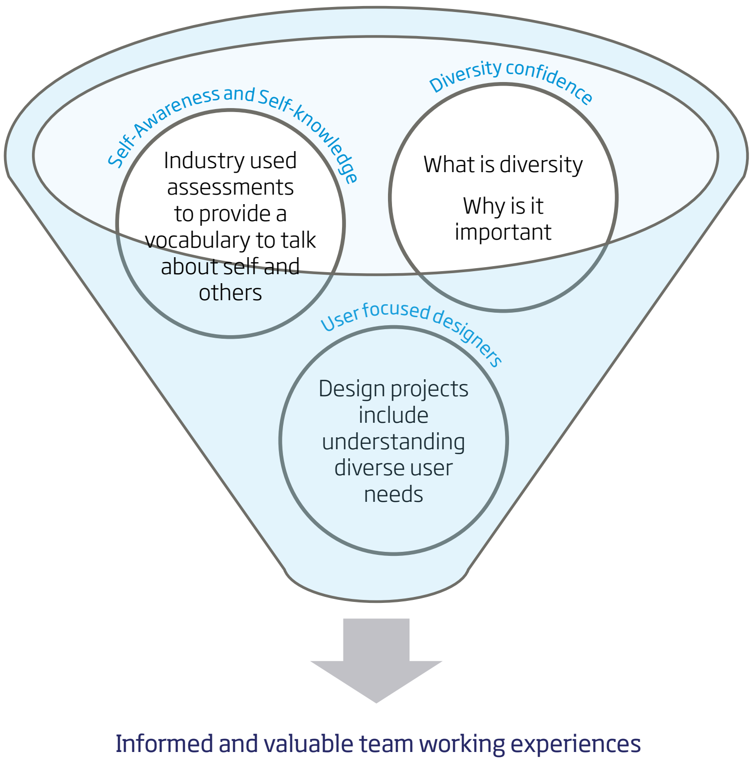


Figure 12: Improving the outcomes of student team working experiences to be more relevant to the workplace and society

“**An inclusive environment for learning** anticipates the varied requirements of learners and aims to ensure that all students have equal access to educational opportunities… by means of inclusive design wherever possible and by means of reasonable individual adjustments wherever necessary.”

QAA: Quality Code for Higher Education

4 Delivery of courses

Mapping the physical and virtual learning space to diverse needs

Engineering programme design has evolved in recent times to encompass a range of active learning approaches including problem-based learning. An increase in designing campuses to be more inclusive has accompanied the expansion of higher education. Great strides have been made with campus accessibility, including lecture theatres, toilet facilities for all and technology for lecture capture. Much of this has been done in consultation with student populations and university estates departments (see AUDE[12]).

This pillar draws together the examples and practices that have been developed to ensure that engineering can be supportive of diverse cohorts. The pillar focuses on 'Delivery'. This is an important way of addressing inclusion within engineering education.

This section highlights examples of emerging practices that cover:

- Teaching methods
- Physical space
- Learning technologies
- Pastoral support and
- Assessment of learning

4.1 Active learning approaches

Since the late 1990s, many reports such as the Wakeham Review and industry associations such as the CBI[13] have called upon university engineering departments to produce graduates with not only the technical skills of the disciplines, but also a wider range of transferable skills and an understanding of the societal context of engineering. In the US, Boeing has led a significant voice for change in engineering education (McMasters, 2004). What these reports and schemes have in common is that they focus on the sociological and economic aspects of engineering, communication and presentation skills, legal and ethical aspects, as well as the importance of teamwork and leadership skills.

Curricula innovations have emerged in response to such reports (see for example the UK government's Perkins' Review, BIS, 2016, and Royal Academy of Engineering, 2007) calling for students with a range of knowledge and innovative problem-solving skills. This includes a wide variety of terms including small-group learning, collaborative learning, cooperative learning and team-based learning; terms that describe a range of similar but different learning experiences. This can make it difficult for educators to choose the right approach and provide the desired learning benefits for their students. Current state of the art is presented by Graham, 2018.

Active learning is not easy to manage unless well designed, planned and understood. For example, managing classrooms with an excess of 100 students takes careful planning and supervision. The learning aims need to capture both the process and product

12 www.aude.ac.uk

13 The CBI is the UK's premier business organisation, providing a voice for firms at a regional, national and international level to policymakers.

Six different features of classroom management used in teaching corporate social responsibility (CSR) to engineers at Aston University (Andrews, Clark and Phull, 2016)

1. Engineering focus: the course content has a dual focus covering 'CSR in engineering' and 'engineering for sustainability'. Wider socioeconomic concepts and issues are covered, but from an engineering standpoint.
2. Nurturing 'independent connectivity': students are encouraged to support each other in active learning within the classroom while working independently outside of the classroom. Weekly group tasks contribute to the overall assessment with a small percentage of marks given each week for group cohesion and presentation. Weekly formative feedback provides students with the conceptual knowledge needed to develop an individual 'portfolio' of learning that is submitted for final assessment at the end of the module.
3. Group work: group work is embedded into weekly classroom activity. Groups are pre-matched, taking into account differences in demography, subject and level of study.
4. Active learning: an hour and half of 'active learning' follows a 30-minute 'traditional lecture'. Different activities are planned around a series of CSR or sustainability case studies as diverse as Chernobyl, The Exxon Valdez Oil Spillage, Bhopal and FoxConn China, to name but a few.
5. Global context: learning is set in a global context, reflecting the diverse nature of students' backgrounds while introducing students to the 'global village' paradigm.
6. Engineers' responsibilities: first and foremost, the module addresses engineers' responsibilities towards society, covering professionalism, ethics and corporatism. It purposefully challenges students' preconceptions of their own and others' views of the role that engineering plays in society.

with every student being given the opportunity to contribute, such as the ENGAGE approach at Aston University (Andrews, Clark and Phull, 2016).

The popularity of active learning approaches such as problem-based learning (PBL) is growing, with their origins in medicine (Barrows and Tamblyn, 1980). The cited benefits include enhanced problem-solving skills, social skills, creativity and criticality (Barkley, Major and Cross, 2014; Johnson, Johnson and Smith 1991; Strobel and Van Barneveld, 2009) as well as belonging and other related attainment gains (Wilson-Medhurst, 2013; Wilson-Medhurst, 2016; O'Mahoney et al, 2013). These cited benefits are aligned with vocational and professional demands, and as a result, such approaches are very attractive in engineering.

Today, several examples of such shifts in the curriculum exist across the world, most notably the CDIO programme (Crawley et al, 2007), the Aalborg model[14] (Aalborg n.d.), the Integrated Engineering Programme at UCL (Mitchell et al, 2015) and a number of developments in Australia, for example Mills and Treagust (2003). To include the recent MIT report that reviews four of the global best examples of innovative engineering programmes. Some of these, for example Aalborg, are very clearly PBL based while others include a wider range of active learning pedagogies including project-led learning and activity-led learning (for further examples see Royal Academy of Engineering, 2010).

Problem-based and project-based activities increase student motivation

14 The Aalborg Model for problem based learning https://goo.gl/1m1xEd through the integration of 'real' problems (Savin-Baden, 2004). These authentic activities offer the student the opportunity to put into practice their technical and theoretical knowledge while at the same time enhancing a wide range of professional skills also broadening their understanding of the societal context in which their solutions will operate.

The impact of these types of activity are two-fold. They aim to strengthen exactly the skills being emphasised by industry as being key to graduate employability, but also aim to demonstrate engineering as a creative, interdisciplinary and inclusive activity that brings together people with different expertise and capabilities to create innovative solutions to societal problems.

4.2 Support for students with active learning

A gender analysis of active learning approaches found that this environment has positive impacts on the learning processes of both men and women engineering students (Du and Kolmos, 2009). Du and Kolmos surmise that problem-based and project-based learning are suitable for increasing gender diversity in terms of attracting and getting the best out of women students. However, the experiences of men and women students are not the same (Dasgupta, 2015, and Seron and Silbey, 2016) and course leaders need to be aware of how teams can be managed better by including women peers within groups, so that female students maximise their learning to the level of male peers.

Not all groups are cooperative, for example simply asking individuals to form a group and giving them a joint task does not mean they will cooperate effectively (Johnson and Johnson, 2009). To be cooperative, so that the individuals within the group work together to accomplish shared goals and become a team, requires five essential elements to be carefully structured into the situation (according to Johnson and Johnson, 1989, 2009):

- Positive interdependence
- Individual and group accountability
- Promotive interaction
- Appropriate use of social skills
- Group processing

Active learning and team management itself is not enough. Projects, especially 'hands-on' projects, need to be scaffolded to support students and staff too. Actions that can be taken to enhance this experience and make it inclusive include:

- support forums for staff working with large mixed groups to help them prepare for and manage situations when students refuse to work with each other
- having an active facilitator such as a trained teaching assistant or coach
- multiple methods for students to access information to appeal to different learning styles and ways of thinking, for example reflective thinkers compared to future thinkers
- cross department or faculty engagement to ensure there is variation and reinforcement of learning contexts
- access to quieter spaces to support those students who struggle in busy and loud environments
- managing team make-up to ensure that students are not alone in larger teams, aiming for 25–30% of a minority group in a team.

Additional support for these methods is covered in section 4.4 and section 4.7.

4.3 Creating the right physical space

Changes in teaching and active learning mean that the space on offer in many institutions doesn't meet the demands of this approach. Creating the right learning environment and learning spaces involves designers and engineers talking to estates teams and, crucially, to staff and students.

Innovative solutions include double row lecture theatres that enable students to swivel round to have small group discussions, while others include increasing demand for flat, flexible

> Students were deeply involved in shaping the learning environment at Olin, starting from before the first full class started."

seating for large groups and smaller seminar rooms. From an inclusion perspective, some considerations might include:

- How do people, for example those on the autism spectrum, respond to large, open and often noisy spaces? What can be done to mitigate any unintended impacts?
- What do people like and dislike about current buildings and spaces in a learning environment? Is there a gendered response that might inadvertently happen, for example with all work desks facing a wall around a space?
- What about lighting? Does it cause a strobe effect as you move with or through a structure? How can people with epilepsy use the space safely?

Universities including City, Exeter and Birmingham have implemented these arrangements.

4.4 Pastoral support - peer learning

For some students, active learning approaches feel unstructured, chaotic and the opposite of what they anticipated – 'lecture and learn'. Further, students, with low social capital for example or from overseas and in the UK for the first time, may find their apparently more confident peers overwhelming. Ensuring that there are systems in place to provide support to staff and students is paramount for achieving high-quality student outcomes as well as raising retention rates.

Support not only helps build confidence in technical areas, it can also provide support in raising aspirations. For example, peer assisted learning (PAL) at Sheffield Hallam University helped 82% of participating engineering students secure a sandwich placement compared to cohorts without PAL, (Nortcliffe and Keech, 2016). BAME students from low socioeconomic backgrounds made up 44% of the PAL cohort. Of the BAME students, 85% secured a placement compared to their peers on another engineering course, of which only 11% BAME students secured a placement.

Peer learning took place in generic teaching spaces and students led the activities for their peers. The additional support was introduced to address

Creating diverse contexts for studying

A series of booklets covering dynamics, fluid mechanics, mechanics of solids and thermodynamics are available on the National Science Foundation funded ENGAGE project website[15].

Everyday engineering examples are successfully used to introduce engineering concepts by bridging any gaps in students' knowledge or experiences. The combination of the approach illustrated in **Figure 8** and Everyday Engineering Examples[16] has been extended to a massive open online course (MOOC) entitled *Energy! Thermodynamics in Everyday Life*, which has attracted thousands of learners from around the world and many different backgrounds (Patterson et al, 2011). These frameworks should be considered in parallel with the approach defined by Andrews et al (Andrews, Clark and Phull, 2016) around managing active learning, described in Chapter 4 and adapted to other disciplines.

For example, in the Everyday Engineering Examples project, using iron bars to explain basic axial stress and deformation and how these concepts could be used to solve statistically indeterminate problems stimulated little interest, but when the same academic used his iPod cable, there was a great deal of interest because many students had broken their cables.

15 www.engageengineering.org
16 https://goo.gl/tTsXyf

gaps in attainment by BAME students (Connor et al, 1996; Berry and Loke, 2011). Students volunteered to be PAL leaders and received two days training on peer mentoring, teaching, session preparation and teaching material preparation. Each week after the PAL session, the PAL team member reflected on the session and prepared the following week's session. Similarly, at Brunel University, a mentoring programme operates between final year and second year students.

Of note is that PAL has a positive impact on retention and contributes to building a sense of belonging, as illustrated by student feedback (Nortcliffe, Keech and Evans, 2014).

4.5 Virtual learning and resources

Multimedia support for study programmes and the use of lecture recording systems is becoming commonplace. The flipped classroom model (Lage, Platt and Treglia, 2000), is now frequently used in universities and is accommodating of different learning styles.

Tracking the access rates of materials and elements of recorded lectures can also provide timely feedback to academics, which helps them understand how their material is being used and allows them to make adjustments or hold an additional review of areas that students access in high numbers.

Virtual learning and online resources provide an opportunity to ensure that each student is not disadvantaged over any other and to reinforce the message of inclusion. The National Union of Students has been proactive in championing this cause and collaborating with universities and colleges to ensure that content and assessment do not create implied or careless disadvantage. Liberate the curriculum[17] resources provide examples and resources to help educators create inclusive materials and methods of delivery.

Engineering leaders:

Monitor the access rates of virtual learning environments by an agreed set of criteria to inform the use and access of materials.

Students also find their own ways of using the resources provided and helping each other. Students working in multinational teams at UCL found that team meetings on Skype were helpful to students who weren't native English speakers, as peers could help clarify words in the chat function without slowing down the discussion. Exporting the chat also provided a record of the meeting.

4.6 Assessment of learning

Multiple methods of assessment are now commonplace. Monitoring and reviewing assessment data by criteria such as gender, non-native English speakers, dyslexia and other sub groups of students, reinforces inclusive intent. Analysis can yield information of unintended outcomes for some students that will remain unknown unless you actively look for it (Mills et al, 2010a). To avoid unintentionally disadvantaging some groups through choice of assessment, consider the following:

- Use a balanced portfolio of assessment methods (for example see the TESTA (Transforming the Experience of Students through Assessment) website[18] and Gibbs' Powerpoint[19]) including peer learning and assessment. Explain to students that this forms an important skill for life, for example undertaking appraisals, providing feedback to a client or as a coaching-style manager.
- Consider the context and appropriateness of assignments and exam questions – add in specific user groups or allow students to choose a group of users for a problem.

17 https://goo.gl/p3o48o
18 http://testa.ac.uk
19 https://goo.gl/o7Gf9J

- Allow students to choose how to present their assignment.
- Encourage students to think about their learning and undertake self-reflections on progress and how it could be improved. Use self-reflections especially the outcomes from the process.
- Conduct post-placement interviews or collect data on students' experience and report back to employers on a suitable cycle. Host organisations need to adhere to the law and there should be a formal process for managing cases of discrimination or harassment.

UCL Computer Science uses a method of asking teams to assign 100 points each week across team members to address social loafing[20]. A teaching assistant mediates the meeting and points allocation if needed, but in reality, teams come prepared and adhere to the constraint that they cannot assign equal points to anyone.

The University of Plymouth has produced a seven-point guide[21] to inclusive assessment:

1. Use good assessment design principles.
2. Use a variety of methods within each module.
3. Incorporate choice.
4. Design inclusive exams.
5. Consider how technology can assist.
6. Prepare, engage and support students in the assessment process.
7. Monitor, review and share practice.

4.7 Summary

Active learning approaches provide an environment that is more aligned to the professional environment than 'traditional' teaching methods and provide a context to develop the skills that will empower engineering students to be more self-aware and better communicators and/or managers. Challenges occur with adapting the existing space and involving students in designing new spaces, as well as using new technology that can support students' diverse needs.

There are many ways in which the curriculum delivery can be adapted to support and ensure equity of learning. Benchmarking of standards across engineering modules and ensuring that the processes, feedback and complaints procedures are in place will ensure that students with disabilities – declared or not – are accounted for. Additional recommendations are based around good practice.

Professional engineering institutions:

Collate a good practice repository on the creation of inclusive learning (including assessment) and design including:

- illustrations for use in preparation work, images in slides and group or tutorial activities. Supported by PEIs these will ensure a positively robust experience for minority students
- a set of team-based case studies with a diversity slant, to be used in tutorials, coursework or to enrich challenges given to students;
- a structured resource of case studies and activities that can help course tutors or leaders extend the examples they use to be more inclusive and contextual for different groups of users
- a list of specific things for the students to consider during their assignment is provided that address who uses the plant, building or product and how.

20 Social loafing: The phenomenon of a person exerting less effort to achieve a goal when they work in a group than when they work alone.

21 https://goo.gl/o7Gf9J

5 Practice for professionalism

Developing competence in a safe and reflective space

Engineers develop technical competence through effective teaching in a safe and reflective place. This is reinforced by the opportunity to practise a wide variety of different skills that are essential foundations for a professional engineer (see **Figure 1**, Chapter 1). The opportunity to interact with other students and graduate engineers, whether through work experience or mentoring, provides a foundation for self-assessment and critical thinking.

The fourth pillar of the model covers the opportunities required for students to be able to practise inclusive behaviour in respect of core engineering skills. It is about creating personal and career confidence.

This chapter defines how a course or programme can be adapted to instil inclusion into the mindset and behaviours of students. The five elements are presented here for the first time, in **Figure 13**. An analytical approach to each element will enable students to grow as an individual, become a valuable team member and set the foundations for being an authentic and inclusive engineer.

The practice of self-reflection, peer assessment and formative feedback reflects the modern-day work environment where performance achievement is replacing the annual appraisal.

Introducing this practice through a structured approach to managing student teams, rather than permitting students to always work in friendship groups, requires additional effort to create specific learning opportunities and to monitor progress. Providing opportunities for self-reflection and self-assessment supports learning and growth. It is important to connect self-reflection to the UKSPEC requirement of being 'aware of diversity' and being able to describe and evidence an instance of how they have demonstrated this.

The five separate elements are covered in turn in this section and are introduced in the context of team-based learning and working for use in course design and review.

5.1 Developing self-awareness

The practice of self-reflection is used increasingly across higher education and, as with problem-based learning, has its roots within the medical profession. Annexe B includes UCL Medical School's self-reflection framework adapted for use in the university's engineering department. It comprises a straightforward series of questions designed to help students analyse and structure their experience, and consider how they might improve.

Employers continue to use aptitude, personality type, engagement or psychometric analysis tests for staff development and selection. Similarly, some such assessments are used in higher education to help students develop self-awareness or aptitudes, delivered most often through the careers teams.

Engineering and science departments are known to use them, with Belbin being most frequently cited

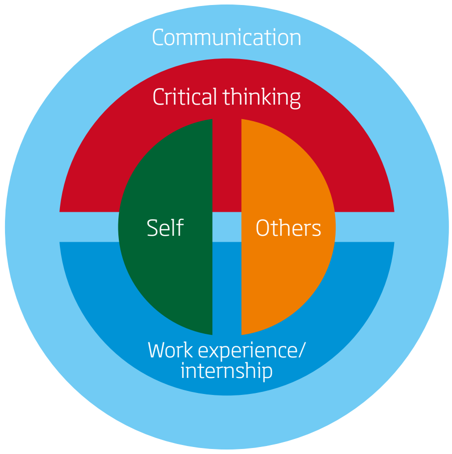


Figure 13: Five elements for the practice of inclusive professional skills

> “Gaining confidence and language to understand themselves and others means that students graduate with a mature view and respect for the contribution other people can make to a team.”

(Peters, 2017) and CliftonStrengths for Students (Gallup, 2017) being highly popular in the US and used at UCL in the IEP.

In the UK, while careers teams use many tools, such as Myers Briggs (MBTI), it is not often that engineering faculties or schools use these same tools as a systematic programme to develop self-awareness in active learning. A joined-up faculty–careers office approach could add value for students. The University of Wisconsin's School of Pharmacy introduced a strengths development programme delivered in three levels over the course of the degree programme (Janke et al, 2010).

The benefit of introducing one of these types of tools is that it can provide students with a vocabulary to describe their personal behaviours, thinking styles and preferred ways of engaging with a piece of work. This can be particularly useful for a student when analysing how they operate in a group environment, understanding what they personally need to be able to perform and similarly what they bring to a team. Equally, as students gain confidence in their own strengths, they learn to respect how others think and get things done. Allowing each other the space to be themselves can help to promote a feeling of inclusion and worth within a team.

Some of these tools offer personal insights using a positive psychology approach that focuses on what people do right, and in terms of inclusion, can help each student appreciate that everyone is different. For example, some team members require more time to think things through and as such need time to prepare for meetings, while others prefer to get things started and pause to think later. There are merits to all approaches.

Having a vocabulary to analyse and reflect on their experiences, or to manage challenging situations in teams, enhances students' learning if the tool is supported with group discussion and reflection. This also provides a framework and language for students to collect useful examples of their personal growth to discuss for CVs and at interviews.

Support from academics, personal tutors, mentors or champions can further maximise the benefit of such tools and help students manage their social interactions.

As a leader in engineering you can:

Commission an internal review of the kinds of personality-type tools used on courses and compare them to those currently used in industry, identifying a consistent approach with support for the tools used. Further, departmental industry contacts might be able to provide information on the tools that they use.

Careers teams are developing technology to aid students with the creation of a personal portfolio that can include reflecting on their 'career readiness' as well as other important aspects of learning from their course including projects. **Engineering departments would do well to engage with the developers so that student learning from problem-based projects or other forms of active learning experiences can be captured in the systems.**

5.2 Learning about others through team working

Exposing young people to diverse cultures, religions and people from diverse backgrounds would seem to be a key aspect of university life. But the reality is that most students appear to actively dislike working in diverse groups, choosing to work with friends or those they perceive are likely to help them gain a higher mark.

Such preferences can (in part) arise from a lack of understanding of the knowledge, skilful practices and attitudes a professional (engineer) requires and the nature of the work they do (see for example Trevelyan, 2009). It can also arise from a privileging of technical knowledge above other attainments such as the ability to communicate or work cooperatively with those from diverse backgrounds and experiences (Wilson-Medhurst, 2016). Within an inclusive culture, such assumptions can be challenged from the outset of a course and this can alleviate the preference to only work with friends or avoid those from other backgrounds or of a different gender.

In this chapter, three examples demonstrate how students are introduced to team working and given tools and opportunities to begin experiencing working with others at: Purdue University, UCL and UniSA. Teamwork-specific learning activities include learning from past teamwork experiences, supportive and constructive communication strategies, team organisation, what can go wrong, personal learning and team agreements, individual rank, inclusive communication, leadership styles, mentoring, conflict management, and diversity in the workplace.

Thus, within an appropriate culture and learning design, students should be 'forced' to mix with each other and to work in diverse groups. **Staff managing these groups will benefit from support as well as access to education and training to anticipate potential difficult situations as well to design learning experiences based on cooperative or collaborative learning principles.**

One of the biggest complaints from engineering students in teams is of 'freeloaders,' also termed 'social loafers' in psychology literature, describing students who do not contribute to the team. Rarely do students see having a social loafer as an opportunity to learn how to motivate others that will repeatedly be applied and learned from over their career. An effective course and assessment design within an inclusive learning environment can help mitigate such problems, including a regular feedback session on team participation in the design can be beneficial. See section 4.7.

As a leader in engineering you can:

Use a list of specific things for the students to think about during their assignment in engineering design projects that address who uses the plant, building or product and how.

A safe and reflective space, to mimic the workplace, for structured, team-based activity can offer multiple learning opportunities and identify challenging people-based issues that students are likely to come across during their careers.

In a diverse team, members come from a variety of social identities based on their backgrounds, cultures, and prior lived experiences. To develop a group identity, members of these teams will need to deploy an attitude that is sensitive to others who may not look, act, or think like them and which can help to integrate individual cultural identities into a group identity. This integration must occur early on in team formation processes (Milliken et al, 2003) and is vital to team effectiveness.

Managing team make-up can create an authentic setting most closely allied to the real world and can be used to extend learning around people who are 'different' and aid integration into a team. This difference will not simply be different in terms of how we each think and do things but also encompasses our cultural and social backgrounds.

For example, in the first week of class at Purdue, the topic of diversity is introduced and a whole-class discussion on the diversity within the engineering classroom is facilitated. Throughout the semester, the topic of diversity is revisited in teaming assignments, roles and engineering design scenarios.

At the UCL symposium, one UK engineering educator said that home students complain about overseas students' difficulties with language and culture, while overseas students report that they feel isolated as they can't keep up with group discussions and don't understand student culture. Some women students say they feel uncomfortable working with male students, while it is not unheard of for some male students to resist working with women students, even going as far as to say that 'girls shouldn't be in engineering'.

Purdue University has also created the comprehensive assessment of

> Work experience gives university undergraduates the opportunity to gain transferable employability skills, bettering their chances of success in securing jobs on graduation. For businesses, work experience provides a means for capturing and nurturing talent early on and for identifying students with work-ready attributes."
>
> **National Centre for Universities and Businesses, 2016**

team member effectiveness (CATME[22]) tool that is available publicly to help with team setup, management and peer evaluation. As a part of the first-year engineering class, students are placed into diverse teams for an entire class using the CATME team formation tool (Layton et al, 2010) and evaluate their teammates' effectiveness several times throughout the semester (Loughry et al, 2007; Ohland et al, 2012). Through CATME, collectively students can begin to understand team and interpersonal dynamics.

Professional engineering institutions:

Create of a set of training scenarios to anticipate the situations for example when a male student refuses to work with a woman student on religious grounds.

Design a resource to assimilate university efforts to manage and support teams and a national team management tool.

Ultimately, team learning is preparation for a career in a diverse workplace. Students can be encouraged to develop their personal growth towards professionalism perhaps in an online diary format or learning journal. This would generate a useful habit to gather experiences that will help after graduation when the graduate engineer starts to consider becoming chartered.

5.3 Critical thinking and self-reflection

Critical thinking is a term used to cover a wide range of intellectual and cognitive skills. Essential to decision-making, engineers use it to:

- identify, analyse and evaluate information
- formulate and present reasoned arguments
- make rational intelligent decisions to inform actions.

Establishing a process and practising using this process, will form a strong habit as the foundation for an engineering career. Few view critical thinking in light of diversity and inclusion. Applying the process to yourself offers a way to highlight your own and others' assumptions and biases within every decision you are making. Academics could **explicitly help students apply critical thinking in this way as an integral part of what they do**. While assisting with discovering, exploring and overcoming personal prejudices and biases, this approach can also bring students' lived experiences to their engineering thinking.

Teaching a class or reviewing critical thinking and applying it to personal performance and awarding a separate assessment mark, offers the opportunity to comment and encourage students to think about their contribution more deeply, for example:

- What is the context for the problem – have I distorted a solution to support an inner argument?
- Do my beliefs affect my approach to the problem or solutions?
- Am I an autocratic visionary and using or abusing my power as team leader?
- How does my behaviour affect others in the group?
- Can I listen to others' approaches and viewpoints and consider them objectively against my own?
- Can I be flexible enough and humble enough to change my position when the facts are clear?
- Can I offer praise to the 'other side'?
- Have I/we taken enough time to specifically consider:
  - others with due respect and give everyone airtime
  - environmental impact
  - socioeconomic impact

22 http://info.catme.org/

Team communication tool at UCL using the CliftonStrengths tool

At UCL, all first-year engineers take the CliftonStrengths assessment in week one and gain their Top 5 strengths.

These are then used to help students learn to understand themselves better and, with support, use a group team map to explore how each team member contributes. Essentially, students are encouraged to give each other space to take time to think and contribute to the team in a way that suits them, so they can be their authentic self. Each team has a team coaching session with a Strengths Coach.

Having a vocabulary to describe each other in a positive way aids team dynamics and provides an analytical tool to aid communication. Undertaking structured self-critical reflections, as is done in medicine, can equip students with plenty of rich examples of their team experience to discuss in both applications and at job interviews. This is just part of the professional skills embedded into the IEP.

Professional skills learning at UniSA

Development of professional skills such as teamwork is too often wrongly assumed to occur by osmosis.

At the UniSA this is not left to chance. In every year of the civil engineering degree, students undertake teaching and learning activities embedded into one or two mainstream courses that provide a scaffolded development of professional skills. These activities are developed and often co-taught in collaboration with non-engineering academics.

With a highly diverse student cohort and more than half of students in at least one defined equity group, developing inter-culturally competent professionals is an essential but challenging task. Formal and informal evaluations undertaken in all courses over several years demonstrate that this approach has provided an effective and deep learning experience for students who develop increased teamwork competence and confidence in working inclusively. When you get student feedback such as 'the group work in this course is great!' then you are probably on the right track.

Team working at Purdue University

Purdue University reinforces the student curriculum on teams and diversity with research into the impact of the approach to diversity.

On average, students have significant positive shifts in their attitudes about teaming and more awareness of diversity after completing the first-year engineering course, but significant negative shifts in the ratings of their effectiveness from overly positive ratings to realistic ratings.

This indicates that working in diverse teams is beneficial for both shaping students' teaming attitudes as well as adjusting their ability to evaluate their own and others effectiveness in teams. These findings indicate that one semester may increase awareness of diversity, but is not sufficient to reshape students' desire to work in diverse teams or act against bias or discrimination within teams. This preliminary work highlights the importance of supporting students in developing positive attitudes about diversity through explicit discussion and training about diversity and teaming in the classroom in a deliberate and distributed (across the curriculum) way.

This doesn't have to be difficult or time consuming. Adding an additional self-reflective dimension into the critical-thinking process will add an extra dimension to this important process and enable students to always consider, in the work they do, their own personal influence on decision-making.

5.4 Internships and work experience

A positive placement and/or internship is a valuable way of gaining useful experience and insights into different companies and job roles, and putting technical expertise into practice. They also build a student's social and engineering capital by enabling them to understand and practise the different forms of communication that take place at work.

Yet all work experience is not equal. Seron et al (2015) report on the subtle and cumulative effects found in the values and norms of the professional culture of engineering that can compromise the experience of women (and by extension minority groups). It isn't known if this sense has percolated through to women students and why fewer women and students from minority ethnic backgrounds undertake work placements than white men (Peters and McWhinnie, 2012). What is known is that undertaking an industrial placement is a significant factor in reinforcing respondents' intentions to seek employment as an engineer/technologist or undertake further study in engineering and technology.

Seron et al refer to a lack of career confidence among women students and yet this is exactly what an internship should build. Women are not the only students to have lower career confidence than white, male students. Students from backgrounds with no working adults or adults with non-managerial experience are also likely to have lower social capital than students from a middle-class home.

To level the playing field, all students need to have access, and encouragement, to seek the best opportunities to build confidence. These experiences, if positive, lead directly to increased confidence and capability to engage in topics of conversation around the workplace that can be deployed at interviews and assessment centres.

In a survey of 4,500 students, 69% of men and 67% of women who had undertaken at least one work placement or internship during their course, were more intent on pursuing a career in engineering or technology (McWhinnie and Peters, 2012). The more positive a respondent's experience, regardless of gender during work placement or internship, the more intent they were on pursuing a career in engineering or technology.

Further, the survey found that an adverse industrial placement appears to negatively affect women's intentions toward seeking employment as an engineer or technologist more than men's (McWhinnie and Peters, 2012). If the proportions of women graduating in engineering and transitioning into engineering jobs are to equal those of men, it is vital that the quality of work placements improves and that more women (and minorities) take one or more placements.

Ensuring that all your students are positively encouraged and supported in seeking work experience will go some way to raising the proportion of underrepresented students who gain valuable experience, but making sure that the experiences are positive is equally important. Placements must be high quality and offer a positive experience.

Brunel University operates a mixed and a woman-only mentoring programme for students, with the opportunity to support students' confidence and social capital, but also to offer them opportunities to visit workplaces with their mentor.

5.5 Communication and interpersonal skills

Communication skills top surveys of skills that employers want in graduates and frequently also top the area of most dissatisfaction. For engineers, communication is critical and needs to cover verbal and written communication, as well as presentation skills. In addition to being able to communicate detailed technical aspects of a project, engineers must be able to communicate with a diverse range of people. Many engineering departments already nurture these skills.

A few points that address inclusion in communication:

- Be aware of who is presenting what information at various stages of projects. For example, are male students doing all the talking or presenting the technical information?
- Multiple, in-progress presentations by teams, rather than a final presentation with formative feedback, ensures that students can do better and reflect on the experience.
- Ensure that students learn to listen, reflect and question each other before providing feedback.
- Use a personality type team tool to give students a vocabulary to use when providing feedback.
- Encourage students to be aware of themselves and others so they can value and appreciate people who think, feel and act differently to themselves.
- Offer a marking scheme that identifies self and team learning to impress on students the importance of appreciating peers and valuing their diverse contributions. Again, the self-assessment tool can help students with expressing and communicating what, at times, may be difficult feedback to peers.
- Provide support, encouragement and recognition to students who actively engage others in discussions.
- Offer tutoring, peer mentoring or coaching by senior students (vertical tutoring).
- Create situations where students can build confidence presenting to different audiences and can practise in different situations.

5.6 Summary

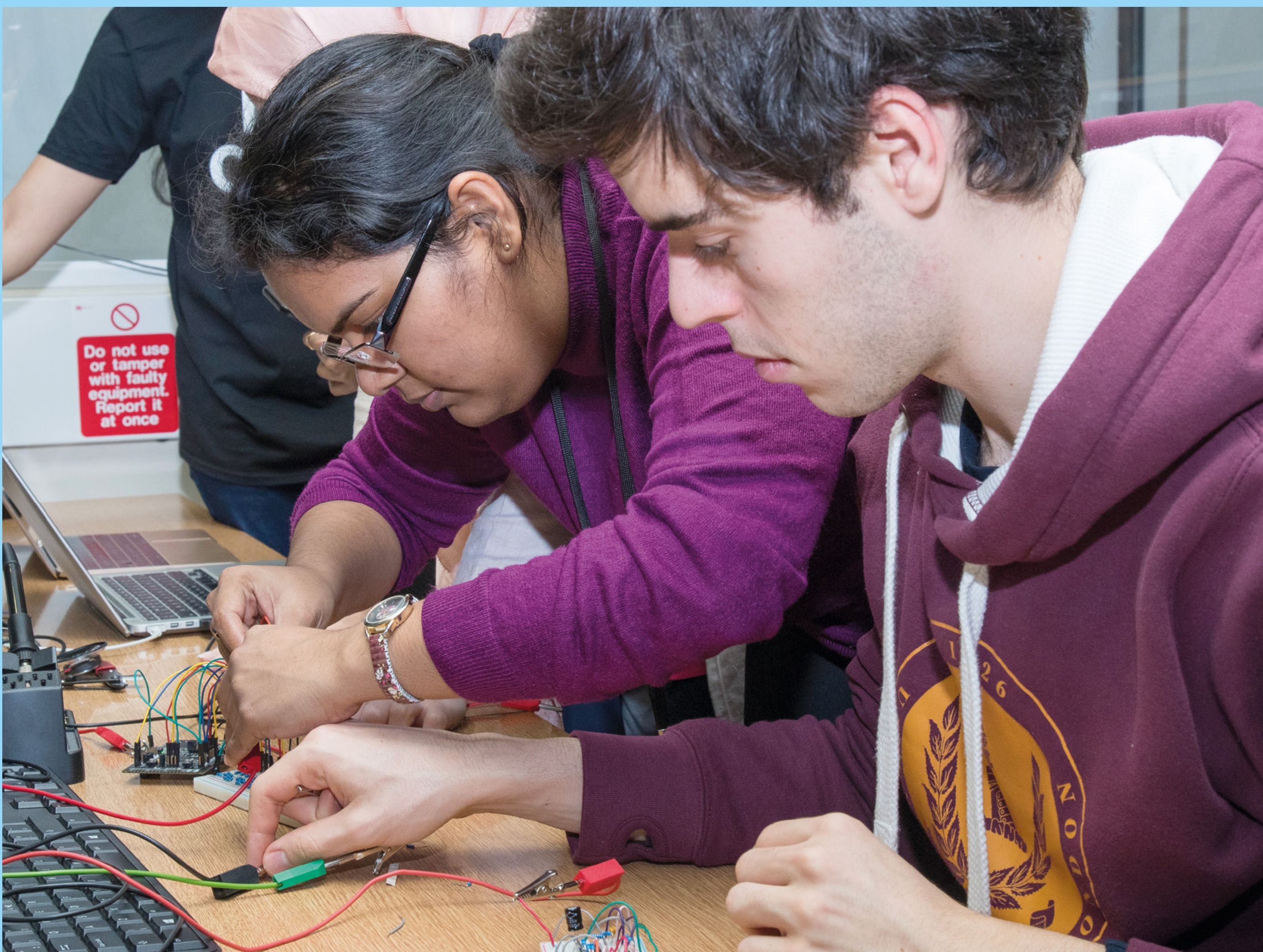
Active learning approaches appropriately managed can provide a safe and supportive environment to practise the non-technical skills demanded by engineering and technology employers. Opportunities exist to improve the support for underrepresented and minority students to gain confidence and unlock their potential as a professional.

Further input from PEIs and employers can enrich the opportunities and experiences across the many industry sectors that employ engineers. Importantly, actions that raise the standards of internships and work experience are needed. Summary actions for engineering leaders are:

As a leader in engineering you can:

- review data about students who have taken a placement and actively monitor it to encourage minority students to apply
- create a 'code of practice' or charter for employers to sign up to, setting out the key elements of positive work placements
- provide students with insights to work behaviours and tips on what to expect
- do more to impress upon students the positive impact that undertaking work placements have on employability
- ensure all interns are paid at least a standard living wage
- establish a student–industry mentoring programme to build links between universities and employers, as well as provide confidence and business insights to students.

> **The challenge has been to clarify how diversity and inclusion can be seen to be relevant** to engineers and engineering, and empower the profession to be both confident and competent in addressing it."



6 Conclusions and recommendations

This report has tried to reframe diversity and inclusion into an engineering context. Examples and practice from across the world have been brought together to expand diversity beyond the visible differences of the students themselves.

The challenge has been to clarify how diversity and inclusion can be seen to be relevant to engineers and engineering, and empower the profession to be both confident and competent in addressing it.

The imperative is to address the three irrefutable facts that engineering:

- has in the past failed to provide solutions for some populations
- is diverse in many ways and there is no excuse for failing to provide equal outcomes for students from different backgrounds
- needs to adapt to meet the standards expected of engineers.

The four pillars for inclusive engineering education provide a framework for dissecting engineering education into many practical steps that can be addressed with regard to diversity and inclusion. The ideas and illustrations are gathered together from educators, social scientists and engineers who have been working to engage and inspire increasingly diverse cohorts of students.

Real-world, context-based projects, scenarios and case studies offer an authentic experience that prepare students to face the engineering challenges of the 21st century. These also provide a context to develop the skills that will empower engineering students to be more self-aware and better communicators and/or managers.

6.1 The inclusive engineer

The term *the inclusive engineer* has been introduced to describe a graduate who can work effectively in a team, making adjustments and allowances for each individual's way of thinking and working, is able to consider a wide variety of users, and be creative and innovative in addressing users within designs and solutions.

An inclusive, diverse and confident engineering profession amounts to each engineer being aware of their personal biases and those that have become inherent in the 'way things are currently done', as well as being be able to take steps to interrupt this for improved evidence-based thinking and design decisions.

This requires a sustainable change in engineering as inclusion and its relevance to the curriculum and profession are articulated when communicated to staff. **Figure 16** summarises the contribution of each group to an inclusive and respectful profession. Deeper analysis of this will help to inform the mapping of this onto the curriculum for the inclusive engineering curriculum.

6.2 Further work

The recommendations for each of the four pillars have focused on the practical steps needed in engineering to nurture the confidence of staff and students in talking about difference.

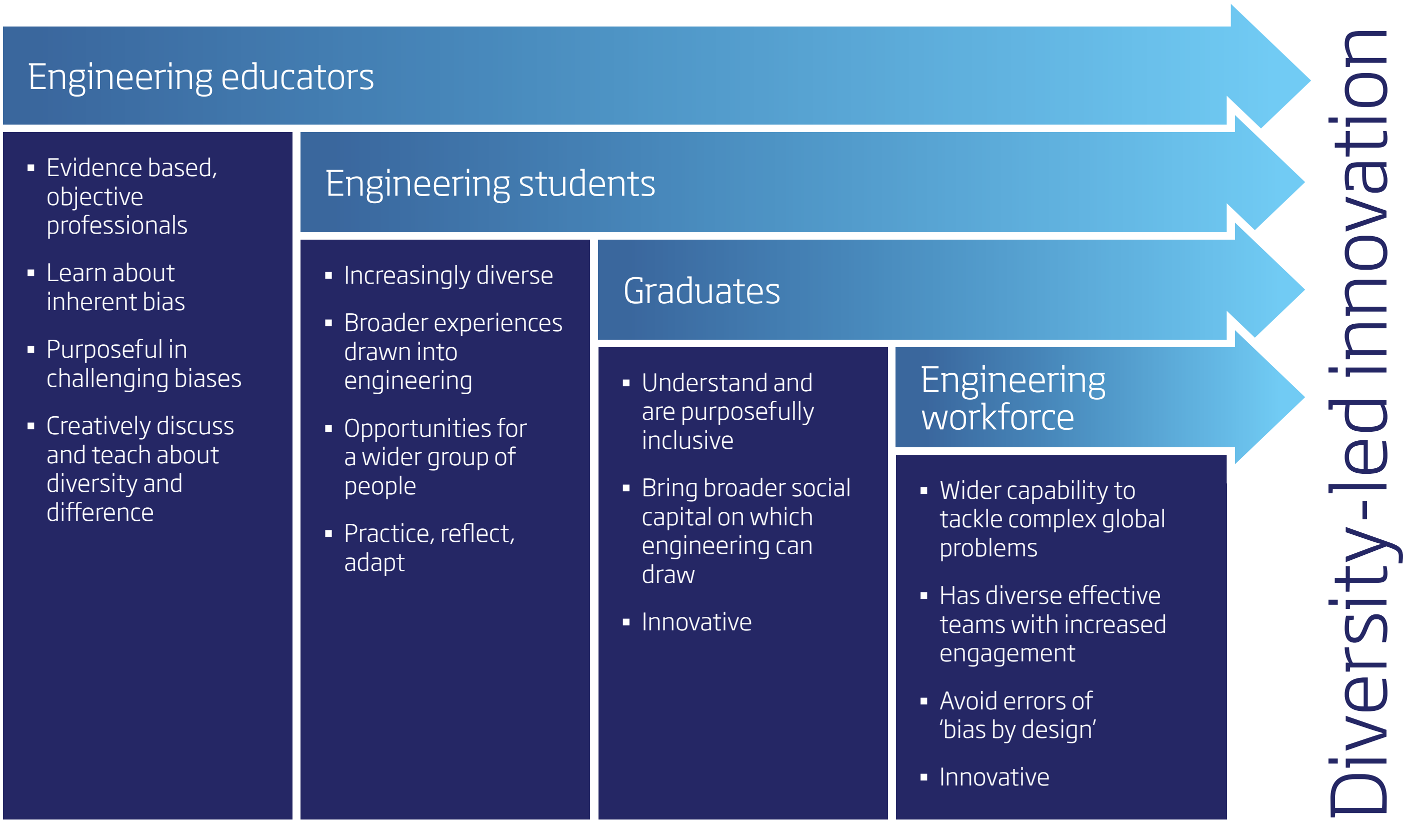


Figure 16: The process and impact of creating inclusive, diversity confident engineers

The many initiatives and programmes in progress across the UK directed towards inclusion in higher education, for example widening participation and achievement, addressing the attainment gap for target groups of students and tackling bullying and harassment as well as generally making the curriculum inclusive, are acknowledged. Further recommendations to those made through the report are directed at:

1. leadership from deans, professional bodies and learned societies
2. benchmarking and good practice
3. monitoring and reporting on change.

Investment and coordination at a national level is required to develop consistent, quality resources that are supported by the PEIs and learned societies. Indeed, perhaps one of the reasons that engineering is slow to address inclusion and the creation of an inclusive culture is the lack of engagement of the many different PEIs compared to the sciences.

The following actions support the development of sustainable change across the engineering disciplines and the relevant PEIs:

- A multi-university project is needed to define a curriculum to create inclusive and diversity confident engineering students. Three or four partner universities need to pilot and evaluate the curriculum. Outputs should include background material, discussion guides and a train the trainer programme and that can be integrated into PEI accreditation of departments.
- A short survey showing how widespread the teaching of diversity is within engineering programmes is needed to identify sources of good practice.
- A benchmarking study is needed into the engagement of inclusion and diversity across engineering departments to collect good practice and monitor change and produce a 'University of Utopia' Engineering Faculty Good Practice Guide.

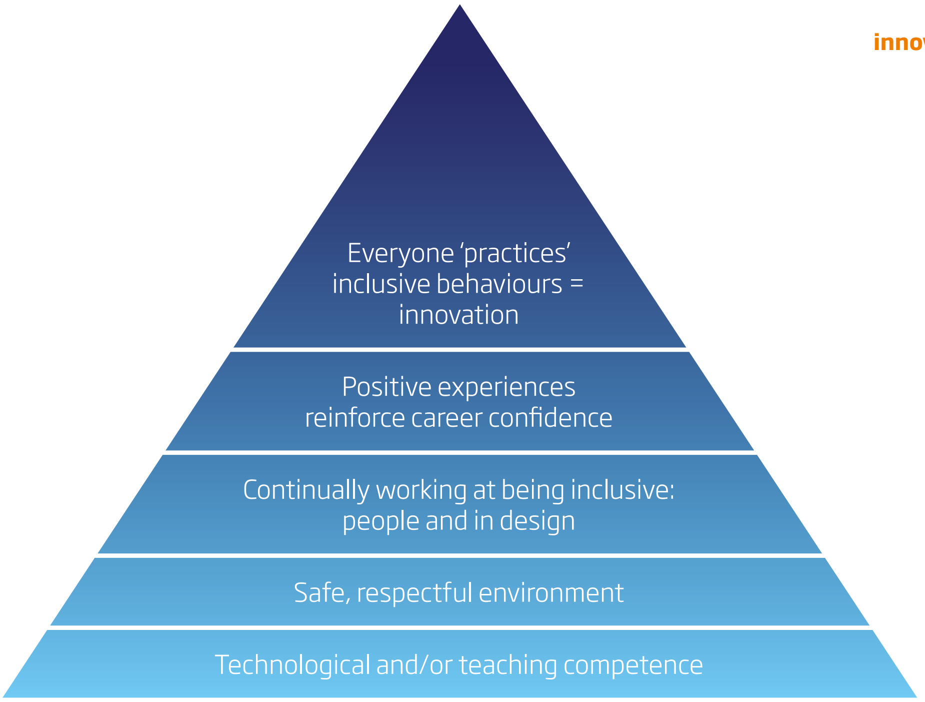


Figure 17: Five essentials for driving innovation (or harnessing) innovation through engineering education

- Research is needed to assess how student engineers use and perceive social science and policy literature. Outputs should include examples of how engineers and student projects have used social science or medical datasets, and how confidence in this information source can be taught to student engineers. The output would be an illustrated resource of social science and policy research that could be used by engineering educators to demonstrate examples of valuable and well-structured research.
- Capstone projects over five years need to be monitored to explore changes in themes and outputs.
- A study into the foundations for leadership and team working for undergraduate engineers is needed to draw together best practice and inform a curriculum with supporting material and training. It could be undertaken in conjunction with PEIs and employers.

6.3 Sustainable change

The profession will become more inclusive as engineers from all backgrounds and genders can contribute and achieve their potential. The expectation is that engineers will innovate around the global diversity change programme as this happens.

Monitoring progress, perhaps by using a traffic light system, will build on quality teaching and technical competence, and should focus on the following stages:

- The environment should be safe and respectful.
- Engineers should strive to be inclusive colleagues, managers, leaders, problem solvers and designers.
- Positive experiences will reinforce career confidence in underrepresented groups who feel able to be only 'partly present at work' for fear of being marginalised.
- Inclusive behaviours and thinking should generate innovation as engineers seek out currently unseen problems.

6.4 Recommendations

This report should facilitate conversations with engineers around diversity and inclusion that are constructive and not threatening or critical.

In summary, inclusive engineering education is about:

1. **providing all students with the chance to achieve their potential** by each person gaining the same quality of experience to make them into a credible and confident engineer
2. **doing the best thing for the profession, creating quality engineers** with an inclusive mindset who will go on to advance the profession and be exceptional engineers, managers and leaders
3. **better engineering solutions for the diverse world and society we live in.**

In working towards this sustainable change the following three recommendations are made:

Recommendation 1:

Leaders and educators in engineering in all higher education establishments should develop a five-year action plan around the four-pillar model for inclusive engineering education.

Recommendation 2:

Professional bodies and learned societies should commit resources and processes to addressing the knowledge and information gaps, and address inclusion through course accreditation in the spirit of professional standards such as in the UK the UKSPEC.

Recommendation 3:

Funding should be allocated for a resource of benchmarking, case studies and tools to ensure that diversity and inclusion are addressed and supported through active learning approaches to education and learning.

Successfully managing and reaping the benefits from multiculturalism and diversity in all its forms in the engineering classroom demands more and more of engineering educators. Above all, to accept and celebrate students' differing prior experiences and diverse perceptions we also must accept that, like the rest of the population, students need to feel comfortable with each other. With careful planning and creative management, students can be encouraged to work together in a successful and synergistic manner. Diversity and difference can promote innovation and invention.

> **It simply makes sense to** integrate this way of thinking, behaving and working into student life and learning."

7 Glossary

ASD	Asperger's Spectrum Disorder
AUDE	Association of University Directors of Estates
BME	Black and Minority Ethnic
BAME	Black Asian and Minority Ethnic
BBC	British Broadcasting Corporation
BIS	Department of Business, Innovation and Skills
CATME	Comprehensive Assessment of Team Member Effectiveness
CDIO	Conceiving Designing Implementing Operating educational framework
CPD	Continuing professional development
CSR	Corporate social responsibility
EE	Engineering education
EI	Emotional Intelligence
ECU	Equality Challenge Unit
ENGAGE	An approach to classroom management
SEFI	European Society for Engineering Education
SHE	European Statistics in Research and Innovation
SWAN Awards	Higher Education Gender Diversity Recognition programme
HE	Higher education
HEFCE	Higher Education Funding Council of England
LGBTQ	Lesbian, Bisexual, Gay, Transgender, Queer or Questioning
MOOC	Massive open online course
MRC	Medical Research Council
NCUB	National Centre for Universities and Businesses
NSF	National Science Foundation
PAL	Peer assisted learning
DISC	Personality profile tool
PBL	Problem Based Learning
PEI	Professional engineering institute
QAA	Quality Assurance Agency for Higher Education
STEM	Science Technology Engineering and Maths
TECAID	Transforming Engineering Culture To Advance Inclusion and Diversity: NSF funded programme
TESTA	Transforming the Experience of Students through Assessment
UKSPEC	UK Standard for Professional Engineering Competence

8 References

Andrews, J., Clark, R. & Phull S. (2016). "Equality & Equity: Effecting a Paradigm Shift in Engineering Education through Pedagogical Research". *UCL Symposium on Equality & Equity in Engineering Education.* Workshop. UCL. London. [Unpublished working paper]

Ashburn-Nardo, L., Morris, K. A., Goodwin, S. A (2008) The Confronting Prejudiced Responses (CPR) Model: Applying CPR in organisations. Academy of Management Learning & Education, 2008, Vol. 7, No. 3. 332-342

Barnard, S. (forthcoming, 2017) 'The Athena SWAN Charter: promoting commitment to gender equality in Higher Education Institutions in the UK' in White, K. & O'Connor, P. (eds) Gendered Success in Higher Education. Palgrave Macmillan: London.

Barnard S., Bagilhole B., Dainty A., Hassan T. (2012) Women in Engineering in the UK. In: Béraud A., Godfroy AS., Michel J. (eds) GIEE 2011: Gender and Interdisciplinary Education for Engineers. SensePublishers, Rotterdam

Barkley, E. F., Major, C. H., & Cross, K. P. (2014). *Collaborative learning techniques: A resource for college faculty* (2nd ed.). San Francisco, CA: Jossey-Bass.

Barrows, H.S and Tamblyn, R.M. (1980) *Problem-based Learning, An Approach to Medical Education.* New York: Springer

Berry, J. & Loke, G. (2011) *Ethnicity and Degree Attainment.* DfeS Research Report RW92. London: DfES

Bilimoria, D. and Stewart, A.J. (2009) "Don't Ask, Don't Tell": The Academic Climate for Lesbian, Gay, Bisexual, and Transgender Faculty in Science and Engineering NWSA Journal, Volume 21, Number 2, Summer 2009, pp. 85-103

Cech, E. A. and Waidzunas (2011) "Navigating the heteronormativity of engineering: the experiences of lesbian, gay, and bisexual students". Engineering Studies Volume 3, Issue 1, 2011 https://goo.gl/zDVqCH

Crawley, E., Malmqvist, J., Ostlund, S., and Brodeur, D. (2007) Rethinking Engineering Education: The CDIO Approach, Springer Press

Dasgupta, N., McManus Scircle, M., & Hunsinger, M., (2015) Female peers in small work groups enhance women's motivation, verbal participation, and career aspirations in engineering PNAS 2015 112 (16) 4988-4993

Department for Business, Innovation & Skills (BIS) and Higher Education Funding Council for England (HEFCE) (2016) Wakeham Review of STEM Degree Provision and Graduate Employability. https://goo.gl/vkJGGf

Department for Education (2017) *Inclusive Teaching and Learning in Higher Education as a route to Excellence.* DFE-00044-2017 https://goo.gl/jn6MTT

Du, X., & Kolmos, A. (2009). Increasing the diversity of engineering education – a gender analysis in a PBL context. *European Journal of Engineering Education*, 34(5), 425–437. http://doi.org/10.1080/03043790903137577

ECU (2015) Gender Charter Athena Swan. Available [online] https://goo.gl/RJAtPF

ECU (2017) ASSET 2016: experiences surrounding gender equality in engineering, and their intersections with ethnicity and disability. Available [online] https://goo.gl/s5wKUm

Eliot, M. Turns, J. (2011) Constructing professional portfolios: sense-making and professional identity development for engineering undergraduates, Journal of Engineering Education, October 2011, Vol. 100, No. 4, pp. 630–654

Ernst & Young. (2014) The Power of Many https://goo.gl/hyoKhn

European Commission (2013) *SHE Figures: Gender in research and innovation*, Luxemburg: Publications Office of the European Union.

European Commission (2015) SHE Figures. *Gender in Research and Innovation: Statistics and Indicators.* Research and Innovation, European Commission.

Etzkowitz, H. Kemelgor, C. and Uzzi, B., (2000) *Athena Unbound: the advancement of women in science and technology* Cambridge University Press, UK.

Gallup (2017) CliftonStrengths for Students. Gallup Press, New York.

Goldberg, D. E. and Sommerville, M. (2014*)* A Whole New Engineer, ThreeJoy Associates, Inc.: Douglas, Michigan USA.

Goleman, D., (1996) Emotional Intelligence and why it can matter more than IQ. Bloomsbury Publishing. London.

Graham R. (2018) Global State of the Art in Engineering Education. MIT. Available https://goo.gl/CM32jA

Grasso, D., Burkins, M. B. (2010) Holistic Engineering Education: Beyond Technology, Springer Science+Business Media.

HEFCE (2015) Causes of differences in student outcomes.

Johnson D. W., & Johnson, R. (1989) *Cooperation and competition: Theory and research*. Edina, MN: interaction Book Company.

Johnson, D.W., & Johnson, F. (2009) Joining *together: Group theory and group skills* (10th ed.). Boston: Allyn & Bacon.

Jost, R. (2004) *Benchmarks for Cultural Change in Engineering Education*. Internal document under project initiated by University of Newcastle's (Australia) Equity and Challenge Unit and funded by the Higher Education Equity Programme of the federal Department of Education, Science and Training. Document overseen by the University's working party on Women in Non-traditional Areas of Study.

Kamp, A., (2014) Engineering Education in the Rapidly Changing World. Rethinking the Mission and Vision on Engineering Education at TU Delft. Hg. v. TU Delft. Delft. https://goo.gl/5VRcKE

Kahneman, D. (2011) Thinking, Fast and Slow. Farrar, Straus and Giroux

Kirn, A. et al., (2016) Intersectionality of Non-normative Identities in the Cultures of Engineering (InIce). In *American Society for Engineering Education Annual Conference & Exposition*. [online] New Orleans, LA: ASEE, p. 19. Available at: https://peer.asee.org/25448.

Lage, M., Platt, G, Treglia, M. (2000), Inverting the Classroom: A gateway to Creating an Inclusive Learning Environment, Journal of Economic Education

Layton, R.A. et al., (2010) Design and validation of a web-based system for assigning members to teams using instructor-specified criteria. *Advances in Engineering Education*, 2(1), pp.1–28.

Leicht-Scholten, C. Bouffier, A (2015) Mehrwert durch mehr Perspektiven. Wie eine Brückenprofessur neue Perspektiven in den Ingenieurwissenschaften aufzeigt. In: RWTH Themen 2/2015, RWTH Aachen University. Online: https://goo.gl/wUqX8S July 7, 2016, pp. 12-14.

Leicht-Scholten, C., Steuer, L. and Bouffier, A. (2016) Facing Future Challenges: Building Engineers for Tomorrow, Proceedings of the International Conference "New Perspectives in Science Education" Ed. 5, Florence, Italy. Online: https://goo.gl/51LLRZ June 23, 2016.

Leicht-scholten, C., Weheliye, A., & Wolffram, A. (2009) Institutionalisation of gender and diversity management in engineering education. *European Journal of Engineering Education*, 34(5), 447–454. https://goo.gl/L9FCzg

Loughry, M.L., Ohland, M.W. & Moore, D.D., (2007) Development of a theory-based assessment of team member effectiveness. *Educational and Psychological Measurement*, 67(3), pp.505–524.

McWhinnie, S. and Peters, J. W. (2012) Jobs for the boys? Career intentions and destinations of engineering and technology undergraduates in UK higher education. www.katalytik.co.uk

McMasters, J.H., (2004) Influencing Engineering Education: One (Aerospace) Industry Perspective," International Journal of Engineering Education, vol. 20, no. 3, pp. 353–371.

McKinsey (2015) Diversity Matters https://goo.gl/ZMvZJ8

Maslow, A. H. (1943). A Theory of Human Motivation. *Psychological Review, 50(4)*, 370-96

Milliken, F.J., Bartel, C.A. & Kurtzberg, T.R., (2003) Diversity and creativity in work groups: A dynamic perspective on the affective and cognitive processes that link diversity and performance. In: P.B. Paulus and B.A. Nijstad, eds. *Group creativity: Innovation through collaboration*, Oxford: Oxford University Press, pp.32–62.

Mills, J. E., & Treagust, D. F. (2003) Engineering education—Is problem-based or project-based learning the answer? *Australasian Journal of Engineering Education*, 3, pp. 2-16.

Mills, J. E., Ayre, M. E. And Gill, J. (2010a) Gender Inclusive Engineering Education. New York: Routledge

Mills, J. E., Ayre, M. E. And Gill, J. (2010b) Guidelines for the design of inclusive engineering education programmes Australian Learning and Teaching Council. Available at: https://goo.gl/zygBSC (accessed 17 July 2016)

Mills, J.E. and Smith, E.J. (2014) You can't leave it all to final year. AAEE 2014, Wellington, New Zealand, 8-10 December 2014 – available through ResearchGate

Mitchell, J.E., Bains, S. Nyamapfene, A., Tilley, E. (2015) Work in progress: Multi-disciplinary curriculum review of engineering education. UCL's integrated engineering programme, 2015 IEEE Global Engineering Education Conference (EDUCON), pp.844-846

National Centre for Universities and Business, (2016). Work experience as a gateway to talent in the UK: Assessing business views. www.Ncub.ac.ok

Nortcliffe, A. Keech, C. and Evans, J. (2014) Closing the BME attainment gap. SEFI (2014) Educating Engineers for Global Competitiveness, 15-19 September 2014

Nortcliffe, A. and Keech, C. (2016) The Impact of PAL on diverse student cohort, Inclusive Engineering Education Symposium, 21-22 April 2016, University College London, UK [on-line at] https://goo.gl/QXrC5a

Ohland, M.W. et al., (2012) The comprehensive assessment of team member effectiveness: Development of a behaviorally anchored rating scale for self-and peer evaluation. Academy of Management Learning & Education, 11(4), pp.609–630.

O' Mahony, J., Thomas, L. and Payens, J. (eds) (2013) Building inclusivity: engagement, community and belonging in the classroom – interviews with Rowena Arshad, Vicky Gunn, Ann-Marie Houghton and Bob Matthew. York: Higher Education Academy.

Patterson E.A., Campbell P.B., Busch-Vishniac I. & Guillaume D.W., (2011) The effect of context on student engagement in engineering, European J. Engineering Education, 36(3):211-224, 2011.

Pawley, A. (2004) The feminist engineering classroom: a vision for future educational innovations. Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition. American Society for Engineering Education

Peters, J. W. (2017) Personal communication, interviews and conversations in the development of this report.

Peters, J. W. and McWhinnie, S. (2012) Jobs for the boys: summary report of Set to Lead: increasing the opportunities for women engineering undergraduates. www.katalytik.co.uk

Powell, A., Dainty, A. and Bagilhole, B., (2011) A poisoned chalice? Why UK women engineering and technology students receive more 'help' than their male peers. Gender and Education, 23:5, 585-599. DOI: 10.1080/09540253.2010.527826

Rock, D. and Grant, H. (2016) Why diverse teams are smarter. Harvard Business Review https://goo.gl/plUmim

Royal Academy of Engineering. (2017) Creating cultures where all engineers thrive. https://goo.gl/UmshJQ

Royal Academy of Engineering. (2007) Educating Engineers for the 21st Century

Royal Academy of Engineering. (2010) Educating Engineers for Industry, Lamb, F. Arlett, C., Dales, R., Ditchfield, R., Parkin, B. and Wakeham, W. https://goo.gl/jQpktY

Royal Society of Chemistry. (2008) Planning for Success: Good Practice in University Science Departments. https://goo.gl/zFW4rC

Savin-Baden, M. and Wilkie, K. (2004) "Challenging Research in Problem-Based Learning". Society for Research into Higher Education and Open University Press,

Schiebinger, L., Klinge, I., Paik, H. Y., Sánchez de Madariaga, I., Schraudner, M., and Stefanick, M. (Eds.) (2011-2017). Gendered Innovations in Science, Health & Medicine, Engineering, and Environment

Seron, C., Silbey, S. S., Cech, E., & Rubineau, B. (2015) Persistence Is Cultural: Professional Socialization and the Reproduction of Sex Segregation. *Work and Occupations*, *43*(2), 178-214. DOI: 10.1177/0730888415618728

Silbey S., (2016) Why Do So Many Women Who Study Engineering Leave the Field? Harvard Business Review August 23 2016 HBR.org

Seymour, E., (2001) 'Tracking the Processes of Change in US Undergraduate Education in Science, Mathematics, Engineering, and Technology.' Science Education, 85(6): 79-105.

Soudien, C. (2010) Transformation in higher education: A briefing paper. Development Bank of Southern Africa (DBSA). Available [online] https://goo.gl/gkBZ8b

Stevenson, J. (2012) Black and minority ethnic student degree retention and attainment. *Higher Education Academy*.

Strobel, J., and van Barneveld, A. (2009) When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms. *Interdisciplinary Journal of Problem-based Learning, 3*(1), pp. 44-58.

Trevelyan, J. (2009) Steps Towards a Better Model of Engineering Practice. Proceedings of the Research in Engineering Education Symposium 2009, Palm Cove Qld

Wilson-Medhurst, S. (2013) *Enabling belonging and engagement through activity-led learning*, Compendium of effective practice in higher education: Volume 2, pp. 132-135, The HEAcademy. ISBN: 9781854494474

Wilson-Medhurst S. (2016) *Student attainment through Activity-Led Cooperative Learning* in Steventon, G, Cureton, D., Clouder, L. (eds.), Student Attainment in Higher Education: Issues, controversies and debates, Routledge.

9 Bibliography

The following references have informed the writing of this report, though not all are directly referenced in the text.

Agapiou, A. (2002) Perceptions of Gender Roles and Attitudes toward Work Among Male and Female Operatives in the Scottish Construction Industry. *Construction Management and Economics* 20: 697-705.

Alpay, E. (2013). Student attraction to engineering through flexibility and breadth in the curriculum. *European Journal of Engineering Education*, 38(1), 58–69. http://doi.org/10.1080/03043797.2012.742870

Appel, M., Kronberger, N. and Aronson, J. (2011) "Stereotype threat impairs ability building: Effects on test preparation among women in science and technology" European Journal of Social Psychology 41:904-913

Andresen, S., Koreuber, M. and Lüdke, D. (Eds.) (2009): Gender und Diversity: Albtraum oder Traumpaar? Interdisziplinärer Dialog zur „Modernisierung" von Geschlechter- und Gleichstellungspolitik. VS Verlag für Sozialwissenschaften.

Atkin J.M. & Karplus R, Discovery or invention? Science Instructor, 29 (5):45-47, 1962.

Bagilhole, B. and Goode, J. (1998) The 'Gender Dimension' of both the 'Narrow' and 'Broad' Curriculum in UK Higher Education: Do women lose out in both? *Gender and Education*, 10 (4): 445-458.

Barnard, S., T. Hassan, B. Bagilhole and A. Dainty (2012b) "They're not girly girls': an exploration of quantitative and qualitative data on engineering and gender in Higher Education' in the *European Journal of Engineering Education*

Barnard, S., Hassan, T., Dainty, A. and Bagilhole, B., 2013. Interdisciplinary content, contestations of knowledge and informational transparency in engineering curriculum. *Teaching in Higher Education*, 18(7), pp.748-760.

Beech, Suzanne E., and B. Rientes. "The Multicultural Experience? 'Cultural Cliques' and the International Student Community." https://goo.gl/bWxfBT Accessed 22.6.16

Borrego, M., & Cutler, S. (2010). Constructive alignment of interdisciplinary graduate curriculum in engineering and science : An Analysis of Successful IGERT Proposals. *Journal of Engineering Education*, 99(4), 355–369. https://goo.gl/6PW6Ce

Bruffee, K. (1993). *Collaborative learning: Higher education, interdependence, and the authority of knowledge*. Baltimore, MD: The Johns Hopkins University Press.

Byrne, D.S., (1999). *Social Exclusion*, 1st ed. T. May, ed., Buckingham: Open University Press.

Carter, R. and Kirkup, G. (1990) *Women in Engineering: A good place to be?* Basingstoke: Macmillan.

Cech, E. a. (2013). Ideological wage inequalities? The technical/social dualism and the gender wage gap in engineering. *Social Forces*, 91(4), 1147–1182. http://doi.org/10.1093/sf/sot024

Carlsson, G., 2009. Topology and data. *Bulletin of the American Mathematical Society*, 46(2), pp.255–308.

Camps, C (2016) *Valuing, harnessing and using the unique asset of working in a bilingual institution: introducing the Welsh language into a postgraduate certificate in higher education* in Equality and diversity in learning and teaching in higher education: Papers from Equality Challenge Unit and Higher Education Academy joint conferences. Available [online] https://goo.gl/mw7xKS

Cockburn, C. (1985) Caught in the Wheels: The high cost of being a female cog in the male machinery of engineering. In: D. Mackenzie and J. Wajcman (Eds.) *The Social Shaping of Technology*. Milton Keynes: Open University Press.

Crompton, R. and Sanderson, K. (1990) *Gendered Jobs and Social Change*. Unwin Hyman: London.

Cronin, C. and A. Roger (1999) Theorizing progress: women in science, engineering, and Technology in Higher Education. *Journal of Research in Science Teaching*, 36(6): 637-661.

Davidson, N., & Major, C. H. (2014). Boundary crossings: Cooperative learning, collaborative learning, and problem-based learning. Journal on Excellence in College Teaching, 25(3&4), pp. 7-55.

Devine, D. J., Clayton, L. D., Phillips, J. L., Dunford, B. B., & Melner, S. B. 1999. Teams in organizations: prevalence, characteristics, and effectiveness. *Small Group Research*, 30: 678-711.

Dickens, L. (1999) Beyond the business case, a three-pronged approach to equality action. *Human Resource Management Journal*, Vol. 9, No. 1, pp9-19.

Dryburgh, H. (1999) Work Hard, Play Hard: Women and professionalisation in engineering – adapting to the culture, *Gender and Society*, 13 (5): 664-82.

Engineers Australia (2016). Accreditation management system for professional engineers. Available at: https://goo.gl/5YYWeU (accessed 8 June 2018)

Evetts, J. (1998) Managing the technology but not the organization: women and career in engineering. *Women in Management Review*, 13 (8): 283-90.

Faulkner, W. (2000) The power and the pleasure? A research agenda for 'Making gender stick' to Engineers. *Science, Technology and Human Values*, 25 (1): 87- 119.

Fielden, S. L., Davidson, M. J., Gale, A. W., & Davey, C. L. (2000). Women in construction: the untapped resource. *Construction Management and Economics* 18(1) 113-121. doi:10.1080/014461900371004

Frein, S. T., Jones, S. L.; Gerow, J. E. (November 2013). "When it comes to Facebook there may be more to bad memory than just multitasking". Computers in Human Behavior 29 (6): 2179–2182. doi:10.1016/j.chb.2013.04.031.

Gale, A.W. (1994) Women in Non-traditional Occupations: The construction industry. *Women in Management Review*, 9 (2): 3-14.

Godfroy-Genin, A. (2009) 'Women's academic careers in technology: a comparative European perspective', *Equal Opportunities International* Vol. 28 No. 1: pp. 80-97

Godwin, A., (2016) Purdue University, Personal communication

Godwin, A., Potvin, G., Hazari, Z., & Lock, R. (2016) Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice. *Journal of Engineering Education*, 105(2), 312–340. http://doi.org/10.1002/jee.20118

Hart R. and Roberts E. (2011) British Women in Science and Engineering: the problem of employment loss rates, working paper, Division of Economics, University of Stirling

Herman, C. (2015). Rebooting and Rerouting: Women's Articulations of Frayed Careers in Science, Engineering and Technology Professions. *Gender, Work and Organization*, 22(4), 324–338. http://doi.org/10.1111/gwao.12088

Hollenbeck, J. R., Beersma, B., & Schouten, M. E. (2012) Beyond team types and taxonomies: A dimensional scaling conceptualization for team description. *Academy of Management Review*, 37(1): 82-106.

Hornsby, D. J., & Osman, R. (2014) Massification in higher education: large classes and student learning. *Higher Education*, *67*(6), 711-719.

Ihsen, S. (2005). Special gender studies for engineering? *European Journal of Engineering Education*, 30(4), 487–494. http://doi.org/10.1080/03043790500213144

Ihsen, S., & Gebauer, S. (2009). Diversity issues in the engineering curriculum. European Journal of Engineering Education, 34(5), 419–424. http://doi.org/10.1080/03043790903137551

Jansen-Schulz, B. and van Riesen, K. (Ed.) (2011) Vielfalt und Geschlecht - relevante Kategorien in der Wissenschaft. Budrich UniPress.

Johnson D. W., & Johnson, R. (undated) *What is cooperative learning*. Available [online] http://www.co-operation.org/what-is-cooperative-learning

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1991) *Cooperative learning: Increasing college faculty instructional productivity* (ASHE ERIC Higher Education Report, No. 4). Washington, DC: The George Washington University.

Kandola, A. and Fullerton, J. (1998) *Managing the mosaic: diversity in action*. Various editions, London, CIPD.

Knoll, B., & Ratzer, B. (2009) "Gender-into-teaching" at the Vienna University of Technology. Experiences and reflections on an Austrian project. *European Journal of Engineering Education*, 34(5), 411–418. http://doi.org/10.1080/03043790903137544

Kochan, T., Bezrukova, K., Ely, R., Jackson, S., Joshi, A., Jehn, K., and Thomas, D. (2003) The effects of diversity on business performance: Report of the diversity research network. *Human resource management*, vol 42 no1,pp 3-21.

Kolmos, A., Mejlgaard, N., Haase, S., & Holgaard, J. E. (2013) Motivational factors, gender and engineering education. *European Journal of Engineering Education*, 38(3), 340–358. http://doi.org/10.1080/03043797.2013.794198

Krell, G., Riedmüller, B., Sieben B. and Vinz, D. (Eds.) (2007) Diversity Studies: Grundlagen und disziplinäre Ansätze. Campus.

Lako, M and Daher, S (2009) *Balancing Work and Life: A Conversation with Fiona Watt*, Stem Cells, April 2009; vol 27, no 4, pp762–763

Little, A. J., & León de la Barra, B. A. (2009) Attracting girls to science, engineering and technology: an Australian perspective. *European Journal of Engineering Education*, 34(5), 439–445. http://doi.org/10.1080/03043790903137585

McGlone and Aronson (2007) "Forewarning and Forearming Stereotype-Threatened Students" Communication Education 56: 119-133

McNiff, J. and Whitehead, J. (2006) *All you need to know about action research*. London: Sage

NAS (National Academy of Sciences), (2006) To recruit and advance: women students and faculty in US Science and Engineering. Available at: https://goo.gl/1sdfwL (accessed 17 July 2016)

Nicolau, M., Levine, A.J. & Carlsson, G., (2011) Topology based data analysis identifies a subgroup of breast cancers with a unique mutational profile and excellent survival. *Proceedings of the National Academy of Sciences*, 108(17), pp.7265–7270.

Ozbilgin, M. and Tatli, A (2011) Mapping out the field of equality and diversity: rise of individualism and voluntarism, *Human Relations*, Vol. 64, No. 9, pp 1229-1253.

Phipps, A. (2002) Engineering Women: The 'Gendering' of professional identities. *International Journal of Engineering Education*, 18(4): 409-414.

Powell, A., Bagilhole, B. and Dainty, A. (2009) How women engineers do and undo gender: Consequences for gender equality. *Gender, Work and Organization*, 16 (4) July 2009.

Ross, R and Schneider, R (1992) *From equality to diversity: A business case for equal opportunities.* London: Pitman

Rothwell, C.J. and Coffin, W.L. (2007) Developing career commitment in STEM related fields: Myth versus reality. In: R.J. Burke and M.C. Mattis (Eds.) *Women and Minorities in Science, Technology, Engineering and Mathematics: Upping the numbers.* Cheltenham: Edward Elgar.

Sagebiel, F. and Dahmen, J. (2006) 'Masculinities in organizational cultures in engineering education in Europe: results of the European Union project WomEng', *European Journal of Engineering Education*, 31:1,5 – 14.

Sang, K., & Powell, A. (2013). Equality, diversity, inclusion and work–life balance in construction. in *Human Resource Management in Construction Projects: Critical Perspectives* (eds Dainty and Loosemore) 163.

Sursock, A., Smidt, H., & Davies, H. (2010) *Trends 2010: A decade of change in European Higher Education* (Vol. 1). Brussels: European University Association

Smeding, A. (2012) Women in Science, Technology, Engineering, and Mathematics (STEM): An Investigation of Their Implicit Gender Stereotypes and Stereotypes' Connectedness to Math Performance. *Sex Roles*, 67(11-12), 617–629. http://doi.org/10.1007/s11199-012-0209-4

Smith, B. L., and MacGregor, J. T. (1992) "What is collaborative learning?" In A. Goodsell, M. Maher, & V. Tinto (Eds.), *Collaborative learning: A sourcebook for higher education* (pp. 10-36). University Park, PA: National Center on Post-Secondary Teaching, Learning, and Assessment.

Thaler, A. (2012) "Interdisciplinarities– students' perception of interdisciplinary engineering education in Europe." In *GIEE 2011: Gender and Interdisciplinary Education for Engineers*, pp. 209-221. Sense Publishers, 2012.

Tuckman, B.W., (1965) Developmental sequence in small groups. *Psychological bulletin*, 63(6), p.384. Yoder, B.L., 2014. *Engineering by Numbers*, [online]. Available at: https://goo.gl/Rya5gP. [Accessed January 16, 2016].

Van Der Zee, K., Atsma, N. & Brodbeck, F., (2004) The influence of social identity and personality on outcomes of cultural diversity in teams. *Journal of cross-cultural psychology*, 35(3), pp.283–303.

Wenger, E (1998) Communities of Practice: Learning, Meaning and Identity. Cambridge: Cambridge University Press

Woods, P., Barker, M., & Hibbins, R. (2011) Tapping the benefits of multicultural group work: An exploratory study of postgraduate management students. *International journal of management education*, *9* (2), 59-70.

Woolnough, B.E. (1994) Affecting Students' Choice of Science and Engineering. *International Journal of Science Education*, 16(6): 659-676.

Zimmerman, J.B. and Vanegas, J., (2007) Using sustainability education to enable the increase of diversity in science, engineering and technology-related disciplines. *International Journal of Engineering Education*, *23*(2), pp.242-253.

Annex A

Model for structured self-reflection

Adapted from UCL Medical School[23]

The following approach can be used to enhance discussions around significant event analysis:

Culture

- Describe this in more detail
- What exactly happened?
- What did you do?

Emotions

- What were you thinking/feeling at that point?

Outcomes

- What were the consequences for a) the project, b) others, c) yourself

Evaluations

- What were you trying to achieve?
- What was good/bad about it?

Analysis

- What internal factors were influencing you?
- What knowledge/values did or should have informed
- How did your actions match your beliefs/knowledge?
- What factors made you act in incongruent ways?

Conclusions

- How does this connect with previous experiences?
- Could you have handled this better in a similar situation?
- How do you now feel about this experience?
- Can you support yourself or others better as a consequence? Faced with that experience again, what would you do?

23 https://goo.gl/hz5N29

Annex B

Departmental action framework towards inclusion

	Communicate and celebrate	Curriculum policy
	Connect and listen to minority groups; define programme. Acknowledge, involve and celebrate visibly those who make up the community.	Define a policy and review process that addresses what is taught and how. Set out a plan to review and adapt all programmes.
Identify a senior lead		
Is there an existing group with responsibility? If so who?		
Q1 milestone		
Q2 milestone		
Q3 milestone		
Q4 milestone		
Year 2 end target		
Year 3 end target		
Year 4 end target		
Year 5 end target		

Training and development	Career development
Review and report on steps for ensuring staff can shape and deliver an inclusive curriculum and inclusive research. Define your good practice standards.	Set up local support for underrepresented staff: consider mentoring, coaching and advocacy.

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