General Introduction

Occupational Bildung in Engineering Education

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"*Bildung, i.e. education that goes beyond the needs of the day, and beyond the vocational core, is more than ever necessary in a society that sees itself not only as open, but indeed as accelerating, in that it holds as a credo that there be unlimited mobility, innovation at any price, and chameleon-like flexibility.*" (Mittelstrass 2006: 1)

"It is rare for engineering students … to question everything under heaven or earth in the way that good science students will." (C.P. Snow (1966) 1973: 123)

This book is concerned with Bildung, with engineers and with engineering education. As observed by Jürgen Mittelstrass, Bildung cannot be instrumentalised, it transcends the needs of the day. Bildung represents a fundamentally critical reflection on the relationship between the whole and the part and thus serves to give knowledge orientation as to its function in a world which abounds with information. According to C.P. Snow, there is a lack of this kind of critical reflection in engineering to the detriment of the profession.

In the context of engineering education, this book discusses the fundamental question of how to expand the thinking of engineers beyond instrumental thinking and mere technicalities. Hence, it argues for the need for a new occupational ideal of Bildung for engineers. The purpose of this ideal is twofold: 1) to provide future engineers with better skills in critical reflection and cross-disciplinary collaboration than today and 2) to make engineering more attractive as a profession to students.

In research on engineering, whether carried out by social scientists (McIlwee and Robinson 1992; Copeland and Lewis 2004; Goujon and Hériard-Dubreuil (eds) 2001), by researchers from the humanities (Ferguson 1977; 1993) or by engineers themselves (Florman 1987; 1996, Bucciarelli and Kuhn 1997;

Beder 1998), in governmental reports and in reports from societies of engineers worldwide (The Institutions of Engineers, Australia, 1996; Ministry of Science, Technology and Innovation, Ministry of Education, Confederation of Danish Industries, The Danish Society of Engineers, Denmark (2005), SEFI) in Boards of accreditation for engineering studies (ABET), the need for a broader education of future engineers seems to be fully documented to an extent that it seems justifiable to speak of a general crisis in engineering education calling for "a new engineer". Willingly or unwillingly engineering in the 21st century is standing at a crossroads.

The call for "a new engineer" is backed up by the UNESCO "Declaration on Science and the use of Scientific Knowledge" agreed to at the UNESCO World Conference held in Budapest in 1999 entitled "Science in the Twenty-first Century: A New Commitment". The ensuing declaration stipulates that the education of all young researchers should encompass research ethics as well as the history, the philosophy and the cultural impact of science. As a consequence of the UNESCO Declaration, the Danish Ministry of Education decided from 2004 onward to make courses in Philosophy of science a compulsory part of all degree courses at the bachelor's level in Denmark. Whereas such courses have already been implemented in universities, they are yet to be implemented in engineering studies in other institutions of higher education.

From a cultural change perspective, much research attention has been paid to the engineering culture (Changing the Culture 1996; Copeland and Lewis 2004; McIlwee and Robinson 1992) and the mechanisms through which it integrates its members and maintains its coherence. On the surface, the notion of "engineering culture" seems to be a contradiction since the engineering profession, as opposed to medicine and law, has no common knowledge base. Engineering can thus be divided into a multiplicity of specialities and specialist knowledge domains, each characterized by specific epistemic cultures. In the same vein, engineering practice can equally be divided into a plethora of communities of practitioners, each characterized by specific occupational cultures. Still, it seems justifiable to speak of an overarching, coherent and pervasive engineering culture.

A core idea in trying to identify a culture is to look for its normative foundation. Engineers are supposedly integrated into the engineering culture through their adherence to a set of norms. Thus the engineering culture has been characterized as a culture of "the right answer". A useful elaboration is presented by Leonardi (2003: 102). Leonardi points to a set of characteristics of the engineering culture which he has derived from an extensive literature review, and he furthermore claims to have found, in his own research, empirical support for the relevance of these characteristics. In the first place Leonardi's characteristics can be interpreted as a Weberian ideal type. For our purpose we interpret these characteristics as norms. For Leonardi, the question is not whether the ideal type portrays the reality of the engineering day-to-day practice, "but rather how (it) intersects with the ways engineers interact with others" (Leonardi 2003: 27). In Leonardi's account, the engineering culture consists of five characteristics (norms):

- The Maverick norm
- The Expert norm
- The Macho norm
- The Technophile norm
- The Non-Communicator norm

This normative concept of "being a real engineer" can be seen as quite parallel to the normative concept of "being a real man". Briefly put, the five norms stipulate:

- A real engineer is an individualist, a tinker by nature who works independently (The Maverick norm).
- A real engineer should be in possession of the expertise to know the right answer (The expert norm).
- A real engineer should be dominant, aggressive, and competitive (The Macho norm).
- A real engineer should be dedicated to technology (The Technophile norm).
- A real engineer should communicate with engineers only on essentials and in technical style but with others "less is better" (The Non-Communicator norm).

It should come as no surprise that, to the extent that this ideal type is portraying the traditional norms of acculturation into the engineering profession and the norms of day-to-day practice in engineering, it becomes a problem. Feminist research has in particular focused on its disablement of women. In our perspective this traditional engineering culture can be said to disable both men and women and is in itself a threat to the engineering profession. If and when this ideal type intersects with actual engineering practice, it makes it difficult to cooperate with engineers and makes it difficult for engineers to transcend this culture.

"In the business world, engineers are often seen as being preoccupied with technical issues to the exclusion of all else, unwilling or unable to appreciate contextual imperatives or to contribute effectively to business and political decisions." (The Institution of Engineers, Australia 1996: 54)

In contemporary society, it certainly also makes it difficult to attract students to degree courses that will initiate this culture. Furthermore, as observed in the quote below, the traditional engineering culture may even favour certain personality traits.

"Autistic children and engineers may have a number of strength in common. Both have strong spatial visualisation skills, being able to picture what objects look like in 3D and recognise them from different angles. Both have a strong affinity with physical objects – they enjoy mechanical things. And both are strongly numerate, recognising patterns and order in numbers. But engineers may also share a number of personality traits with autistic children." (Dunn 1996: 14)

As we see it then, the image problems and the negative stereotypes of engineers cannot be explained as a public conspiracy against engineers. They seem to originate in a culture which, in a certain sense, bears strong resemblances to the arcane practice of freemasonry – C.P. Snow speaks of engineers as "the forgotten people" – and which, in its struggle for social respectability, has lost the sense of its historical roots, its philosophical foundation and its public obligations. Historically speaking, the traditional engineering culture was closely linked to the advent of the industrial society. To display an image of engineers as applied scientists was a means to gain social respectability. However the consequence of this strategy was that engineering became too narrowly defined with an almost exclusive focus on engineering science.

In this book we intend to broaden the scope and to contribute to a critical reappraisal of engineering as a noble profession. Occupational Bildung thus includes a strong element of critical self-reflection. This critical self-reflection also comprises the ethical dimension of engineering and technology.

The need for reflection on the Bildung of engineers may be an indication that the context, the activity and the products of engineering are questioned. There seems to be an ambivalence between the inherently positive connotation of words like "progress" and "growth", and the uneasy feelings of many people living in rapidly changing times. "Progress" and "growth" are almost self-evidently and exclusively interpreted as (and reduced to?) "technological progress" and "economic growth" (Van der Pot 1985), and it is debated whether these also automatically imply "human progress" or "human growth". And even if this technological development (as a whole, or in the development of particular new processes or products) is evaluated to be positive, it is not self-evident that individual people or society as a whole can keep up with this evolution. Günther Anders (1956) described man to be (in German) "antiquiert" compared to technology.

To the extent that engineers play a role in technological and economic development (and they undeniably do), the ambivalent feelings about "progress" may affect the image of engineers and engineering. The low visibility of individual engineers and their work (as well in their self-perception as in the external image towards the public, they often appear as mere "parts of the system"), instead of protecting them from being stained by this criticism, seems even to raise more suspicion still.

The concrete forms under which the questions about the engineers' work and role are raised, are ethical discussions. These may have to do either with accidents or deficient products for which engineers are blamed (e.g. on the occasion of product recalls), or with larger tendencies in technological development (e.g. concerning nuclear arms, biogenetics, …), or with some perceived threats or negative evolutions in society as a whole (e.g. the environmental question, or a primitivist longing for "the good old days" – both matters in which technology often serves as a scapegoat on which all blames are concentrated). These questions are raised anyhow, and engineers – willingly or unwillingly – have to deal with them, take a stand and adopt an attitude. Engineers who are conscious of the sense and context of these ethical questionings are better engineers than those having a "narrow", instrumentalistic view of their activity. Hence the importance of a specific awareness of and training in ethics during engineering education.

Could it be a coincidence that one of the first persons for whom the term "engineer" seems appropriate, Leonardo da Vinci (1452-1519), is also known to have exercised some kind of "technology assessment" on some of his projects? Although he knew very well that part of his technological research and design work took place in a military context (which suggests that he had no overruling objections against military technology as such), at least on one occasion he decided that a project had better be stopped. When developing a device for under-water motion, he realised that it could be used as some kind of "weapon of mass destruction", and he considered the scope and the consequences of this development to be too overwhelming for him to take this responsibility (Van der Pot 1985).

Obviously, ethical reflection and technological development are both embedded in and constitutive of a larger culture, with which they are in continuous co-evolution. With the Industrial Revolution, engineering gradually arose as a separate discipline; the codes of ethics of the first engineering associations were often deeply marked by the search for a self-definition of this new occupation or profession. With World War II, it became clear that technology henceforth could no longer be reduced to the mere design and manufacturing of machines or tools. Concentration and extermination camps as well as nuclear weapons were the results of projects in which engineers had played an important role, and which confronted humanity as a whole with ethical questions of an unprecedented scope. Here too, statements of engineering associations had to deal with these developments and with the roles of engineers in it. And in the last decades of the 20th century, environmental problems, the development of ICT, and the political and economic globalisation once more led to questions with which humanity had never had to deal before; here too, engineers had to position themselves in this evolution.

The ambiguous perception of technology and engineering mentioned before comes back in a sharpened version in questions where the mere survival of humanity seems to be at stake. Technology appears as the origin of some of the problems, but simultaneously it is expected to deliver the means of salvation. This is particularly manifest in questions like "sustainable development". Among the multiple aspects of the cultural and societal evolutions having led to the environmental problems, technology is often chosen as the more visible domain to cast the blame upon. Yet, at the same time (again in the middle of other evolutions which may be equally necessary), one also casts one's hopes on the development of new technologies, which should allow a growing population to maintain a decent standard of living in a world with limited resources. Attempts to take hold of the problems (e.g. through the implementation of the "precautionary principle" in the sustainability discourse, as in the Rio Declaration on Environment and Development (1992) or through the introduction of the "Triple P-bottom line" of People-Planet-Profit in management styles) are inevitably ideologically laden, and often debated as to their practical consequences or even their internal logical possibility.

Thus the ideal of occupational Bildung embraces the whole range of individual and collective issues – ethical, philosophical, political, social and economic – the "new engineer" is bound to be confronted with throughout his professional career, and indeed throughout his life as a responsible citizen. It entails that the engineer needs to be equipped with a broader range of skills and competencies than the traditional mastery of science and technicalities, in order to meet the requirements of companies and, above all, of society at large.

This approach proves to be all the more relevant today as the current economic context of global competition has induced a new industrial paradigm (Attwell 1996) comprising:

- new forms of work organisations, in which hierarchical structures tend to flatten out to the benefit of "project teams" who make collective decisions;
- flexible production systems, whereby firms concentrate their activities and resources on their core business so as to be more innovative and responsive;
- "total quality management" procedures, which require each member of staff to be actively engaged in all aspects of the company's life;
- customer orientation, as opposed to product-orientation, which has become a dominant structuring principle for modern firms.

This new organisational pattern is having a considerable effect on the level and range of skills expected of the engineer, as well as on the requirements towards engineering education. As regards skills, Anette Kolmos (2006: 165) notes that, due to fast-changing technologies and constant shifts in the evolution of our society, it is difficult "to predict the knowledge, competencies and skills that will be demanded of tomorrow's engineer". However, there seems to be a general consensus in the current literature on the engineering profession and education that, beside the classical scientific and technological skills, a "socio-cultural approach", in A. Kolmos' terms, is also a core component of the engineer's formation. This approach covers such process skills as teamwork, communication, leadership, project management, learning to learn, lifelong learning, etc. Similarly, Beder contends that "the new engineer will be an engineer who is aware of the social dimensions and context of engineering work and takes responsibility for its consequences" (1998: 308).

What is fairly new in the above-mentioned literature, and indeed among professionals, is the current emphasis laid on "reflective skills". These skills comprise two different concepts: "reflection in action" and "critical reflection". The first concept, developed by D.A. Schön (1983), whereby the engineer is able to analyse a specific problem, to use contextual knowledge and reflect on own experiences, is already familiar to company managers and, to a lesser extent, to engineering educators; here, reflection has an instrumentalistic dimension. The second concept, "critical reflection", is central to the ideal of Bildung, in that it addresses both the contents and the process of the individual's formation. It is an essential foundation on which to construct other engineering skills and transcend them; thus it is a fundamental feature of occupational Bildung.

Engineering education cannot stay away from the profound changes that take place in our global knowledge-based society. Christensen et al. (2006: 11) observe that: *"The changes in the engineering profession and in society in general are paralleled in the conception of skills, competence and Bildung, as these are not fixed concepts, but change in the course of history"*. They point out to the gaps between the theoretical teaching of engineering schools and the engineer's daily professional tasks and needs. Can engineering education fill these gaps? What changes are to be implemented in engineering institutions to respond to these new challenges? What skills and knowledge will be required to shape the new multicultural engineer? This book does not claim to provide all the answers to these questions, even though some proposals are actually put forward in a number of articles; it essentially aims at an in-depth analysis of and reflection on engineering science and the engineering profession, in order to promote the necessary reforms of engineering study programmes in European educational systems.

Besides, engineering education is not the only institution that must contribute to respond to the new demands – let alone future ones – set on the engineer. The company is another key "actor" in the education of the engineer, in that it provides an essential dimension: experience at work. "Deep-seated competence is dependent on a balance between learning for work and learning at work" (Attwell 1996). The workplace has then an essential role to play. Piaget (1970) supports this idea when he argues that learners gain knowledge through a process of personal and co-operative experimentation, questioning and problem solving, through which meaning can be constructed.

Beder (1998: 309) stresses the necessity of a new educational approach to meet the new demands of companies, of engineers themselves and more generally of society. "*It is no longer sufficient, nor even practical, to attempt to cram students full of technical knowledge in the hope that it will enable them to do whatever engineering task is required of them throughout their careers.*" In the same perspective, this collective book advocates the need for a broader, more general approach so that students can acquire not only basic scientific and engineering principles, but can also understand the social context in which they work and reflect on the consequences of their work. Thus, it is through this ideal of occupational Bildung that the new engineer will be able to transform the profession and its image.

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