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Engineering leadership education:
A snapshot review of international good practice

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Engineering Leadership Program

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Executive summary

This summary report presents the findings of a snapshot review of *engineering leadership education* conducted between September 2008 and March 2009. The review aims to provide insight into current provision, highlight international variations in approach and identify examples of good practice. It does not therefore provide an exhaustive survey of the field.

Much of the information gathered during the review was collected through detailed interviews with international experts in engineering education and directors of established engineering leadership programs. Over 70 individuals were consulted and over 40 programs were investigated.

Three key observations emerge from the review.

Firstly, there is a distinct divide between the US and the rest of the world in both attitude and approach to *engineering leadership education*. During the interview phase of the study, it became apparent that the US-based experts are familiar and comfortable with the concept of targeting 'leadership' as a specific theme within engineering education. However, there is greater discomfort amongst the non-US interviewees with this approach, which is seen to run counter to an educational culture that emphasizes inclusiveness and equality.

Secondly, the vast majority of programs of *engineering leadership education* identified in the study are based within the US and most are relatively new (developed in the last 5 years). US-based programs typically fall in one of the following two categories: (i) those based around leadership/management 'theory', often with a strong partnership with the university's business school, and (ii) those based around team projects with a global, environmental or service theme. Most non-US programs identified in the review have been in operation for over ten years and typically fall into one or more of the following categories: (i) those involving 'coaching' of more junior students, (ii) those involving industry-based 'real-world' projects, where the entire program is funded through companies 'sponsoring' one or more team, and (iii) those based around team projects with a global, environmental or service theme.

Thirdly, the review uncovers a surprising dearth of resources, expertise and formal networks currently available in the field of *engineering leadership education*. This finding is in sharp

contrast to the related disciplines of '*engineering entrepreneurship education*' and '*global engineering education'*, for which strong communities and resources have emerged over recent years. Opportunities clearly exist to develop new partnerships, knowledge and networks in this emerging field.

The report also presents examples of international good practice in *engineering leadership education.* These examples are grouped into two categories: (i) '*explicit'* programs, where engineering leadership development is the primary and explicit objective, and (ii) '*non-explicit'* programs, where the engineering leadership development is embedded within a broader remit. Examples presented of good practice with an '*explicit'* leadership objective include the *Engineering Leadership Development Minor* at Penn State University, the *Gordon-MIT Engineering Leadership Program* at MIT, the *Engineering Leadership Program* at Iowa State University and *Leadership in a Technological Environment* at Monash University. Examples presented of good practice with a '*non-explicit'* leadership agenda include the *Constructionarium* in the UK, the *Engineering Cultures* course at Virginia Tech, and the *EWB Challenge* coordinated by Engineers Without Borders Australia.

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Contents

1 Introduction

This summary report presents the findings of a 'snap-shot' review of international good practice in *engineering leadership education*, conducted between September 2008 and March 2009. The review focuses on curricular and co-curricular programs that principally cater to engineering undergraduates. The definition of engineering leadership used in the review is based on the 'capabilities of an engineering leader' identified by the *Gordon-MIT Engineering Leadership Program*, as outlined below.

Core Values and Character	Initiative and decision making (responsibility, integrity, loyalty, self-awareness, personal vision)
Sense making	Making sense of the world around us (the needs of society, technology, system thinking, solution judgment)
Relating	Developing key relationships and networks (listening and seeking compromise, communicating and advocating, wide connections, enterprise)
Visioning	Creating a compelling image of the future (tapping creativity, defining solutions, creating concepts)
Realizing the vision	Getting the job done (building a team, managing a project, innovating, inventing, implementing and operating)
Technical knowledge and critical reasoning	Grounding in the disciplinary fundamentals (problem solving, critical thinking, inquiry)

The report is not an exhaustive examination of the field, but seeks to provide an insight into current practice, highlight international variations in approach and identify examples of good practice. Much of the information gathered during the review has been collected through detailed interviews with international experts in engineering education and directors of established engineering leadership programs. The process adopted for the study is outlined below.

1. *Background review and study*: literature search and review to identify the broad spectrum of international activities in *engineering leadership education* and related initiatives.
2. *Targeted interviews with international experts in both engineering education and engineering leadership education*: interviews with international leaders to:
    a. better understand global trends in the field,

b. identify the most highly-regarded programs around the world, and
c. identify other experts in the field for follow-up interviews.

3. *Investigation of targeted programs*: further investigation of the most highly regarded programs through detailed interviews with program staff, undergraduate participants and related faculty.

During the research phase of this study, over 70 experts have been consulted (as listed in Appendix A) and over 40 programs have been investigated.

All web-site references given in this report were last accessed on 5th May 2009.

2 Overall observations

2.1 The international field of engineering leadership education

Much of the information gathered in this study has been collected through discussions with international experts in engineering education. These interviews indicate that *engineering leadership education*, as a sub-discipline, is not currently on the radar of most engineering education experts outside the US. The interview process also revealed a level of discomfort with the notion of 'leadership education' by many of the non-US interviewees, as they felt that this concept ran counter to their educational culture of inclusiveness and equality. In these cases, however, the interviewees were able to identify with all of the characteristics of the engineering leader as defined by the *Gordon-MIT Engineering Leadership Program*, and they were able to highlight examples of good practice on this basis.

A very clear divide was therefore apparent between the responses from the US interviewees and the non-US interviewees. The US interviewees were generally comfortable with the concept of educating undergraduates in 'leadership', were able to identify programs in engineering leadership, but were typically only familiar with the engineering education scene in the US. The non-US interviewees tended to be much more familiar with the international scene in engineering education, but were less engaged with 'leadership' as a specific discipline and tended to identify examples of good practice in which leadership development is embedded in a broader program. For this reason, the international approaches to *engineering leadership education* discussed in this report are divided into two categories:

1. '*Explicit*' – programs where engineering leadership development is the primary and explicit objective.
2. '*Non-explicit*' – programs which involve engineering leadership development, but this may not be explicit and/or may be embedded within a broader remit or program.

Further discussion on the differing regional approaches to *engineering leadership education* is given in the following section of this report (Section 3).

There are a number of strong common threads running across many of the programs of *engineering leadership education* identified in the study with respect to their operation and management:

- As with many novel engineering education initiatives, the programs identified in this study are often directed by a relatively high-profile, highly passionate champion, on whom the success and continuation of the program largely rests.
- Many programs operate on a relatively small budget with a very small project team – in many cases the team simply comprises a part-time director and a part- or full-time administrative assistant.
- Almost every program director interviewed has experienced significant difficulties in identifying and employing suitably qualified staff to both design and deliver the programs.
- A large number of the programs identified operate outside of the formal engineering curriculum. Many program directors commented that this was, in part, due to a lack of resources and/or a lack of engagement in the field of *engineering leadership* by the core engineering faculty. Often this independence from both the curriculum and departmental procedures allows for more creative educational approaches and a much greater flexibility in the structure and design of the programs. For this reason, a number of programs investigated in the study were able to launch their operations, secure funding, design the activities and welcome the first cohort of students, all within a matter of a few weeks.
- Some tension is apparent in many institutions between the business schools and the engineering schools, in terms of who should be 'owning' and operating the programs. In almost every case, engineering leadership programs are hosted within the school of engineering or equivalent. It was clearly felt that such programs should continue to be hosted within engineering schools in order to provide the required academic and professional context for the students when seeking to apply and reflect on their developing leadership abilities.

One interesting finding that emerged through the study is the dearth of formal networks, events and research programs in *engineering leadership education*. This is in stark contrast to the

parallel educational themes of '*engineering entrepreneurship'* and '*global engineering'*, for which a number of formal learning communities[1,2], resource centres[3,4] and annual events[5,6] exist. Very limited numbers of research programs have been identified in the field of *engineering leadership education*. The majority of this work is of modest ambition, linked directly to specific educational programs, and mainly focused on the area of student assessment.

2.2 Current and future trends

Across the world, the mission statements of many undergraduate engineering degrees include aspirations such as *'… to produce engineering leaders for the 21st Century'*. However, the majority of programs appear to have no formal or articulated mechanism to deliver the leadership component of this goal, beyond (typically) student involvement in project- or problem-based learning activities.

A simple Internet search of *engineering leadership education* will reveal a wide variety of programs currently being offered at undergraduate level, many of which are based in the US. When investigated more closely, however, it appears that many of these are not coherent programs designed for engineering students, but simply pull together a series of pre-existing modules from across the university with perhaps one additional team-based project at the end of the sequence.

Where programs of *engineering leadership education* have been specifically 'designed', they tend to fall into one or more of the following categories:

1. those based around leadership and management 'theory', often including a strong partnership with the institution's business school or 'leadership' centre,
2. those based around team projects with a global, environmental or service focus,
3. those involving 'coaching' of more junior students, usually in project teams, and

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[1] *Entrepreneurship Division*, American Society for Engineering Education (http://www.asee-ent.org/)
[2] *Online Journal for Global Engineering Education* (http://digitalcommons.uri.edu/ojgee/)
[3] *GlobalHUB* (http://globalhub.org/)
[4] *Entrepreneurship Corner*, Stanford Technology Ventures Program (http://stvp.stanford.edu/outreach/educators-corner.html)
[5] *Roundtable on Entrepreneurship Education,* Stanford Technology Ventures Program (http://ree.stanford.edu/)
[6] *International Colloquium on International Engineering Education* (http://www.uri.edu/iep/colloquia/)

4. those involving industry-based 'real-world' projects, where the entire program is funded through companies 'sponsoring' one or more team.

For the vast majority of programs investigated, their inception was originally motivated by one of the following drivers:

1. *to develop leaders who are able to operate effectively inside and outside the engineering profession*. Many interviewees were motivated by a desire to see world leaders, in all spheres, who had been educated as engineers.
2. *to ensure that their nation improves or maintains its globally competitive position*. This vision is particularly evident in US-based programs.

Most programs identified in this study are either relatively new in their inception (less than 10 years old) or operate in relative isolation within the geographical region. Perhaps for those reasons, very few of the programs identified based their provision on existing models of *engineering leadership education*. The majority of programs investigated were either developed following no prior external research, or else were based on models found in general leadership education, those found in industry or those used in the military.

One major current trend in *engineering leadership education* is the development of the students' global awareness and their ability to work on complex cross-national projects – which is seen by many as the environment within which the engineering leader of the future will need to operate. Many of the programs which were most highly rated by interviewees incorporate some global elements either through international travel, remote link-ups with overseas universities/companies or project briefs involving an international or cross-cultural context. The trend towards a more 'global' view of leadership education was seen by many of the interviewees as one that would continue.

The majority of programs identified in this study use some form of psychometric testing of the students as part of their leadership development. In most cases, this is used in conjunction with some form of leadership development 'journal' and/or on-going individual mentoring. Another emerging theme, particularly amongst the most high-rated programs, is the provision of a flexible education that is tailored to the changing needs of each individual student.

During the interview process, three related trends were predicted for *engineering leadership education* in the future:

1. ***global engineering***: increasing focus on the students' ability to operate in complex, international multi-disciplinary teams, with a stronger awareness of national and cultural differences in their approach to engineering problems.
2. ***program collaborations***: greater development of cross-national partnerships between engineering leadership programs, in part to offer students greater 'global' exposure.
3. ***self-analysis and reflection***: awareness-building of the students' personal skill set, analysis of how this will impact their own leadership ability and provision of a tailored program to accommodate the students' individual development needs.

3 The international picture: regional variations in approach

The review highlights some interesting geographical differences in both attitude and approach to *engineering leadership education* across the world. The most striking observation is that the vast majority, probably 80-90%, of programs which explicitly focus on leadership are based in the US. Outlined below is a summary of the current status of *engineering leadership education* by region, as identified in the review.

3.1 Europe

The notion of educating students in leadership clearly does not sit comfortably with many engineering faculty in Europe, and very few European programs have been identified in the study that explicitly use the term *leadership* in the course description. The overall visibility of *engineering leadership education* as a discipline is also very low – almost all of the leaders of existing engineering leadership programs interviewed were unaware of other comparable activities across Europe or worldwide. However, the majority of European programs identified in this review have been in operation for over 10 years.

Within Europe, the UK is the most active country in the provision of '*explicit*' programs in engineering leadership. UK-based examples include the *Teamwork and Leadership* module at Loughborough University[7], the *Engineering Leadership Advanced Award for Undergraduates* run by the Royal Academy of Engineering[8] and the *Engineering Design* MEng degree at Bristol University[9].

A number European engineering schools have developed peer tutoring models with a strong leadership element, where more senior students 'coach' junior student project teams. An example of such a model is the *Project Management in Practice*[10] course at the Universitat Rovira i Virgili, Spain, where selected fourth year students lead first year group design project teams.

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[7] *Teamwork and Leadership Module*, Civil and Building Engineering, University of Loughborough (http://cisinfo.lboro.ac.uk/epublic/WP5015.module_spec?select_mod=08CVD017)

[8] *Engineering Leadership Advanced Award Scheme for Undergraduates*, Royal Academy of Engineering (http://www.raeng.org.uk/education/undergrad/ela/default.htm)

[9] *Engineering Design MEng,* Bristol University (http://www.edes.bris.ac.uk/index.html)

[10] Ozgen,S., Alabart, J.R. and Medir, M. (2008) *A 360°-Degree Feedback Process to Assist Senior Engineering Students in Their Leadership Development,* SEFI 36th Annual Conference on Quality Assessment, Employability and Innovation, July 2-5, Aalborg, Denmark

This experience is supported by leadership development modules and intensive tutoring for the students to reflect on and learn from their leadership experiences. Many such 'coaching-based' programs were originally motivated by departmental resource constraints, with more senior undergraduates being trained and paid to supervise group projects. For example, in the Faculty of Aerospace Engineering at the Delft University of Technology[11], carefully selected third-year students are provided with training and paid as teaching assistants to supervise first and second year project groups.

Across Europe, many of the programs that incorporate leadership elements also have a strong focus on global and cross-cultural teaming. For example, students participating in the *Global Engineering Teams*[12] program at the Technische Universität Berlin in Germany work in teams with students from across a number of different continents to deliver a project or product to a strict set of deadlines.

3.2 North America

The vast majority of '*explicit*' engineering leadership programs are based in the US. The offerings range from small extra-curricular programs through to engineering minors and even include an engineering school that has identified leadership to be the central theme of their engineering education[13]. US-based interviewees were very comfortable and familiar with the concept of educating 'leaders'. The only concern raised related to the ability of current engineering faculty to deliver effective leadership programs and the difficulties of identifying suitably qualified staff from outside their own institution. The majority of engineering leadership programs in the US have been developed following the introduction of the ABET Engineering Criteria 2000, with a significant number established in the past 5 years.

US-based programs tend to fall into two categories:

(i) those based around leadership/management 'theory', often with a strong partnership with the university's business school, and

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[11] Andernach, J.A. and Saunders-Smits, G.N. (2006) *The Use of Teaching Assistants in Project Based Learning at Aerospace Engineering*, ASEE/IEEE Frontiers in Education Conference, October 28-31, San Diego, CA

[12] *Global Engineering Teams*, Technische Universität Berlin (http://www.global-engineering-teams.org/)

[13] Lyle School of Engineering, Southern Methodist University (http://lyle.smu.edu/)

(ii) those based around team projects with a global, environmental or service theme.

In general, the programs most highly rated by those interviewed in this study fall into the latter category.

The 'global' theme is particularly strong within US programs. Many US faculty members identified a lack of global experience or understanding as a major weakness of their engineering students – it was observed by a number of those interviewed that many of their students had never left their own state. The ability to work effectively across cultures in an international sphere is clearly seen by many as an increasingly vital element of an engineer leader, which is reflected in many of the programs. Examples include the *Engineering Global Leadership Honors Program* at the University of Michigan[14] and the *Engineering Leadership Development Minor* at Penn State University[15]. A number of highly-rated programs in 'global engineering' for which leadership development is a non-explicit goal emerged in the study, such as the *Global Engineering Program* at Purdue University[16].

Another strong theme within US *engineering leadership education* is 'student empowerment in their own leadership development', and many programs are partially or almost fully managed and delivered by the students themselves. Examples include the extra-curricular *CAMP* program at South Dakota School of Mines[17] and the *Engineering Leadership Program* at Iowa State University[18].

Perhaps the most ambitious program of *engineering leadership education* investigated in the study is the recently established *Gordon-MIT Engineering Leadership Program*[19], based at MIT. The program combines a suite of educational activities to develop the leadership capabilities of the undergraduate engineers at MIT with a broader national role to improve the leadership capabilities of future US engineering graduates. In pursuit of these goals, the program has

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[14] *Engineering Global Leadership Honors Program*, University of Michigan (http://www.engin.umich.edu/egl/)

[15] *Engineering Leadership Development Minor*, Penn State University (http://www.eldm.psu.edu/)

[16] *Global Engineering Program*, Purdue University (https://engineering.purdue.edu/GEP/)

[17] *Center of Excellence for Advanced Manufacturing and Production* (CAMP), South Dakota School of Mines (http://camp.sdsmt.edu/index.php)

[18] *Engineering Leadership Program*, Iowa State University (http://www.eng.iastate.edu/leadership/index.asp)

[19] *Gordon-MIT Engineering Leadership Program*, MIT (http://web.mit.edu/gordonelp/)

already secured external funding of $20m, with a view to matching this sum over the next few years.

A number of 'engineering entrepreneurship' programs in the US are based on broad definitions of entrepreneurship which encompasses a significant focus on leadership, such as the *Stanford Technology Ventures Program* at Stanford University[20]. US-based activity also includes the *Centre for Engineering Leadership and Learning* at the University of Central Florida[21]. This group is seeking to develop new educational programs, offer training and resources in the field of engineering leadership, and undertake research into the '*science of learning and teaching engineering leadership*'.

Each year, the National Academy of Engineering awards the Gordon Prize[22] to a US-based engineering education program which displays '*new modalities and experiments in education that develop effective engineering leaders across the US*'. Since its inception in 2001, the $500k prize has been awarded to a number of the programs highlighted in this study.

Only two engineering leadership programs have been identified in Canada: (i) the *Leaders of Tomorrow* program at Toronto University[23], which combines curricular, co-curricular and extra-curricular activities, and (ii) a *Masters of Engineering and Public Policy* and a *Masters of Engineering Design* offered by the Walter G. Booth School of Engineering Practice at McMaster University[24].

3.3 Australasia

As with the European interviewees, many of the Australasian engineering educators interviewed expressed discomfort with the concept of selective programs in leadership development. Concerns were particularly focused on how students should be selected for such programs and on whether leadership ability or potential can be demonstrated in an application process.

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[20] *Stanford Technology Ventures Program*, Stanford University (http://stvp.stanford.edu/)

[21] *Centre for Engineering Leadership and Learning*, University of Central Florida (http://www.engineeringleadership.us/)

[22] *Bernard M. Gordon Prize for Innovation in Engineering and Technology Education* (http://www.nae.edu/nae/awardscom.nsf/weblinks/DWHT-4UJPVA?OpenDocument)

[23] *Leaders of Tomorrow*, University of Toronto (http://www.undergrad.engineering.utoronto.ca/students/vice-dean/leaders.htm)

[24] Walter G. Booth School of Engineering Practice, McMaster University (http://msep.mcmaster.ca/)

Only one '*explicit*' program in engineering leadership has been identified in Australasia – the *Leadership in a Technological Environment* program at Monash University[25]. This program offers a three year co-curricular leadership development experience to the top tier of engineering students with the highest entry qualifications.

A number of engineering schools offer 'high potential' fellowship programs, often linked to a student scholarship, that provide a range of leadership development opportunities. Examples include the *Dean's Scholars Program* at Queensland University of Technology[26].

The Australian government requires all engineering students to participate in an industrial experience where they work under the direct supervision of an industry professional. This mandatory experience is seen to provide students with significant leadership development opportunities. In addition, the Australian accreditation system has been outcomes-driven for nearly 15 years, which has resulted in an increased focus on students' personal and professional development. Across Australia, there are many examples of '*non-explicit*' programs where leadership is embedded into courses or projects. One example is the *Engineers Without Borders Challenge* program[27] where first-year engineering students from universities across Australia are provided with a real design brief from the developing world and asked to produce '*engineering and design solutions that are tailored to the local social, cultural, political, environmental and economic context'.*

3.4 Asia, Africa and South America

The study revealed a dearth of engineering leadership programs across Asia, Africa and South America. Although some interesting programs have been identified, these tend to operate in isolation and the program leaders are often unaware of any other leadership programs available in their region. No programs were identified in Africa.

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[25] *Leadership in a Technological Environment,* Monash University (http://www.eng.monash.edu.au/current-students/merit/leadership/)

[26] *Dean's Scholars Program*, Queensland University of Technology (http://www.bee.qut.edu.au/study/scholarships/commencing/deans.jsp)

[27] *Engineers Without Borders (EWB) Challenge*, EWB Australia (http://www.ewb.org.au/ewbchallenge/)

Among almost all programs identified in Asia and South America is a very strong 'global' theme. For example, the *Global Leadership Engineering Education Program*[28] at Kyoto University focuses on the development of global leaders with a strong cross-cultural understanding.

A number of leadership programs are structured around project-based industry placements alongside supplementary leadership development courses and opportunity for students to reflect on and develop their leadership style. One example of such an approach is at the Universidade de São Paulo in Brazil, with a program that can be roughly translated as '*Program of capacity-building in leadership'*.

A number of institutions, particularly in Asia, are involved with US-based engineering leadership programs. For example, Rice University, along with a number of US-based partner universities, offer the INNOVATE[29] program – a 10-day symposium, held in different regions of Asia each year, for 60-70 US and regional engineering students. This experience seeks to develop the students' ability to make culturally sensitive decisions.

Many universities across Asia have recently started looking at how leadership might be integrated into the engineering curriculum. However, most of these initiatives are at an early stage, and are only likely to produce modest leadership elements which are embedded into group project work. For example, from 2005 all engineering programs in Malaysia have been required by the Ministry of Higher Education to include a number of professional skills (including leadership) within the learning outcomes. In response, a number of universities have started to develop a problem-based learning approach to many elements of the undergraduate engineering education, with 'leadership development' embedded within this structure.

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[28] *Global Leadership Engineering Education Program*, Kyoto University (http://www.t.kyoto-u.ac.jp/en/undergrad/lectures/glprogram)

[29] *INNOVATE* (http://innovate.rice.edu/)

4 International good practice

As part of the study, experts from across the world were invited to make a judgment on international best practice in *engineering leadership education*. Through compiling these judgments, it has been possible to identify a number of programs that are particularly highly regarded in the community. This section provides a summary of these 'good practice' approaches.

As discussed in Section 2, two distinct categories of program have been identified in this study – ones for which leadership is an explicitly defined focus and ones that embed the development of leadership characteristics within a broader remit. For this reason, the examples of international good practice discussed in this section are presented within each of these two categories.

Provided in Appendix B is a table that summarises the activities of eight highly-regarded engineering leadership programs from across the world.

4.1 Explicit leadership programs

The vast majority of '*explicit*' engineering leadership undergraduate programs are based within the US, and inevitably this is where many of the examples of good practice were identified. A number of programs were particularly highly rated during the interview process, as listed below.

- *D. School*[30], Stanford University
- *Engineering Leadership Development Minor*[15], Penn State University
- *Engineering Leadership Program*[18], Iowa State University
- *Gordon-MIT Engineering Leadership Program*[19], *MIT*
- *Leadership in a Technological Environment*[25], Monash Univeristy

It should be noted that the programs at Iowa State, MIT and Monash are still in the early stages of development.

There were a number of other engineering leadership programs identified that do not hold the level of national or international visibility of those listed above, but which were nevertheless very highly rated by a number of interviewees. These programs include:

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[30] *Hasso Plattner Institute of Design at Stanford ('D.School'),* Stanford University (http://www.stanford.edu/group/dschool/)

- *Center of Excellence for Advanced Manufacturing and Production*[17], South Dakota School of Mines
- *Leaders of Tomorrow*[23], University of Toronto, Canada
- Lyle School of Engineering[13], Southern Methodist University (SMU)
- *Teamwork and Leadership Module*[7], Loughborough University, UK
- *The Archer Center for Student Leadership Development*[31], Rensselaer Polytechnic Institute

It should be noted that the Program at SMU is still in the very early stages of development.

A number of industry-based engineering leadership development programs were also widely recommended. These include the *Engineering Leadership Development Program* at Lockheed Martin[32].

4.2 Non-explicit leadership programs

The identification of best practice approaches in which 'leadership' is not explicit but embedded within broader programs has proven to be an interesting challenge. Even within the '*explicit*' programs described in Section 4.1, definitions of 'leadership' vary considerably and result in quite significant differences in emphasis. Without the formal label, the identification of programs that embed 'leadership development' has been based on the subjective judgment of the individuals interviewed during the study and that of the author.

Outlined below is a selection of the highly-rated '*non-explicit*' engineering leadership programs from across the world.

- *Constructionarium*[33], UK university and industry partnership
- *Engineering Clinic*[34], Harvey Mudd College
- *Engineering Cultures*[35], Virginia Tech

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[31] *The Archer Center for Student Leadership Development*, Rensselaer Polytechnic Institute (http://archer.union.rpi.edu/)

[32] *Engineering Leadership Development Program*, Lockheed Martin (http://www.lockheedmartinjobs.com/college_leadershipdev_engineering.asp)

[33] *Constructionarium*, UK university and industry consortium (http://www.constructionarium.co.uk/)

[34] *Engineering Clinic*, Harvey Mudd College (http://www.eng.hmc.edu/EngWebsite/index.php?page=Clinic.php)

[35] *Engineering Cultures*, Virginia Tech (http://www.engcultures.sts.vt.edu/overview.html)

- *EWB Challenge*[27], Engineers Without Borders Australia and Australian university partnership
- *Global Engineering Alliance for Research and Education*[36] *(GEARE)* and *Engineering Projects in Community Service* (*EPICS)*[37], both at Purdue University
- *Global Engineering Teams*[12], Technische Universität Berlin, Germany

When asked to identify best practice approaches to engineering leadership, many non-US interviewees also spoke about successful approaches using problem-based learning. Aalborg University and Olin College of Engineering were both widely cited and highly recommended in this regard.

[36] *Global Engineering Alliance for Research and Education (GEARE)*, Purdue University (https://engineering.purdue.edu/GEP/Programs/GEARE/)

[37] *Engineering Projects in Community Service* (*EPICS)*, Purdue University (http://epics.ecn.purdue.edu/)

5 Case studies

Outlined in this section are four case study examples of good practice. The case studies have been each selected to highlight a strong theme or trend in international *engineering leadership education* that emerged during the study, as outlined below.

- *Programs with a strong focus on global engineering leadership* – Engineering Leadership Development Minor, Penn State University
- *Programs whose design and management are strongly student-led* – Engineering Leadership Program, Iowa State University
- *Highly-selective programs providing intensive and challenging student experiences* – Gordon-MIT Engineering Leadership Program, MIT
- *Co-curricular programs catering for selected 'high-potential' students* – Leadership in a Technological Environment, Monash University

5.1 Case study 1: Engineering Leadership Development Minor – Penn State University

5.1.1 Overview of Program

The *Engineering Leadership Development Program*[15] (*ELDP*) at Penn State was first launched in 1995 through the *Leonhard Center for the Enhancement of Engineering Education*[38] and offers students from across the university the opportunity to pursue a minor in engineering leadership development. The *Engineering Leadership Development* minor (*ELDM*) '*uses a combination of in-class discussion, international travel and contextual learning to teach leadership skills'*. There is a significant focus on socially-relevant, hands-on projects, many of which are based outside the US, which seek to provide a '*transformational'* experience for the students in the development of their leadership outlook.

The *ELDP* was one of the first engineering leadership programs in the US and its focus has been very much shaped by the driving interests of the three directors who have led the program over the past 10 years – in turn centering on business leadership, personal leadership and global

[38] *Leonhard Center for the Enhancement of Engineering Education*, Penn State University (http://www.engr.psu.edu/leonhardcenter/)

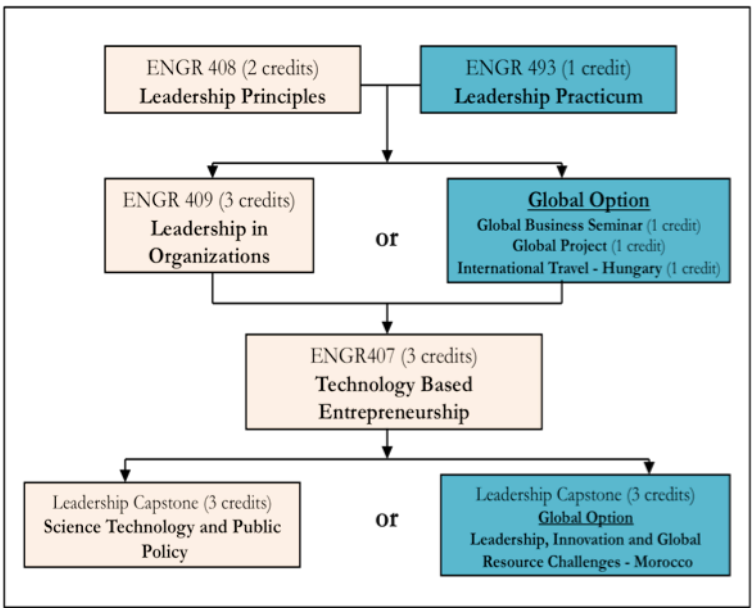
leadership. The most recent director, Dr Rick Schuhmann has significantly enhanced the global dimension to the program: '*Students in the program are trained not just in leadership theory and skills, but to be global leaders with knowledge of the world, skills in cross-cultural communication, and experience in participating in change processes in other countries'*. The 'global' elements of the program are highlighted in blue in the *ELDM* structure, illustrated below.

The *ELDP* operates through the S*chool of Engineering Design, Technology and Professional Programs* (*SEDTAPP*). In addition to the *ELDM*, *SEDTAPP* also offer a minor in *Engineering Entrepreneurship* (*E- Ship*), which also received a number of strong recommendations during the review. Around 90% of the *ELDM* participants and 60% of the *E-Ship* minor participants are engineering majors and both programs are case-study driven and based around active-learning.

5.1.2 Program structure and focus

The *ELDM* comprises a total of 18 credits, of which 6 credits form the compulsory core in the following modules:

- *ENGR 408 - Leadership Principles*
- *ENGR 493 – Leadership Practicum*
- *ENGR 407 - Technology-based Entrepreneurship*



Students who successfully complete *ENGR 408* and *ENGR 493* are then eligible to take the minor. The program subsequently offers two paths, with the 'global option' allowing the students to travel to either Morocco or Hungary. Currently, around 50 students per year take the full *ELDM* with around 50% following the global pathway, although many more opt to take the individual modules.

The objectives for the course are described as follows: '*There are three commonly accepted critical attributes of an effective leader: being able to communicate a shared vision,*

demonstrating integrity, and focusing on results. Five additional factors have emerged as critical for leaders in the new "flat world" of the 21st century: thinking globally, appreciating cultural diversity, developing technological savvy, building partnerships and alliances, and sharing leadership. These eight core attributes, as well as possessing an entrepreneurial mindset, serve as the cornerstone for the course educational outcomes'.

The structure of the *ELDM* is likely to be 'streamlined' in the future, such that the global experiences become the core element of the program rather than an option.

The *ELDP* group is currently working with the *Leonhard Center*[38] to develop a set of tools to allow them to assess the impact of the program on the participating students. During the past couple of years, they have developed survey instruments to assess leadership development that will be trialed over the coming year. Preliminary work is also under way to better understand the incremental impact of the three elements of the international module (in turn, an academic study of global leadership, remote international link-ups and a travel element) to see which brings the greatest benefit to the student leadership development.

5.2 Case study 2: Engineering Leadership Program – Iowa State University

5.2.1 Overview of Program

The *Engineering Leadership Program* (*ELP*) at Iowa State is a co-curricular program currently in its third year of operation. The *ELP* was initially established as a 4-year pilot program following a $1m donation from 3M. The program employs a skeleton staff (0.75FTE Academic year Director with 0.5FTE secretarial support), but is otherwise entirely managed and operated by the student participants.

The program seeks to develop engineers who are equipped to take on leadership roles both within and outside engineering and has a strong focus on the responsibility of engineers to better society. All participants currently receive a $2500p.a. scholarship ($10k in total), although this is likely to be allocated only on a needs-based system once the pilot phase of the project is completed in 2010.

Participants typically enter the *ELP* in their freshman year and follow the program throughout their four-year degree, although provision is also made for students to enter at later stages in

their studies. Selection to the program is made by a committee of staff, students, faculty, alumni and industry and is based on the applicants' academic achievement to date, extra-curricular involvement, leadership experience and interest in the program. The selection process is designed and managed by the *ELP* student participants and would typically accept 15 students from over 100 applicants each year.

5.2.2 Program structure

The *ELP* is structured in two phases, with year 1 devoted to community-building and years 2-4 providing a more individualized program guided by a set of eight learning outcomes of a leadership model. The leadership model was designed through an iterative group exercise over the course of a year, involving students, staff and faculty and professionals from the wider Iowa State community, and provides a common language for goal setting and assessing progress. A significant focus of the upper years is the development of a 'leadership learning project'. An outline of the two phases is given below.

Year 1 activities include:

- **Leadership Retreat**: an overnight off-campus team-building experience for students as they join the program as freshmen, which starts to introduce leadership concepts.
- **Leadership Seminar**: a weekly one-hour seminars focusing on leadership skills and styles led by the student director and incorporating external speakers.
- **Peer Mentor Program**: each student entering the program is allocated with a mentor, who would typically be a more senior member of the *ELP*. Meetings are held with mentors on a bi-weekly basis and the forum is used for support and development.
- **Faculty Mentor Program**: each student selects a faculty mentor from a roster of volunteers updated annually. Scholars are encouraged to meet with the faculty mentors in groups of 2-3 each month.
- **Service Learning Projects**: during the second semester, students participate in a service learning project, as a mechanism to apply and develop their leadership skills.
- **Reflection Journals**: all students are required to complete a 'reflection journal' each week, which is reviewed and discussed. Weekly topics are suggested for these journals,

although students may also select their own areas of focus, relating it to their personal development.

Years 2-4 activities include:

- **Community Building Retreats**: annual day-long community building events to re-energize and reconnect participants with their peer groups.
- **Leadership Seminar/ Learning Tracks**: weekly one-hour seminar provides a community-building role as well as a forum for discussion and development for the first semester after the freshman year. For others there are small group thematic learning tracks and/or book groups to maintain a sense of community while allowing for scheduling flexibility.
- **Leadership Learning Project**: this project is the main focus of the *ELP* following the first year, and students identify their own project theme, based on their personal goals and passions. Students are initially asked to submit their proposed project under one of two themes: (i) personal development and discovery (short-term projects aiming to help students to refine their goals for the future) or (ii) action, engagement and contribution (longer-term projects aiming to make an impact on a local, national or international community).
- **Personal Leadership Portfolio (e-Doc):** an electronic portfolio for students to plan, track and reflect on their leadership development (as discussed below).

5.2.3 Tracking students' development

A set of 19 student competencies is defined for the program, grouped into four themes, as outlined below. These competencies support eight ABEST-aligned learning outcomes.

- *Leadership Characteristics*: initiative, integrity, analysis and judgment, communication, energy and drive,
- *Engaging Others*: building a successful team, developing others, coaching, teamwork, leading through vision and values,
- *Awareness and Growth*: engineering knowledge, general knowledge, cultural adaptability, continuous learning, and

- *Demonstrating Excellence*: quality orientation, customer focus, innovation, professional impact, planning.

The leadership development of students within each of these competencies is tracked using an electronic portfolio system, which was developed in-house at Iowa State. Through this system, students are able to create their own individually-customised portfolio to set goals, track progress and reflect on their own development. These portfolios can also be shared externally with supervisors, other program members or prospective employers.

5.3 Case study 3: Gordon-MIT Engineering Leadership Program - MIT

5.3.1 Program overview

The *Gordon-MIT Engineering Leadership Program* (*Gordon-MIT ELP*) was launched in 2007, following a $20m gift from inventor, philanthropist and MIT alumnus Bernard M. Gordon, who has a long-standing commitment to develop the leadership capabilities of US engineers.

Unlike other engineering leadership initiatives identified in the study, the *Gordon-MIT ELP* combines activities of leadership development for its own undergraduate engineers with a broader aim of using this educational approach to inform and improve engineering leadership education across the US. The MIT-based elements of the program offer academic courses and hands-on, practical experiences and are focused on three concentric groups of engineering students, catering respectively for the 'all', the 'many' and the 'few'. Based on this distinction, the educational aims are stated as:

- *to give **all** MIT engineering students hands-on visceral experience in project-based learning and results-oriented leadership as part of their normal academic experience;*
- *to prepare **many** ('Gordon Engineers') MIT engineering students to be more effective contributors to engineering invention, innovation and implementation efforts through advanced courses and multidisciplinary projects;*
- *a focused program to educate and prepare a **few** ('Gordon Engineering Leaders') MIT engineering students to be future leaders of engineering invention, innovation and implementation efforts.*

Two clear themes emerge within the program: (i) providing a range of opportunities to contextualise and apply the students' developing leadership skills, and (ii) ensuring that the participants take an active role in the design and direction of the overall program. The core team supporting and delivering the *Gordon-MIT ELP* activities includes 5 full-time staff, with associated administrative support. The program is directed by two senior engineering professors within the School of Engineering and is also supported by a number of high-level advisory boards, with a strong focus on US-industry partnerships.

The two key components of the *Gordon-MIT ELP* – one focused on MIT engineering undergraduates and one focused on enhancing engineering leadership education across the US – are each discussed in turn in the following two sections.

5.3.2 Structure of educational offering

The MIT-based educational activities of the program comprise three elements: (i) curricular enhancements available to all MIT undergraduate engineers, (ii) co- and extra-curricular activities offered to a annual cohort of approximately 200 '*Gordon Engineers'*, and (iii) an intensive, mainly co-curricular program for a smaller, highly selective group of '*Gordon Engineering Leaders'* (approximately 20-30 students per class year). Development of the program's educational material started in the summer of 2008, and the majority of early work has been focused on the '*Gordon Engineering Leaders'* track.

The first thread of the programs' educational offering aims to provide leadership development opportunities to all MIT undergraduate engineers. Although this work is still at an early stage, planned activities include the development of four one-hour leadership modules to be led by the undergraduate program participants.

Applications to the two selective tracks of the program (the *Gordon Engineers* and the *Gordon Engineering Leaders*) will be considered during the sophomore year, once the student has successfully completed the *Undergraduate Practice Opportunities Program* (UPOP). Both tracks will operate in the students' Junior and Senior years and aim to provide a framework that continuously exposes them to cyclic phases of *theory*, *application* and *reflection* in their leadership development. Reflecting this cycle, both tracks combine regular leadership classes, project-based experiences for leadership application and significant mentoring and guidance.

The '*Gordon Engineer'* (*GE*) track is currently in the design phase. Students accepted into this track will participate in leadership courses and a *'realistic scale project'* (such as Formula SAE or 'design-build-fly'), be offered opportunities to complete and reflect on a personal leadership plan and be provided with mentored support from program staff and industry partners.

The '*Gordon Engineering Leaders'* (*GELs*) very much lie at the heart of the *Gordon-MIT ELP*, and the second cohort of GELs will join the program in September 2009. This highly-selective program track provides a more intensive and challenging experience to that planned for the *Gordon Engineers*. The *GEL* track is centered around a weekly *Engineering Leadership Lab*, which provides students with '*real-life experiential scenarios'*. This activity is designed and delivered by the *GEL* participants with a strong focus on the senior students guiding the juniors. Around this core *Engineering Leadership Lab*, the three phases of *theory*, *application* and *reflection* are offered to the participants through the following means:

- ***Theory***: GELs are exposed to frameworks, models and case studies in engineering leadership through curricular and co-curricular modules. In all, students must select four 'short subjects' and one 'advanced subject', all available through the program.
- ***Application***: GELs are provided with leadership practice opportunities throughout their two years in the *Gordon-MIT ELP*, and are expected to remain involved with the program in some capacity beyond their graduation from MIT. During their active time in the program, they are required to complete two '*realistic scale projects'* and participate in a summer industry internship. GELs also have a 'service' responsibility within the *Gordon-MIT ELP*, which may include assisting with the operation, design and delivery of program, or acting as a 'leadership coach' or mentor to more junior students.
- ***Reflection***: All participants complete a personal development plan and are provided with opportunities for evaluation and reflection on their own leadership development with program staff, industry leaders and mentors.

5.3.3 Dissemination and outreach

The second overarching program aim is to '*increase the focus of national engineering education on the development of leaders of product, process and system development'*. Early work is already underway in this area, and overall goals include:

- development of a US-based community of institutions engaged with *engineering leadership education*,
- development of an engineering leadership educational model that can be replicated in engineering schools across the country, with supporting resources and workshops, and
- hosting of an annual *Bernard M. Gordon-MIT Engineering Leadership Conference* to highlight best practice in the field.

5.4 Case study 4: Leadership in a Technological Environment – Monash University

5.4.1 Program overview

Leadership in a Technological Environment a co-curricular program that operates for three years of the undergraduate engineering degree at Monash University. This structured leadership program was established by the Faculty of Engineering in 2006 (and commenced in February 2007), a decision which was driven by two key factors: (i) calls from industry for improved leadership skills and attitudes in engineering graduates, and (ii) a desire to attract top performing prospective engineering students to the university.

The program explicitly targets 'elite' students, with two entry mechanisms:

1. Each year the Faculty of Engineering offers 50 to 60 *Engineering Excellence Awards* of $6000 (AUS) p.a. for entry students who achieved the highest scores in their Year 12 examination results. To date this has meant cutoff scores of 98.3, 98.4 and 99.4 for the three entry cohorts. All Award holders are invited to enter the *Leadership in a Technological Environment* program.
2. An additional 10-15 places are also allocated during the first year of study for non-Award holders. Applicants must demonstrate motivation and proven leadership abilities determined through an application and interview process.

Core staffing levels on the program are very small - program design and management is driven by the *Associate Dean for Teaching*, with a *Special Projects Officer* proving full-time development and administrative assistance. Much of the content delivery is out-sourced to external speakers. The program costs around $150k (AUS) p.a. to operate. It is currently wholly funded through the Faculty of Engineering, although external support is now being actively sought.

5.4.2 Program structure and focus

The program comprises a range of different activities, including residential workshops, modules, work-shadowing and networking, as outlined below.

1. ***'Residentials'.*** At the start of each academic year, all program participants attend an intensive 2-3 day residential workshop. This experience is designed to build the community bond, shape the students' leadership awareness and prepare them for the coming year's activities. For example, during the first year 'residential', students spend one day examining their personality type (using a Myers Briggs profile) and exploring how this impacts their leadership approach.

2. ***Modules***: A total of nine short modules are provided over the three years, in topics such as '*What is leadership?*', '*Ethics* ' and '*Change Management*'. Each module is typically structured in three parts: (i) a presentation on the module theme from an expert in the field, (ii) related team activities/projects, and (iii) a final discussion and reflection exercise with an industry panel.

3. ***Industry experience***: This experience includes a half-day industry shadowing in the first year of the program and a one-week work experience during the second year. Regular seminars and presentation are also given by industry. These activities have already led to some students obtaining vacation work experience at an earlier stage than most employers would offer.

4. ***Networking***: Participants are provided with a number of networking opportunities, including an annual dinner attended by senior representatives from industry and academia.

Although there are no publications available relating to this program, a paper is currently in planning which describes the unexpected outcomes of the students' personality profiling exercise. One point to note from the profiling is that the full range Myers Briggs types were found in the program cohort, with concentrations in groups that would not normally be expected to be found in engineering students.

6 Concluding comments

The report presents the findings of a snap-shot review of best international practice in *engineering leadership education*. A range of interesting programs have been identified from across the world.

The study reveals significant international differences both in attitudes and approach to *engineering leadership education*. In this regard, a clear distinction is apparent between the US and the rest of the world. It is clear that the hub of activity in '*explicit' engineering leadership education* is likely to remain in the US, at least for the next 5-10 years.

The study reveals a dearth of expertise and resources currently available to engineering schools wishing to establish new programs of *engineering leadership education*. The majority of programs currently in operation are relatively new (less than 5 years old since their inception) and therefore are not in a position to provide the community with proven models of success or long-term longitudinal data on the impact of their educational approach. The difficultly in identifying and securing faculty and support staff to design and deliver the program activities is seen as a particular challenge by program leaders.

Across the world, there is a very strong 'global and cross-cultural' theme evident in programs of *engineering leadership education*. Understanding how to operate effectively within complex international and cross-cultural environments is clearly seen as an important element of successful engineering leadership in the future, so this theme is likely to become an ever-stronger focus.

The majority of *engineering leadership education* programs identified in the study are managed at the school (rather than departmental) level by a relatively senior faculty member with a small project team, operating predominantly outside of the curriculum. The size and position of such programs allows for high levels of flexibility to develop new educational approaches to *engineering leadership education*. Looking to the future, as such models are proven, opportunities exist to embed successful approaches within the curriculum.

The most striking finding of the review is the dearth of resources or formal networks currently available in *engineering leadership education*. Given the emphasis that many international

engineering education programs place on ‘educating future leaders’ in their promotional material this represents a key gap to be filled. In recent years, the profile and knowledge-base for the related fields of ‘*global engineering education*’ and ‘*entrepreneurship engineering education’* have grown considerably. It is clear from the study that partnerships across and between these communities will be an important factor in the future development of excellence in *engineering leadership education*.

Appendix A. Individuals interviewed/consulted

A.1. North America

Krishna Athreya	Director, Engineering Leadership Program, Iowa State University
Lori Breslow	Director, Teaching and Learning Laboratory, MIT
Tom Byers	Faculty Director, Stanford Technology Ventures Program, Stanford University
Ed Crawley	Co-Director, Gordon-MIT Engineering Leadership Program, MIT
Monica Cox	Department of Engineering Education and Director, 'Leadership Policy and Change' graduate course, Purdue University
Lesia Crumton-Young	Former Director, Center for Engineering Leadership and Learning, University of Central Florida, currently on secondment at the Center for the Advancement of Scholarship on Engineering Education, National Academy of Engineering
Melanie D'Evelyn	Project Director, National Consortium for Character-Based Leadership, Center for the Study of the Presidency and Congress
Dan Dolan	Professor of Mechanical Engineering and Co-Director, CAMP, South Dakota School of Mines and Technology
Gary Downey	Professor of Science and Technology Studies and Course Director, Engineering Cultures, Virginia Tech
Clive Dym	Fletcher Jones Professor of Engineering Design, Harvey Mudd College
Norman Forenberry	Director, Center for the Advancement of Scholarship on Engineering Education, National Academy of Engineering
Peter Gray	Director of Academic Assessment, United States Naval Academy
Kamyar Haghigi	Head, Department of Engineering Education, Purdue University
Dan Hastings	Dean for Undergraduate Education, MIT
Dan Hirleman	Head of Mechanical Engineering and Director, GEARE, Purdue University
Beth Holloway	Director, Women and Engineering Program and Director, 'Women and Leadership' course, Purdue University
Donnie Horner	Professor of Leadership Education, Department of Leadership, Ethics and Law, United States Naval Academy
PK Imbrie	Department of Engineering Education, Purdue University
Brent Jesiek	Department of Engineering Education, Purdue University
Amy Joines	Student Director, Engineering Leadership Program, Iowa State University

Amery Kuhl	Student Leader, CAMP, South Dakota School of Mines and Technology
Tom Litzinger	Director, Leonhard Center for the Enhancement of Engineering Education, Penn State University
Bill Lucas	Director of Research, Gordon-MIT Engineering Leadership Program, MIT
Susann Luperfoy	Executive Director, Undergraduate Practice Opportunities Program, MIT
Cheryl Matherly	Associate Dean for Global Education and Director, INNOVATE, University of Tulsa
Pamela McCauley-Bush	Acting Director, Center for Engineering Leadership and Learning, University of Central Florida
Linda McCloskey	Director, Archer Center for Student Leadership Development, Rensselaer Polytechnic Institute
Leo McGonagle	Executive Director, Gordon-MIT Engineering Leadership Program, MIT
Rick Miller	President and Professor, Franklin W. Olin College of Engineering
Rabi Mohtar	Director, Global Engineering Program, Purdue University
Geoffrey Orsak	Dean, Bobby B. Lyle School of Engineering, Southern Methodist University
David Radcliffe	Associate Head, Department Of Engineering Education, Purdue University
Teri Reed-Rhoads	Assistant Dean of Engineering for Undergraduate Education, Associate Professor of Engineering Education, Purdue University
Doug Reeve	Chair, Department of Chemical Engineering and Applied Chemistry and Co-Leader, Leaders of Tomorrow, University of Toronto
Chell Roberts	Chair of Engineering, Arizona State University
Joel Schindall	Co-Director, Gordon-MIT Engineering Leadership Program, MIT
Rick Schuhmann	Director, Engineering Leadership Development Program, Penn State University
Sheri Sheppard	Associate Vice Provost for Graduate Education, Professor of Mechanical Engineering, Stanford University
Karl Smith	Professor of Cooperative Learning in Engineering Education, Purdue and Minnesota Universities
Diane Soderholm	Education Director, Gordon-MIT Engineering Leadership Program, MIT

A.2. Europe

Alison Ahearn	Lecturer in Educational Development and Coordinator, Constructionarium, Faculty of Engineering, Imperial College

Joan Alabart	Department d'Enginyeria Química, Universitat Rovira i Virgili and Director, *Project Management in Practice*
Carol Arlett	Centre Manager, Higher Education Academy Engineering Subject Centre, Loughborough University
Peter Bullen	Director, Blended Learning Unit, University of Hertfordshire
Bob Ditchfield	Director, Education Affairs and Diversity, The Royal Academy of Engineering
Erik de Graaff	Faculty of Technology, University of Delft
John Dickens	Director, Higher Education Academy Engineering Subject Centre and Engineering Centre for Excellence in Teaching and Learning, Associate Dean (Teaching) of Engineering, University of Loughborough
Kristina Edström	KTH Learning Lab, KTH
Marco Eisenberg	Program Director, Global Engineering Teams, Technische Universität Berlin
Mark Endean	Engineering Programme Director, Faculty of Mathematics, Computing and Technology, The Open University
Mike Gregory	Head of the Manufacturing and Management Division of the University Engineering Department, University of Cambridge
Alison Halstead	Pro-Vice-Chancellor, Learning and Teaching Innovation, Aston University
Michael Hush	Faculty of Technology, The Open University
Anette Kolmos	Professor in Engineering Education and PBL and Chairholder, UNESCO Chair in Problem Based Learning in Engineering Education, Aalborg University
Julia King	Vice Chancellor, Aston University and Chair, Royal Academy of Engineering '*Engineers of the 21st Century*' Program
Caroline Lowrey	Assistant Manager, Engineering Centre for Excellence in Teaching and Learning, Loughborough University
Mark Russell	Deputy Director, Blended Learning Unit, University of Hertfordshire
Gillian Saunders	Chair of Aerospace Structure, Faculty of Aerospace Engineering, Delft University of Technology
Dave Twigg	Civil and Building Engineering and Director, '*Leadership and Teamwork*' module, University of Loughborough

A.3. Rest of the world

Lizzie Brown	Director of Education, Training and Research, Engineers Without Borders Australia

Ian Cameron	Senior Fellow, Australian Learning & Teaching Council and Professor, Chemical Engineering, University of Queensland
Duncan Campbell	Alternate Head of School, School of Engineering Systems, Queensland University of Technology
Gary Codner	Associate Dean (Teaching) and Director, Leadership in a Technological Environment, Faculty of Engineering, Monash University
Caroline Crosthwaite	Director of Studies and Associate Dean, Faculty of Engineering, Physical Sciences & Architecture, University of Queensland
David Dowling	Professor of Engineering Education, Coordinator, Master of Engineering Practice program, Faculty of Engineering and Surveying, University of Southern Queensland
Liz Godfrey	Faculty of Engineering, University of Auckland and President, Australasian Association for Engineering Education
Roger Hadgraft	Director, Engineering Learning Unit, Melbourne School of Engineering
Doug Hargreaves	Head of School, School of Engineering Systems, Queensland University of Technology and Deputy President of Engineers Australia
Ashraf Kassim	Vice Dean (Undergraduate Studies), Faculty of Engineering, National University of Singapore
Nick Noakes	Director, Center for Enhanced Learning and Teaching, Hong Kong University of Science & Technology
Aldo Ometto	Departamento de Engenharia de Produção, Universidade de São Paulo
Khairiyah Yusof	Deputy Director, Centre for Teaching & Learning, Universiti Teknologi Malaysia

Appendix B. Summary table of selected programs

Provided overleaf is a table summarising some of the key features of eight selected programs of *engineering leadership education*. The programs included in the table are:

- *Engineering Leadership Program*[18], Iowa State University (***Iowa State***)
- *Teamwork and Leadership Module*[7], Loughborough University (***L'borough***)
- *Gordon-MIT Engineering Leadership Program*[19], MIT (***MIT***)
- *Leadership in a Technological Environment*[25], Monash Univeristy (***Monash***)
- *Engineering Leadership Development Minor*[15], Penn State University (***Penn State***)
- *Leaders of Tomorrow*[23], University of Toronto, (***Toronto***)
- *Global Engineering Teams*[12], Technische Universität Berlin (***TU Berlin***)
- *Constructionarium*[33]*, UK University and Industry Partnership (**UK Part.**)*

The table provides an overview of the **most significant activities or themes** within each program, presented within in six main areas:

1. ***Central program themes***: the key theme/s around which the activity is centred and which is embedded throughout the program. For example, those programs identified with a '*global/cross-cultural*' theme may involve students spending a portion of their time overseas, cross-national project teams with overseas partners or a significant focus on developing students' cross-cultural understanding.
2. ***Content and educational approach:*** the overall educational approach, structure and content of the program. For example, this section will identify whether the program includes an '*intensive 'transformational' experience'* where students are fully immersed in a deliberately challenging activity over a defined period or whether the program holds a regular '*leadership seminar/workshop'* designed to unite the cohort around the central program ideas.

3. ***Leadership practice opportunities***: the opportunities provided for students to apply and hone their leadership skills. This section identifies the practical opportunities offered for 'leadership practice', such as '*campus-based hands-on projects'* (such as Formula SAE), intensive '*residential off-campus retreats'* or opportunities for '*mentoring or coaching of more junior students'*.

4. ***Reflection, guidance and assessment***: the mechanisms used to encourage students to reflect on their leadership development, the guidance offered and the student assessment processes used. For example, this section will identify whether programs facilitate students to develop '*reflective journals'*, whether '*peer-evaluation'* is employed or whether the program/institution have developed '*associated assessment tools'* specifically tailored for engineering leadership and used within the program.

5. ***Structure and organisation***: how the overall program is structured and organised. For example, this section will identify whether there is a '*competitive selection process'* for admittance to the program, whether the program has developed any '*associated research projects'* in engineering leadership, whether the program is offered as a '*curricular'* and/or '*co-curricular'* activity or whether there is a focus on '*dissemination of the program's outcomes'* outside the institution.

6. ***Governance***: how the overall program is administered. This section covers aspects such as whether the program is predominantly '*student-led in its design and direction'* or whether '*external expert groups'* are engaged to provide guidance and advice to the program development team.

It should be noted that most programs will touch on almost every criterion presented in the table in some form. However, only those aspects that represent a **significant focus** of the programs' activities are represented overleaf.

Significant program elements	**Iowa State**	**L'borough**	**MIT**	**Monash**	**Penn State**	**Toronto**	**TU Berlin**	**UK-Part.**
Central program themes								
Global/cross-cultural context				✔	✔		✔	
Business/entrepreneurship context							✔	✔
Contribution to society or environment	✔			✔	✔	✔	✔	
Professional practice and partnerships		✔	✔	✔			✔	✔
Content and educational approach								
Articulated learning outcomes	✔	✔	✔		✔	✔	✔	✔
Uniting 'leadership seminar/workshop'	✔		✔	✔		✔		
'Case-study' led instruction					✔			
Leadership/business 'theory'		✔	✔	✔	✔	✔		
Engineering-design focused			✔					✔
Project-based approach	✔	✔	✔	✔	✔	✔	✔	✔
Personality profiling exercises			✔	✔		✔	✔	
Intensive 'transformational' experiences		✔			✔			✔
Leadership Practice Opportunities								
Campus-based hands-on projects	✔		✔	✔	✔	✔	✔	
Off campus 'real-world' experiences			✔	✔				✔
Residential off-campus 'camp' or 'retreat'	✔	✔		✔			✔	✔
International experiences					✔		✔	
Peer mentoring or 'coaching' of junior students			✔				✔	
Reflection, guidance and assessment								
Mentoring (by faculty, industry etc.)	✔		✔	✔		✔	✔	✔
Personal leadership development plan	✔		✔					
Reflective journals/portfolios	✔	✔				✔		✔
Self-evaluation	✔	✔	✔			✔		
Peer-evaluation	✔	✔					✔	✔
Novel (in-house developed) assessment tools	✔		✔		✔		✔	
Structure and organisation								
Program individually-tailored for each student	✔		✔		✔			
Curricular elements		✔	✔		✔	✔	✔	✔
Co-curricular elements	✔		✔	✔		✔		
Associated research projects					✔		✔	✔
Competitive application and selection process	✔		✔	✔			✔	
Associated student scholarship program	✔			✔		✔		
External program of dissemination and outreach			✔					✔
Program in operation for over five years		✔			✔	✔	✔	✔
Governance								
Student-led design, delivery and direction	✔		✔			✔		
Housed within Engineering School/s	✔	✔	✔	✔	✔	✔	✔	✔
External advisory groups			✔					✔