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Liberal Studies in Engineering and Technology

William Grimson
Technological University Dublin, william.grimson@tudublin.ie

Michael Dyrenfurth
Purdue University

MIke Murphy
Technological University Dublin, mike.murphy@tudublin.ie

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Chapter 8

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William Grimson, Michael Dyrenfurth & Mike Murphy

Abstract: A general case can be made for making Liberal Studies available to those students undertaking engineering programmes. But a more specific case can be made that engineers need to be well equipped if they are to be leaders in their community and capable of entering into meaningful dialogue (discourse) with their fellow citizens. Engineers contributing to or initiating a debate with those who do not understand technology, or who express an anti-technology stance, need to understand the "language" of all participants; and it is not reasonable for the engineer to expect that others adapt to the language and mind-set of the engineer. In Europe and the United States criteria have been established specifying the broad outcomes required of accredited engineering programmes and within these criteria it is clear that the wider interests of society become the concern of the engineer. These criteria, being outcomes-focussed, are not prescriptive as to the means within engineering curricula by which this is to be accomplished, but they point to the need for, if not Liberal Education, at least a move in that direction. This chapter reviews the rationale supporting the addition of a Liberal Education dimension to Engineering programmes and briefly considers Liberal Studies subjects that might be included in an Engineering or Engineering Technology Curriculum and their relevance and suitability. The chapter also emphasises the role of Accreditation Boards in the process by which curricula are reviewed and developed.

Key words: Liberal Education, Liberal Studies, Arts, Engineering Curriculum, Engineering Technology, Philosophy, Leadership

Introduction

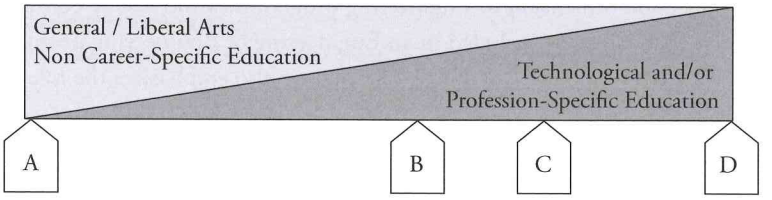
Understanding the needs of society and meeting those needs in a technologically sound and sustainable manner, whilst keeping within the constraints set by citizen stakeholders, is a fundamental goal for engineers. To set and reach this goal requires leadership. Since engineering has been and continues to be at the forefront in shaping our modern world, such leadership should come from within the engineering profes-

sion in cooperation with society. This in turn requires mutual understanding and effective communications between those involved in the design and implementation of technology and those who use and are affected by the use of those technologies. "Broadly educated engineers will be better able to explain technology to fellow citizens involved in democratic decision-making" (Jackson, 2002).

On both sides of the Atlantic, however, engineers and technology professionals are under-represented at the highest levels of governmental and policy decision making. This creates a challenge to the engineering profession in establishing a true dialogue between decision makers and engineers. In turn, this also creates a challenge to those charged with the responsibility for the education of engineers to ensure that their graduates are capable of participating in the dialogue. With this as context, this chapter explores the role of Liberal Studies within the engineering curriculum as one means of equipping engineers with the "tools" of critical thinking, leadership, and "language" by which they can engage in effective discourse with society and its decision makers, and hopefully increase their participation in that latter role.

Pragmatically, the extent to which engineering and engineering technology baccalaureate programmes incorporate, and even integrate, liberal studies depends on each university's view of what professional programmes at that university should encompass. Perhaps such views can be characterized along a continuum of varying proportions of liberal arts versus technical focus as shown in Figure 8.1.

Figure 8.1: The Education Continuum



In some universities, engineering programme content is almost exclusively technical (i.e. science, technology) in nature. This is depicted by position D on the above continuum. In direct contrast is, of course, the traditional liberal arts college where no treatment of profession-specific content is provided and the focus is on classics, critical thinking, philosophy, etc. This is depicted by position A in the continuum. Perhaps the typical US professional baccalaureate degree programme (depicted by position B) represents a plausible compromise, where generally between 20-45% of the curriculum (Russell & Stouffer, 2005) is devoted to the liberal arts and general edu-

cation. The position on the spectrum for many European universities is somewhere between B and D, say at C. However, on a practical note, even in such environments (B and C) the issue comes down to who controls the decision about what is considered to be a liberal arts/general education course. Is it the liberal arts teaching staff or is it the professional programme's teaching staff who decides?

According to Jackson, "recognition of the importance of liberal studies to engineering education dates to the Morrill Act of 1862, which established the land-grant colleges, and there has been an abiding recognition that engineers must appreciate and understand the human condition, in order to apply the principles of mathematics and science in the service of humanity" (Jackson, 2002). This line of reasoning can also be traced back to the late forties (App, 1946) and the heart of the argument calling for increased presence of the liberal arts in engineering and engineering technology programmes of the future is more recently articulated in Badley (2003). He states:

Indeed, the crisis in culture is our uncritical adoption of a mechanistic – scientific – technological – world view (see Biesta & Burbules, 2003, p.13).. This crisis in culture is also a crisis in rationality since scientific rationality is thought to be confined to hard facts and means while human values and ends appear to be excluded from rational (i.e., scientific) deliberation (Biesta & Burbules, 2003, p.13). ... The solution is an integration of the beliefs we have about the world and the values and purposes that should direct our conduct (p.487-488).

Curriculum design for engineering educational programmes is itself a typical engineering exercise in that many constraints need to be taken into account. Judgements are made that are not necessarily based on a set of educational principles. However the underlying objectives in including a Liberal Education dimension are clear and are set out in a technical report in the UK by Heywood (1994) and from a similar but not identical perspective in a set of recommendations for MIT by Dertouzos *et al.* (1989). University traditions and professional accreditation criteria may find themselves in conflict given the crowded nature of baccalaureate curricula. Frequently, optimum curriculum solutions are not readily apparent. Custom and practice play a role within the university, and an understandably conservative approach is often adopted.

It must be acknowledged that engineering curriculum design is a non-trivial task, and retrospection suggests that one particular dimension of this task has been underweighted. This is the societal dimension in which engineering is practiced and technology operates. At its bleakest this dimension may be absent completely, or it may be addressed in a solitary ethics course. Even then, more often than not this concentrates on cases studies where some catastrophe occurred and seldom deals with the more general aspect of the welfare of the public. For example, there are complex is-

sues surrounding the tensions between collective and individual responsibilities, and the legal and protection aspects surrounding whistle-blowing. MacIntyre (1990) was far from convinced by the provision of applied ethics courses within universities and colleges partly because of their focus on separate modes of professional life: a more general approach is required.

The issue of a societal dimension not featuring more significantly in the engineering curriculum is increasingly at odds with the thinking and writing of senior members of the profession. The reasons for this disconnect are clear enough – much time is required to achieve competency in mathematics, the sciences, engineering fundamentals, discipline-specific skills, and technology. This leaves little time to address other subjects in an already crowded undergraduate curriculum. Therefore even finding space in the curriculum for the development of effective communications skills – writing, communications and team work – has not been an easy one. It is not surprising then that the challenge to find time for inclusion of topics considered by some engineering academics as extrinsic to any particular discipline of engineering, namely philosophy, the history of science and technology, etc., seems so difficult to surmount. One partial remedy is to take an Integrated Studies approach where certain themes can be picked up across a set of subjects reinforced by a consistent use of terminology and concepts.

But, can a future-oriented profession, whose rationale is to serve the needs of society, afford to ignore the evidence that points to the necessity of addressing shortfalls in what it means to be a professional?

Before addressing this question, let us first turn our attention to the study of liberal arts for their own benefit, as distinct from our specific question as to whether they are of benefit to the student engineer. The next section addresses this question. It should be noted, however, that the arguments presented are derived from documentation originating on either one side of the Atlantic or the other. It may well be that a given perspective has more legitimacy on one side than the other but clearly the contention is that such points, regardless of origin, are worthy of consideration on both sides of the ocean. It is also perhaps worth noting that John Henry Newman (1959) in his *Idea of a University* had more impact directly and indirectly on the development of universities in the USA than in the UK and Ireland, where a focus on specialization eventually prevailed. But there is a hankering for a return to at least some of the ideals of Newman and re-engineering the curriculum accordingly. Trinity College Dublin, one of the classical universities that Newman based his model on, has introduced measures to counter the excesses of specialization by broadening the curriculum (TCD, 1999).

The Purposes of Liberal Arts

What are the purposes of the liberal arts in our universities? What do liberal arts educators claim as the purposes of their own curricula? How do they set forth their own goals and aspirations? Youngdahl (1942), Reiner (1975), Bradley (1985), Hersh (1997), Nussbaum (1998), Badley (2003), Boren (2004), Brint *et al.* (2005), Berube (2006), and Lind (2006) have all spoken to this point. And whilst its focus was not solely on university education the *Padeia Proposal* as a system of liberal education originating from Mortimer Adler (1988) should be mentioned as well as the work of the Boyer Commission in Reinventing Undergraduate Education (1998). Also, the objectives of Andrew Carnegie and the philanthropically driven concrete outcomes both sides of the Atlantic should not be forgotten.

Badley is concerned that our culture is "bombarded with competing *ideologies*" (2003, p.480) one of which is the primacy of the career preparation function of the university. Already in 2003 Badley (p.483) asked "what is education for?" In answering his own question he suggests that: "the current answer appears to be that the purpose of education, even higher education, is simply to help society become more economically productive and competitive (p.483)." He buttresses his argument with Rhodes' (2001) claim "that professionalism has now shifted the function of the university from that of providing students with an opportunity for education to that of acquiring employability" (Badley, 2003, p.486). Indeed the philosopher Wolff has argued that such a shift is detrimental to the fundamental role of the university and that consequently the education of the professions should not even reside within the modern university (Wolff, 1971).

Badley worries that "our current cultural consensus is too dominated by a form of *competitive globalization*" (2003, p.478), and claims that two ideologies *science-technology* and *business-economics* dominate "our post modern world culture" (p.487). Badley continues with, "governments now see the university as an economic investment rather than as a cultural and educational asset" (p.488). Despite compelling arguments such as those raised by the USA Council on Competitiveness (2005), pragmatists "resist the attempt of the new economy to consume our valued educational institutions. They do so on the grounds that institutions such as universities have always had and should continue to have broad cultural, humanistic, and social objectives which should not be overwhelmed or crushed by globalization, commercialization and marketization" (p.489). Given this, and working from the pragmatic perspective of contemporary culture, Badley claims that effective education must serve integrative purposes that "bind culture and education together" (p.477).

Badley (2003) cites Rorty's (1999, p.118) perspectives on higher education, that it is "a matter of inciting doubt and stimulating imagination, thereby challenging the

prevailing consensus. If pre-college education produces literate citizens and college education produces self-creating individuals, then questions about whether students are being taught the truth can safely be neglected."

In 2005 the Association of American Colleges and Universities launched its LEAP (Liberal Education and America's Promise) initiative to speak to "the aims and outcomes of a twenty-first-century college education" (National Leadership Council, 2007, p.1). In many respects LEAP echoes the work of the Enterprise Learning initiative referred to earlier (Heywood, 1994). The LEAP initiative identified the following essential learning outcomes (p.3) summarised as follows:

The Essential Learning Outcomes
Beginning in school, and continuing at successively higher levels across their college studies, students should prepare for twenty-first-century challenges by gaining:
• Knowledge of human cultures and the physical and natural world through study in the sciences and mathematics, social sciences, humanities, histories, languages, and the arts
Focussed by engagement with "big questions", both contemporary and enduring
• Intellectual and practical skills, including inquiry and analysis, critical and creative thinking, written and oral communication, quantitative literacy, information literacy, teamwork and problem solving
Practiced extensively, across the curriculum, in the context of progressively more challenging problems, projects, and standards for performance
• Personal and social responsibility, including civic knowledge and engagement – local and global, intercultural knowledge and competence, ethical reasoning and action, foundations and skills for lifelong learning
Anchored through active involvement with diverse communities and real-world challenges
• Integrative learning, including synthesis and advanced accomplishment across general and specialized studies
Demonstrated through the application of knowledge, skills, and responsibilities to new settings and complex problems

In working towards these outcomes, the LEAP initiative claims that "liberal education has always been this nation's signature education tradition" and that the tradition's core values are: "expanding horizons, building understanding of the wider world, honing analytical and communication skills, and fostering responsibilities beyond

self" (2007, p.3). Because of this, the LEAP leadership not only advocates that these aims be fostered in general education but also within the courses in students" majors "whether the field is conventionally considered one of the arts and sciences disciplines or whether it is one of the professional and technical fields" (2007, p.4). The inevitable conclusion is that, regardless of the discipline, the inclusion of liberal studies should be an essential feature of any undergraduate programme.

Leadership and the Engineer

There are many definitions of "engineering" in circulation and they have in common some or all of the following features: the use of mathematics and the natural sciences; the exercise of judgement; the optimum use of the resources of nature; meeting the needs of society or mankind. It is the two words "society" and "needs" that are at the core of the arguments within this chapter.

The President of the Royal Academy of Engineering, Lord Browne (2008), at a presentation in Oxford University noted that "too few engineers get involved in public life" and he went on to quote his colleague Lord Darzi that "engineering is about the technological solutions to human problems," from which he concluded that "engineers must appreciate the nature of human problems as well as understand the technical aspects of their solutions." In his Presidential Address (as President of Engineers Ireland) *Who will be tomorrow's leader? The engineering profession's 21st century challenge*, Jack Golden (2008) noted that Plato believed that the foundation of leadership was expert knowledge, accompanied by such factors as courage, self-discipline and a philosophical mind. Meijknecht and van Drongelen (2004), who are not themselves engineers, explored how engineers are "produced" in Delft University, came to the realization that for engineers "the days of comfortable autonomy are over and done with. Engineers can no longer hide in the realms of science and technology and focus solely on the development of new technologies. As mediators between science and the world they live in, engineers have the task of finding ways to sustain and develop life in a balanced and adequate way by controlling and explaining the complicated processes in nature and human existence." Rosalind Williams has conjectured that the profession of engineering has lost its identity and argues that in the long run professional engineers will have to face up to a long term convergence between technological and liberal education. The prediction is that if engineers do not accept a hybrid educational activity they will be consigned to purely technical work activities. And consequently the professional engineer would not be ideally suited to provide the type and level of leadership required in our more complex society (Williams, 2003).

There is also a need to counter or at least understand the anti-technology stance often associated with the postmodern movement and that is discussed in Samuel

Florman's (1976) book *The Existential Pleasures of Engineering*. As an aside, that book was first published in 1976 and was re-printed in 1994, and its main topic and themes are as relevant today as they were over a quarter of a century ago – pointing to at least a partial failure of the profession to heed its message. Engineering as political judgement has been considered by many authors, and Little, Barney and Hink (2008) in a general review of professional ethics make the point that "the call to engineers to engage in their practice politically echoes the obligation to attend to the public welfare that is explicitly stated in most of the ethical codes that govern the contemporary profession." Taft Broome (2006) arguing for a "unity principle" applicable to engineering notes that generalist expertise, being different to specialist expertise, "consists in the ability to obtain meanings of a broad variety of learned works from their storied terms, and in the skill to bring them to bear upon the problems of participating effectively in public decision making venues, and finding and fulfilling one's destiny in globalizing cultures." This phrase *participating effectively in public decision making venues* echoes a point made by Florman and succinctly states the challenge that the profession should be obliged to address.

One of the engineering profession's largest professional organisations, the IEEE (Institute of Electrical and Electronics Engineers), has among its member societies the Society on Social Implications of Technology. Within its scope this society includes such issues as environmental, health and safety implications of technology; engineering ethics and professional responsibility; history of electrotechnology; technical expertise and public policy; peace technology; and social issues related to energy, information technology and telecommunications. On the European side of the Atlantic, the Royal Academy of Engineering (RAE) in the United Kingdom initiated in 2006 a series of seminars on the philosophy of engineering and this initiative is continuing. The topics that the RAE has chosen to explore have been wide in scope and have included the nature of engineering knowledge, ethics, and metaphysics. All these initiatives have as a basic underlying objective the idea that engineers need to be in a position to provide leadership to society.

Consequently, senior figures in engineering and professional and honorary academic bodies should be aware of the challenges in providing leadership, entering into dialogue with the public and generally understanding the needs of humans both in terms of society and as individuals. This in turn leads to a central question: why is it that engineering educators appear not to deliver an education that sufficiently considers societal and humanist challenges in their baccalaureate engineering programmes?

The situation has not been helped by the engineering science movement which has led to a gradual de-contextualising of engineering programmes. Johnston, Lee and McGregor (2006) express their "concern that the discourse of engineering education has been dominated by the discourse of engineering science, to the virtual exclu-

sion of other discourses which contribute importantly to the practice of engineering." Already in 1994, Herbert Simon wrote that "schools of engineering have become schools of mathematics and physics" in which, it must be admitted, dialogue and negotiation with the public is not a central objective. Even earlier, and making a more general point, George Bugliarello (1991), former Chancellor of Brooklyn Polytechnic University noted that C.P. Snow's two cultures are in fact on diverging trajectories (Snow, 1998). In part this might be due to difficulties with the language of discourse. Wittgenstein (1998) pointed out in his posthumously published *Philosophical Investigations* that although we may believe we are speaking a common language with our fellow colleagues, it is very often the case that what we understand from our own perspectives is quite different for each. An economist or historian may understand things quite differently than do colleagues in civil engineering or environmental science. In Wittgenstein's terms, we are involved in different "language games" and we must learn the rules of the different games if we are to communicate meaningfully.

Finally, a more general set of points are covered in a number of chapters in the section titled *The Roles and Status of the New Engineer in a Global Knowledge Society* in the book *Philosophy in Engineering* edited by Christensen, Meganck and Delahousse (2007). In particular the status of the engineer in Europe, as discussed by Gasparetto, Avila and Arias, considers the disconnection between engineers and humanism.

This section has made two central arguments, summarised here. The first is that the challenges that the engineer of the 21st century faces require a different engineering education, a broader engineering education, and that the broadening aspects should be drawn from among traditional liberal arts subjects. While it can be argued that a key purpose of a liberal education is to be an end in itself, this chapter has argued that aspects of such a liberal education should be applied for purposes which are external to it. Through such application the engineering student develops critical reasoning, discourse and contextual skills. But this section has not explored the possible effects on the liberal arts students sitting in the same class with the engineering students: a topic that might usefully be explored as part of addressing the "two cultures" issue.

The second argument is that, upon completing their education, engineers can no longer focus solely on the development of new technologies. They must act as mediators between science and the world they live in. To successfully achieve this, they must seek to play leadership roles within society. Some of these leadership skills cannot be developed without liberal studies within the context of their engineering education. Again in paraphrasing Plato that the foundation of leadership was expert knowledge, accompanied by a philosophical mind, it might be argued that this could be interpreted as a call for philosophers to provide leadership. However, in the world of the 21st century, the relevant "expert knowledge" is scientific and technological and supports the argument that the engineers should become leaders with some philosophical insight.

To enable engineering leadership a deeper understanding of societal needs and their context must be achieved and coupled with a form of communications that ensures a common view of the issues involved. Where better to start than through education?

Framing a Curriculum Solution

In contrast to this chapter's earlier perspectives which emanated from inside the liberal arts community, consider the statements from the world of engineering and engineering technology. Here, many of this profession's leaders and reports have called for curriculum change despite significant national or continental differences in preparatory programmes at the baccalaureate level. Among them are the Boeing Corporation's description of the desired attributes of an engineer, the American Society of Engineering Education (ASEE), and the National Academy (2006). After reviewing 25 years of change within the National Science Foundation (NSF) and other drivers of reform in the USA, Padros (1998) outlined an action agenda for systemic engineering reform. Included in his new paradigm were integration, increased attention to social concerns and the creation of a more holistic baccalaureate education. Another valuable compilation of reports addressing engineering education and change was contributed by Ernst (1998) and published as Appendix I to the National Conference proceedings on the same theme. A broader perspective on change in university mission was published by Scott (2006).

Undoubtedly, one of the more powerful voices for engineering education reform has been that of William Wulf, the former president of the US National Academy of Engineering. In various speeches (Annual Meeting of the American Association for the Advancement of Science [1998]; Realizing the new paradigm for engineering education [1998], for example) he highlighted the urgency for reform of engineering education. He noted that while engineering considers the baccalaureate degree a professional degree "most professions (e.g., business, law, medicine) do not... Doing so is a misrepresentation" (p.28). He goes on to comment that one of the consequences is that "liberal education in the humanities is being squeezed out of the engineer's undergraduate experience, as are courses in social and management sciences" (p.28).

Even leading industrialists call for a well rounded engineering education. For example, Arthur Glenn, a former vice-president of General Electric, stated that "the broader context of engineering education is necessary for our engineering graduates today and tomorrow, and if we don't broaden the education, we will be shortchanging them to be prepared for the workplace they will find" (1998, p.31). More recently, Jones (2005) has joined this call as has Reed (2004).

Ernst & Peden (1998) compiled the proceedings of a national (USA) conference addressing needed changes in university engineering education programmes. They cited the purpose of the conference was to explore: "what an individual institution does to change from its present approach to the new engineering education, one that seeks to develop students as emerging professionals with the motivation, capability, and knowledge base for life-long learning; one that helps students see the whole world and sense the coupling seemingly disparate fields; one that incorporates a diversity of backgrounds and approaches; and one that enhances student capability to build connections between the world of learning and the world beyond" (p. ii).

Some innovative approaches to curricula, for example the Worcester Polytechnic Institute's PLAN incorporated attention to the liberal arts because they noted that "knowledge of human relationships and human need was as important to engineers and scientists as to liberal arts majors" (Durgin & Parrish, 1998, p.63). Similarly, in Drexel University's approach "humanities are integrated into the freshman curriculum. Humanities faculty coordinate the content of the course with all other course instructors" (Bilgutay & Mutharasan, 1998, p.67).

In summary, there are significant voices in the engineering profession who place real value on including liberal studies in the educational phase of forming a professional engineer. Further, collectively they have influenced professional bodies charged with establishing accreditation criteria to include outcomes that would best be obtained by the inclusion of liberal studies in an engineering curriculum.

The Role of Accreditation Criteria in the Curriculum Solution

As described in greater detail in Chapter 5, the current approach with respect to the professional accreditation of engineering programmes is that they be outcomes-focused. Programme criteria do not need to be prescriptive about how learning outcomes are achieved. Once it is clear that the desired competencies have been developed by the student, the precise mechanism by which they were gained is chiefly of concern to the provider of the education.

Accreditation of engineering and engineering technology programmes are conducted by engineering education accrediting bodies such as the Accreditation Board for Engineering and Technology (ABET) in the US, the Engineering Council in the UK (EC^{UK}) and Engineers Ireland in Ireland. There are also pan-national accrediting initiatives such as the EUR-ACE project in Europe which has developed a progressive, outcomes-based framework for the accreditation of engineering degree programmes within the European Higher Education Area.

Under EUR-ACE, the six Programme Outcomes of accredited engineering degree programmes are: Knowledge and Understanding; Engineering Analysis; Engineering Design; Investigations; Engineering Practice; and Transferable Skills. It is readily apparent that the learning outcomes specified in the EUR-ACE Framework require, in addition to the expected scientific, mathematical and engineering material, non-technical and liberal studies input. An interpretation can therefore strongly be made that is supportive of a broad education that considers the context and societal aspects of engineering. For example, under the Knowledge and Understanding outcome the Framework states that "graduates should demonstrate their knowledge and understanding of ... the wider context of engineering." Similarly, and more directly, under the Transferable Skills outcome, the Framework states that the "skills necessary for the practice of engineering, and which are applicable more widely, should be developed within the programme." Therefore, it is reasonable to conclude that the EUR-ACE Framework does indeed set an accreditation agenda in which engineering programmes should be designed to address the issues discussed in the first section of this chapter.

Turning to the US, ABET's new accreditation criteria (ABET, 2007), in addition to technical and analytical competences, call for an ability to understand professional, ethical and social responsibilities, and a respect for diversity and a knowledge of contemporary professional, societal and global issues. Again, it is reasonable to conclude that the accreditation criteria in the US provide the demand and stimulus for engineering and technology curricula to be designed so that the wider societal dimensions are addressed.

Looking beyond Europe and the US, and due in part to the need to have multinational engineering accords, there is strong convergence worldwide with respect to the criteria used in accrediting engineering programmes. Consistent with an outcomes-focussed approach, these criteria generally do not specify how the outcomes are to be achieved: that is a matter for the education providers to consider and thence to design appropriate curricula.

In concluding this section, the agenda has been set by which the concerns of senior members of the engineering profession to broaden the curriculum can be addressed. The onus is primarily on the education providers to rise to this challenge. But, it should also be noted that to coherently bring about such curriculum changes, those charged with undertaking an accreditation of a programme must be fully empowered to discharge all their duties. Currently, the members of accreditation teams are drawn from within the engineering community, and so the pace of curriculum reform lies, in the first instance, within the hands of the engineering profession itself. The inclusion of lay persons on accreditation teams has been raised in some quarters – a concept that is being considered by other professions too.

The Choice of Liberal Studies

It has been said that in some respects the Russian composer Igor Stravinsky was a magpie – borrowing styles and ideas from diverse sources for whatever musical project he was working on at the time. The practice of engineering has this same characteristic in that it willingly takes ideas, knowledge and techniques from wherever in pursuit of completing its goal. Yet engineering educators appear reluctant within their curricula to borrow and use material from other disciplines in the furtherance of offering their students the ability to conduct a satisfactory dialogue with society as well as providing the basis for the development of leadership. If it is accepted that there is a shortfall in what constitutes the engineering professional, should it not follow that engineering educators are prepared to make curricula or learning changes that would help to improve the situation?

What means are best suited to the task of curriculum reform in this dimension? For those who have tried to deal with the challenge, more commonly encountered in the USA than in the UK and Ireland, a number of solutions have been tried. For example, MIT has a general policy that requires all engineering undergraduates to take credit bearing courses from within the Humanities. As another example, Virginia Tech has University Core Curriculum Areas (UCCA) that include topics such as Creativity, Aesthetic Experience, Ideas, Cultural Traditions, and Values, Society & Human Behaviour and these can be found in the engineering curricula. Another very different approach is one that has been promoted in Denmark where in 2004 the Danish government recommended the inclusion of philosophy of science courses in degree programmes at the bachelor's level. This was in response to a UNESCO (1999) declaration in which it is stated that "science curricula should include science ethics, as well as training in the history and philosophy of science and its cultural impact". And it should be noted that engineering was also included in the declaration.

Taking a broad view of the challenge and the many possible solutions it appears that some form of framework is needed in which various strands can be drawn together. Using the Library of Congress classification, for example, it is possible to divide subjects into three broad categories: (a) those that are generic and are foundational and contribute to a "breadth of mind", e.g., philosophy; (b) those that aim to provide generic competences and skills, e.g., languages; (c) those that seek to provide specific competences in what for some would be their professional area but for others provide useful insight e.g., economics, law. Most universities that make provision for the inclusion of liberal studies in the curriculum are relaxed about the choices made by students. Nevertheless some writers have argued that philosophy, because of its truly foundational character, and the history of science, engineering and technology, because it provides context, are prime candidates for inclusion in a curriculum

that sets out to develop within the engineer a broad vision of what it means to be a professional. The inclusion of history needs little in the way of justification but why philosophy? Grimson (2007) has previously attempted to provide an explanation and so only a few points will be made here. First, much of western philosophy is about coming to terms with, in the simplest of language, who we are, how we see the world, and how it all fits together. Wittgenstein used the metaphor of philosophy being about the unravelling of knots which when resolved become science or established knowledge. Considering that the greatest of minds over many centuries have devoted their lives to philosophical matters it would be strange if general insight had not been created. Second, whether by choice or due to the innate nature of philosophy, the insight gained and the "tools of the trade" that evolved are extremely, if not completely, general. And so the five classical branches of philosophy (Epistemology, Metaphysics, Ethics, Logic, and Aesthetics) that have been developed and tested across time and in different domains are as applicable to engineering as to any other human activity. Specifically the relevance of these branches to engineering can be summarised as follows:

Epistemology seeks to understand the distinction between different forms of knowledge (rational, empirical etc); to consider how knowledge is acquired, recorded, organised, maintained and used; and to provide a platform by which the provenance and limits of applicability of knowledge may be evaluated.

Metaphysics considers the question of what is reality, including abstract concepts such as substance, knowing, time and space. Metaphysics also includes ontology, mereology, and teleology considerations.

Ethics examines the determinants of appropriate behaviour, placing value to personal actions, decisions, and relations; impact of legislation and professional code of ethics.

Logic studies concepts of "right reasoning", forms of logic (e.g., temporal logic), role of logic in building conceptual models, the role of logic in how knowledge is deployed.

Aesthetics examines the distinction between "values" in arts, science and engineering; the tension or even dialogue between form and function. Since engineering involves designing and making things that did not previously exist, the aesthetic issue is raised at each departure, and case studies would illustrate the concerns.

The claim, then, is that philosophy coupled with history (of engineering, science and technology) are fundamental subjects that should be included in an engineering curriculum. And, as a co-requisite, technological education should also be added as a mandatory component of second-level education. What of the other subject areas?

These might include Economics, Law, Theory of Organisations, Library & Information Sciences, Ethnography, Education, Psychology, Social Sciences, Public Administration, Languages, Music, Visual Arts, Architecture, etc. Clearly room can never be found in the curriculum to enable a student to study more than a limited number of subjects, so one strategy could be to encourage diversity by which cohorts of students don't all make the same choice, that way the profession generally is enriched across a spread of non-technical subject areas. A more focussed approach would be to have engineers educated in specific liberal studies. Upon reflection this would appear to be an over-engineered approach, and one that runs counter to many of the arguments presented earlier. It could lead to an overly prescriptive curriculum which would in turn risk alienating both the students and the staff conscripted to teach those subjects. Better then to rely on the enthusiasm of staff, local expertise, free choice for students and the diversity argument.

Conclusions: Consequences of the Liberal Arts

Badley maintains that much of what the engineering reformists are calling for by the inclusion of more liberal arts in baccalaureate programmes with "the kind of integration we hope for... is one that seeks to unite culture and higher education in a *cooperative* or *democratic globalization* which values and implements social and educational practices and narratives based on such democratic and pragmatist principles as freedom, growth, justice and tolerance" (2003, p.478). Pascarella *et al.* (2005) even compiled evidence of such impacts.

Notably, many of the voices for change have, on the surface, called for increased presence of the liberal arts in baccalaureate engineering programmes. Looking more critically one might note that many of the calls have been more for the outcomes or consequences most frequently attributed to the liberal arts rather than to increased "seat time" in required liberal studies courses. These outcomes include the aforementioned ABET outcomes, in particular outcomes g, h, i, & j (see Chapter 5).

But, even beyond this it should be noted that the LEAP initiative, as one of the cogent calls for educational change:

"places special emphasis on liberal education as the portal to economic opportunity because so much of the public – and so many students – have been told just the opposite. Today, powerful social forces, reinforced by public policies, pull students – especially first-generation and adult students – toward a narrowly instrumental approach to college. This report urges educators to resist and reverse that downward course. It is time to guide students away from limiting choices and toward a contemporary understanding of what matters in college" (2007, p. 17).

It should also be noted that within the US and parts of Europe, and for complex reasons, liberal arts has changed its perspective and is seeking to remap itself from a purview for an elite to one that is a necessity for all (and this includes engineers and engineering technologists). In addition to the consequences/outcomes of liberal arts as highlighted by LEAP's essential learning outcomes referred to earlier in this chapter, the LEAP initiative encourages programmes, including engineering ones, to address seven principles – called principles of excellence – that in their totality provide further detail to the desired consequences of increasing the presence of the liberal arts in engineering and engineering technology programmes. These include such worthy ideals as teaching the arts of inquiry and innovation, engaging in the "big" questions, fostering civic perspectives, connecting knowledge with choices and action, recognising intercultural and diverse aspects of society, and all conducted within an ethical framework.

In conclusion, regardless of any particular stance taken, the overall picture is that it would be wise to include liberal studies in engineering programmes. To set the bar at a high level, engineers need to be able to act in the role as public intellectuals and not just as technocrats. And in achieving that position the choice of what non-technical subjects to include in the curriculum remains an open question with the possible exceptions of both a philosophical and historical treatment of engineering.

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