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Educating Engineers for the 21st Century … and why some elements of History and Philosophy should be incorporated into the curriculum

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ABSTRACT

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. 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. Further, Engineering is, at least in part, in agreement with Fyodor Dostoevsky – 'if everything on Earth were rational, nothing would happen'. Against such a background it is proposed that a framework based on both philosophy and the history of engineering, science and technology constitutes a valid footing upon which engineers can be enabled to see and develop their profession in a suitably rounded manner.

Engineering as a discipline has advanced considerably in the technological sense and a thorough understanding of technological developments is an important part of the 'creation' of an engineer. But it is becoming increasingly clear that there is a lot more to engineering than science and technology together with a few elements of business. Today, the established and accepted method of educating the engineer evolved in the post-war era of the 1950's and was based on first teaching the fundamental scientific principles and following in later years with discipline-specific knowledge and design techniques. Industry was then left to educate the young engineer in the on-the-job skills of teamwork, communications, ethics, etc. In recent years a number of important and influential bodies have begun to explore whether this accepted method is the appropriate model for educating engineers given the challenges that they will face in their career. For example the US National Academy of Engineering has described the engineer of 2020 and proposed mechanisms to educate that engineer. Educational standards bodies such as ABET and corresponding ones in Europe including Engineers Ireland have developed new accreditation guidelines for engineering programmes to ensure that graduates from these programmes have the skills that were traditionally left to industry to develop in their engineering employees. Within industry, companies have identified the desired attributes that they seek in an engineer. All these revised skills and attributes leads one to the conclusion that the modern world requires a more rounded and developed engineer. Coming from a different direction authors such as Rosalind Williams and John Heywood (both from what might loosely be termed the liberal arts) have conjectured that the engineering profession has lost its identity. And it is argued that in the long run engineers will have to face up to a long term convergence between technological and liberal arts education. Their prediction is that if engineers do not accept a hybrid educational activity they will be consigned to purely technical work activities. And consequently the engineer would not be ideally suited to provide the type and level of leadership required in our more complex society.

In Europe, implementation of the Bologna Declaration provides an excellent opportunity to examine how some degree of convergence between technological and liberal arts education can be achieved in the context of a two-cycle engineering system of education. The first cycle, of normal duration three years, might not admit much in the way of such a convergence and it might also be problematic in the second-cycle especially if such a degree is not designed to follow on directly from a specific first cycle one. However there is good scope for incorporating appropriate elements of liberal education in an integrated five year programme. But what should these elements be? Reaching any consensus on this will not be straightforward when one considers, for example, the report by the Royal Academy of Engineering (UK) *Educating Engineers for the 21st Century*, June 2007 which states that "Universities must continue to teach 'core engineering' and not dilute course content with peripheral subject matter. They add that 'there is a limited requirement for training in key business skills, envisaged primarily as commercial awareness - an understanding of how businesses work and the importance of the customer – combined with the basic principles of project management." This view is sharply contrasted with that of IBM where they envisage services, sciences, management and engineering "bringing together ongoing work in computer science, operations research, industrial engineering, business strategy, management sciences, social and cognitive sciences, and legal sciences to develop the skills required in a services-led economy." Going a little further, educators such as Gary Downey have developed an Ethnographical approach exploring the relationship between knowledge and personhood (engineer). Again from an educational perspective, consider Harvey Mudd College, California, which "seeks to educate engineers, scientists, and mathematicians, well versed in all of these areas and in the humanities and the social sciences so that they may assume leadership in their fields with a clear understanding of the impact of their work on society." The National Academy of Engineering (US) in *The Engineer of 2020: Visions of Engineering in the New Century* sets the goal to "maintain the nation's economic competitiveness and improve the quality of life for people around the world, engineering educators and curriculum developers must anticipate dramatic changes in engineering practice and adapt their programs accordingly." In addition to identifying the ideal attributes of the engineer of 2020, the report recommends ways to

improve the training of engineers to prepare them for addressing the complex technical, social, and ethical questions raised by emerging technologies. Boeing have, *inter alia*, identified the Desired Attributes of an Engineer other than technical that includes a basic understanding of the context in which engineering is practiced. Amongst topics addressed are: economics, history, ethics, the environment, as well as customer and societal needs. Some of the skills identified include: good communications, high ethical standards, an ability to think critically and creatively and independently, the ability and self-confidence to be flexible, and an understanding of the importance of teamwork. What is clear overall is that a body of engineers and engineering educators do believe that the educational development of a "more rounded" engineer needs to be achieved.

This article considers one particular aspect of what could be best achieved through an exposure to elements of a traditional liberal arts education and that is the role of the history of ideas in engineering coupled with an analysis of some major engineering developments from a philosophical perspective. A range of examples are included with particular emphasis on 'design' illustrating the proposed approach and the examples are chosen not for the depth involved but rather to ensure that they can be understood by a general audience. The roles of heuristics, empiricism, rationalism, logic, ethics, and aesthetics are considered illustrating the relevance of philosophy to the practice of engineering. In addition some comments on an evolutionary perspective are presented using the 'meme' concept of Dawkins. Our goal in this paper is to demonstrate that the education of the modern engineer will be improved by focusing on the development of a range of attributes both from the traditional engineering pedagogy but also attributes more usually developed through a liberal arts education, including history and philosophy. The successful result, we argue, will be the well-rounded or more-rounded engineer of the 21st century.

But, however convincing the case might be to the authors, it is an entirely different matter when it comes to winning the argument with academic staff in an engineering faculty or school to include some element of liberal arts education in what is usually an already tightly packed curriculum. And even if an acceptance is won there still remains the problem of deciding how to deliver to the students the chosen liberal arts. For the first challenge there is no ready simple solution. Colleges are often conservative for good reasons and are not overly susceptible to the current demands of industry and would generally claim that they are educating their students not for 'the first job' but for life. Nevertheless this 'for life' aspect coupled with the recruitment policies of some influential employers should eventually bring about the conditions by which the engineering curriculum is opened to include liberal arts studies such as philosophy. There is also peer pressure as an agent of change by which well regarded institutions can influence others. Further once some empirical evidence is accumulated that demonstrates that there are benefits to be obtained accrediting bodies will be encouraged to make provision in their requirements for a broadened engineering curriculum. Finally, on this first challenge, the identification of some metrics by which the benefits can be assessed in time is a task that engineering educationalists should address now.

Regarding the second challenge – how to deliver the liberal arts material in an engineering programme. This question has a parallel with what is sometimes a contentious matter in an engineering faculty, namely should mathematics be taught by engineers to engineers or should mathematics be a subject taught by mathematicians. Happily the evidence is that both approaches can work and depends heavily on the teaching style, interests and enthusiasm of the staff involved. The authors of this article favour a 'have your cake and eat it approach' by first having engineering staff embed in their technical subjects some elements of philosophy, history of engineering and science, and the history of ideas, largely through well chosen examples. And then at a later stage introducing a more formal exposure of the students to philosophy, history, ideas etc by specialists in these fields. The supporting argument for 'embedding' is that engineering is inherently philosophical and also it is natural to include a historical account of engineering developments in presenting topics such as the internal combustion engine, digital computers, jet engine, bridges etc. The argument for later deploying a specialist is that such an approach is best suited to gaining a deeper appreciation of the liberal arts topics and a better facility in using the methods and tools associated with the study of philosophy and history. On this last point, for some it is sufficient to study these areas for no other reason than that they are interesting topics in their own right, but most engineers would be appreciative if the knowledge, insight and skills so gained allowed them to be better citizens of their profession.