Engineering Science, Skills, and Bildung

Jens Christensen, Lars Bo Henriksen, Anette Kolmos
Engineering Science, Skills, and Bildung

Jens Christensen, Lars Bo Henriksen, Anette Kolmos, eds.

ISBN 87-7307-765-8

Copyright 2006 The Authors and Aalborg University Press

Printed by: Publizon A/S

Cover: Kommunik and Aalborg University Press

Published by
Aalborg University Press
Niels Jernes Vej 6B
9220 Aalborg Ø
Phone + 45 96357140
Fax + 45 96350076
E-mail: aauf@forlag.aau.dk
http://www.forlag.aau.dk
### Contents

**Preface** .................................................................................................................................. 5

**Chapter 1: Engineering Science, Skills, and Bildung**
Jens Christensen, Lars Bo Henriksen, Anette Kolmos .................................................. 7

**Chapter 2: The Polytechnic Breakthrough in Denmark 1780-1930**
Michael Wagner .............................................................................................................. 21

**Chapter 3: Engineers and Bildung**
Lars Bo Henriksen .......................................................................................................... 43

**Chapter 4: Practical Knowledge**
Jens Christensen ........................................................................................................... 61

**Chapter 5: Paradigmatic Movements in Engineering**
Lars Botin ...................................................................................................................... 83

**Chapter 6: Engineering and Design Skills**
Lise Schröder ............................................................................................................... 105

**Chapter 7: Scientific Bildung for the Post-Normal Epoch**
Tom Børsen Hansen ....................................................................................................... 131

**Chapter 8: Bildung and Identity Development in Engineering Education**
Xiang-Yun Du ............................................................................................................... 147

**Chapter 9: Future Engineering Skills, Knowledge and Identity**
Anette Kolmos ................................................................................................................. 165

**Chapter 10: Master of Science as Change Masters**
Jette E. Holgaard, Pia Bøgelund, Anette Kolmos, Mona Dahms ............. 187

**Chapter 11: Reengineering Engineers**
Steen Hyldgaard, Erik Ernø-Kjølhede ................................................................. 209

**Bibliography** .................................................................................................................. 233
Chapter 9

Future Engineering Skills, Knowledge and Identity

Anette Kolmos

Abstract: What are the requirements engineers are going to meet in the future? We do not know – but we have some predictions based on the technological, scientific, and societal development. Normally, these requirement analyses are based on only the technological and scientific development. In this chapter, this traditional approach will be supplemented with socio-cultural considerations concerning the development of future societies. The point is that it is no longer enough to base development of engineering skills on trends in technological and scientific development– even though this approach in undergoing tremendous change. Engineers have to act and live as persons in a multicultural society where the requirements for global capacity are increasing. In order to be capable of social reproduction and production, the questions of identities become relevant for engineers both at a community level as well as at an individual level. The chapter will end by analyzing if the existing engineering education contributes to the outline of future skills.

Introduction

It is not easy to predict the knowledge, competencies, and skills that will be demanded of tomorrow’s engineers. Tomorrow’s engineers may find themselves in a hierarchical, highly technological global society or in a network-based, local green society. The societal development is constantly shifting and extremely dynamic, and it will present engineers with major challenges in form of new roles and functions in both the international and the local work organization and in terms of continuous development of technological knowledge.

Traditionally, the development of engineering education is closely connected with the understanding of scientific and technological development.
Engineering is closely connected with the production of new goods and the creation of new markets and capital. Of course, there is also a link to society and the responsibility for the impact of technology and ethical issues. However, engineers serving society from a moral purpose is not the norm in education, this point has to be argued.

Because of this very obvious and close relation between the economic-scientific-technological development and the contents of engineering education, these aspects of societal development will form the one axis of the comprehension of future society and competencies. This is the normal way of analyzing future technological knowledge and skills.

However, the question is if this is sufficient for developing tomorrow’s engineer. In this age of globalization, we are facing new challenges—concerning not only the development of knowledge and skills, but also new globalized life forms where the traditional family and social reproduction structures are under tremendous change. Because engineers are the front-runners in the technological development, they are also one of the first professions involved in creating global and work-based life forms. Thus, a socio-cultural dimension will supplement the analysis of future competencies, underpinning that development of individual and cultural identity, self-reflection, and dialogue will be added to the understanding of future technological competencies.

In the end of this chapter, I will develop a model for future engineering skills based on both a scientific-technological and a socio-cultural approach and analyze what kind of approaches engineering education take into consideration. Furthermore, I will discuss whether engineering education lives up to the outline for future engineering skills.

**Scientific-Technological Approach**

There is a parallel between the development in approaches to the relation between scientific and technological knowledge, knowledge production, technological change, and innovation on the one side, and the development in the engineering education on the other side, even though it is— in time- an asymmetric development. The traditional progression in the engineering education begins with 1-2 years of basic science, which mostly consists of mathematics, physics, computer science, or other basic natural science courses. After this, the more technology-related courses in the programme begin, often regarded as a type of applied science. Typical discussions concern how much basic and applied science the students should learn, and
how the basic and the applied sciences should be related to each other. This
may very well soon become an obsolete discussion because innovation and
the development of technological knowledge are to be taken into
consideration.

From a historical point of view, the creation of technological knowledge has
changed character throughout history. Before WWII, technological
knowledge was dominated by the craftsmen traditions along with more
specific discipline-based research. Following WWII, when industry became
seriously oriented towards mass production, a research and development
approach to technology was established. Here the perception of big science
dominated (Jamison, 2001)– i.e., the perception that technological
knowledge builds fundamentally on the natural sciences, which in turn form
the basis for engineering science as a type of applied science (Figure 1).
Engineering knowledge, if it is even reasonable to call it science, therefore
constitutes a natural scientific application. For the engineer during that time
period, the formative ideal was, however, not natural science, but rather a
multidisciplinary approach in which the engineer possessed knowledge of
several technical fields. This traditional view on technology and
technological knowledge dominated up until the 1980’s and influenced the
curriculum traditions that still exist in engineering today. For instance, it is
still relatively widespread practice across Europe that the first two years of
the engineering education are dominated by the basic sciences (mathematics,
physics, and computer science). This perception of basic science also serves
as the foundation for innovation, and there is a clear progression from
science to application.

![Diagram](image)

**Figure 1. Traditional approach to technological change**

In this era, technological knowledge was perceived as universal knowledge
and the innovation process encompassed was considered as linear processes.

During the 1960’s and 1970’s, mass production realized its limits and there
was more focus on innovation, new product discovery, and new markets.
This period is often referred to as the techno-science era when technology
and science were judged as being equal. For the commercial agents of the
technological development, it was irrelevant whether basic science or
applied science was used– focus was on the production of new products. At
the same time, increasing awareness emerged concerning the environmental problems attributed to the technological growth in both the northern and southern regions of Europe. In the course of the 1980s and 1990s, consideration for the end user and their respective cultures began to be evident in the technological innovation process (Figure 2).

During the 1990s, a number of new research fields arose. However, there were also those which spanned across science and engineering such as genetic engineering, which is neither a technology nor a basic science (Jamison, 2001)—but rather a development of new areas of knowledge spanning across traditional boundaries.

The techno-scientific approach is very similar to the notion of mode 2-knowledge. Nowotny, Scott, and Gibbons (2001) argue for a mode 2-society parallel to the concept of mode 2-knowledge where we will find a much more dynamic society and a very complex mix of drivers behind innovation and economic development. Like the techno-scientific approach, the mode 2-concept do not argue for a rigor logic between science and technology, but rather for the establishment of new interdisciplinary areas where it can be difficult to draw the line between science as basic science and engineering as applied science.

One dimension of this type of society can be interpreted as a knowledge society. They argue that the growth of complexity and uncertainty are linked phenomena, and there is a decreasing belief in the cause-effect relationship. The relation between science and society has changed radically— it is no longer “science speaking” to society, but rather a notion of “society speaking to science”, which means that science has somehow become contextualized.
Especially green technologies are context-dependent, but there are still knowledge areas that are not contextualized as, e.g. physics, etc.

Knowledge production no longer takes place only at universities, but at a range of institutions in society—both private and public institutions. There is a growth in the establishment of corporate universities, which are new institutions funded by universities and companies. In many countries, the traditional university and college system has been reorganized so that colleges now have the possibility for research.

**Technological Knowledge**

For techno-science, two critical issues exist in the development of skills: firstly, the interdisciplinary or transdisciplinary cooperation between different engineering sciences is a MUST, where those involved are required to participate in complex, innovative developmental processes. Secondly, culture and context play a more central role, and so the development of skills was to relate technological knowledge to society. This new development is a form of contextualized technological development, which has become important on a much larger scale, particularly concerning 'green' technology and the environment where local solutions are often sought.

The related understanding of production of knowledge is consequently based on a mode 2-form (Gibbons et al., 1994), which represents a flexible and dynamic form of knowledge; in the techno-scientific paradigm, the contextualized approach weight culture, organization, values, and social relationships, extending far beyond typical environmental risk-analysis technology. These tendencies within innovation consequently also demand that the engineer as an actor in the technological development must be capable of relating his/her own knowledge to other areas of knowledge.

Technological knowledge exists between the universal knowledge and its context, rendering it just as important that engineers are able to analyze the context in order to find the optimal solution for the context. Therefore, demands for analytical problem analysis and solving, creativity and interdisciplinary arose, such as those required for undertaking new combinations of existing knowledge in relation to new fields of application. At the very least, this requires that people possess knowledge across the areas of basic and applied sciences, and even broader, across the typical distributions of knowledge: knowing ‘that’, ‘how’, and ‘who’ (figure 3). This conception of knowledge weights the context as an equal part in the development of knowledge (Jarvis, 2001).
These three forms of knowledge interact in innovation and in the development of technological knowledge. This notion of knowledge is broader compared with the basic/applied science dimensions in that the practical and social dimensions are incorporated and, thus, represent interdisciplinary knowledge. These three forms of knowledge differ from each other and each in turn lead to different learning methods. Knowledge concerning ‘how’ and ‘who’ cannot be learned through intellectual learning—this is the type of knowledge that is learned through practice and includes elements of tacit knowledge (Jarvis, 2001). And exactly due to the fact that this is a case of learning in practice, these forms of knowledge blend in with the concept of competence, which entails the ability to implement in practice.

Knowledge Society

At the political level, there are great concerns for future academic labour force. During the 90s, globalization as an economic term for market forces arrives at the political arena. When industrial jobs move east or south, the north and west have to change strategies for production, innovation, and knowledge creation.

The European political system has responded to the dramatic changes taking place by creating a knowledge society. The European Commission (EC) formulated ideas of a European Knowledge Society as an answer to the issue of industrial production moving to areas where production is cheaper than in Europe. The European wealth will have to come from design, creativity, innovation, and the creation of new markets (Knight 2003), and most private and public institutions have to become learning organizations in order to develop their human capital (Nowotny et al., 2001).
There will be a need for highly educated people who are able to establish new products and markets. Valued knowledge will be future-oriented creative and innovative knowledge, self-developing and active, ranging across traditional disciplinary boundaries in order to create new products (Bourgeois, 2002; Knight, 2003).

There will be a demand for more high-level job qualifications with both very advanced knowledge in special areas, and also more generic knowledge to bridge the gaps between a growing numbers of specialists. Consequently, there will be more focus on educating young people to science and engineering.

Science and technology are basic elements of the knowledge society that are needed in order to be innovative in creating new types of products. There is an expectation of not only creating products within the limits of exiting scientific and technological knowledge, but of creating fundamental technologies that will develop the societal values and quality of human life. There are great expectations to new energy systems such as wave energy, hydrogen, nanotechnology, etc. Many new knowledge areas are created across disciplines– the problem right now is the recruitment of young researchers and, at a more basic level, the recruitment of students to engineering and science. Already now, we have reached a situation where there is a decrease in the number of young people studying science and engineering. Recruitment is on the political agenda not only in Europe but also in America.

Lifelong learning in order to update the ageing population can be one type of answer– as least the society can no longer afford not updating the labour force at 50 or above. Another type of answer will be to recruit young people from outside of Europe or from the pool of immigrants coming to Europe. This will entail an increased need for intercultural learning and globalization on a cultural level. (European Commission 2001, European Commission 2003, Knight 2003).

Socio-cultural Identity

In the notion of a mode 2-society, Nowotny et al. (2001) emphasize the existence of two axes: the first is the scientific-technical and economic that underpins the production. The other axis is the socio-cultural aspect of societal development. When discussing the shape of future human capital, there is a tendency to highlight the economic and technology determinism
and ignore the socio-cultural dimension. Theories in these two axes may contradict each other as regards the comprehension of societal forces—whereas the first set of theories emphasize structures and systems, the second axis emphasizes actors, cultures, and socially constructed meaningfulness. Nevertheless, both approaches have formulated trends for future competencies.

Among the representatives for the socio-cultural dimension are Giddens, Beck, and Wenger—all with very different theoretical, complex approaches, but pointing out some of the same trends for the future society: the importance of identity and meaning. The late period of modernism means that institutional traditions no longer are inherited and no longer determine the individual’s behaviour. With the growing globalization, institutions will be disassembled and new institutions will be established. Both Beck (1992) and Giddens (1991) regard the society as a risk society. Beck with a more gloomy view of society than Giddens; however, Beck manages by his concept to emphasize the challenges in the desynchronic rifts among societal institutions. He points out social risks, especially the dissolution of the family institutions as women have entered the labour market. He also underpins intellectual risks in a growing scepticism towards science since science and knowledge will be questioned as truth and a increasing pluralism will emerge.

When social institutions change, individuals have to redefine their own identity both at the individual and the organizational level. Giddens (1991) defines the late modern humans as reflexive individuals who are able to relate to both their selves and their surroundings. The individual has to acquire new knowledge, apply the knowledge, and create new experiences and actions. The reflexive project consists of the individual constantly having to use and produce knowledge and experiences. In this way, the individual creates his own narrative stories—his own traditions within new social frameworks.

The questions of self-identity and identity work are on the agenda for individuals. When social institutions as families are disassembled and reconstructed at a global level, close relationships between individuals might become rare. Instead, the individual has to construct, deconstruct, and reconstruct social relationships at and in very different settings and groups. Lave and Wenger (1991) have developed a concept to capture this development of belonging to different groups, emphasizing the identity work contained in working practically together—sharing practice and experiences. Their hypothesis is that learning is situated and contextualised and is determined by the communities of practices one might participate in. People can participate in several communities of practices, but learning really takes
place when participation is no longer peripheral, but at the very complex core.

Wenger (1998) has continued this work by developing a social theory of learning. He points to four elements that influence learning: community, practice, meaning, and identity. All components are important to individuals’ self-reflection—community as the group one belongs to, practice as what one does together with others, meaning as the experiences that are created and give individuals an inner understanding, and identity “a way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities” (Wenger, 1998:5).

In a globalized age, with market forces driving towards more and more globalized collaboration among companies, national states, and human beings, there will be many different communities of practice for engineers. For engineering knowledge production will become more and more complex by being created at very different institutions, at the same time universal and context dependent, and by providing multicultural memberships. Consequently, engineering will require a very strong individual identity as an engineer who is able to work independently, shift communities of practices, and work closely together in different communities of practices. New life forms will be needed for the future to support the conditions in work life.

Professional Identity

This involves a strong ability to work and develop identity at both an individual and a professional level. Identity can be interpreted at different levels:

- as a self-reference for the individual in order to understand own history and interpret and reinterpret the self in relation to surroundings, or
- at a community level for groups of individuals in order to profile and develop. Especially in engineering, the group identity is very strong. Like medicine and law, engineering is a profession which entails that all over the world there are very well-organized bodies for the profession, as well as organizations for the development of engineering education.

What is characteristic of professions is that there is a close link between the professional body and the education. In order to become member of the professional body, you are required to have achieved a degree from a recognized educational institution. The classical understanding of
profession-based education is that the profession and education share common knowledge and values between. A more modern understanding is that professions today might defend special knowledge and values, and, further, the professions individually have to profile themselves as a relevant institution together with defending their societal power position (Nylehn and Stokken, 2002).

For profession-based educations such as engineering it might be a great advantage for the students to have a clearly profiled community to relate to in their identity work. There are organizational bodies where they can reflect engineering practice and development. However, the disadvantages might be that the engineering society develops a common identity more slowly than the individual engineer has to because of work and social situation. So there is still a need for future engineers to be capable of conducting their own personal identity work and have the ability to shape relevant life forms.

Educational Research

The question is who is responsible for developing capabilities of identity work? Is this a task for Higher Education— in this case, engineering education— or is it the students’ own responsibility to learn?

Bowden and Marton (1998) formulate it like this: “Conceptualized in this way the university is not primarily about the reproduction of the collective mind (i.e. the complex of all the different ways in which we are capable of thinking about the world), but is about expanding, widening and transforming the collective mind. The Humboldtian concept of Bildung refers to the process of self-formation that is how individuals form and transform themselves. In analogy with this, the university is the most vital instrument in the process by which the collective mind is formed and transformed through its diverse ways of grasping the world.” (Bowden and Marton 1998:5).

Originally, the concept of Bildung was formulated by German philosophers like Hegel and Kant. At that time, it was a concept combining knowledge, spirit, and socialization (Klafki 2001). Today it is an ambiguous concept that covers both contents and process- contents in the sense that there is a direction for the Bildung, and process in the sense that individuals have to grow through their inner resources and by social cultivation. In order to behave and act in society, individuals must have certain abilities and values and know the reasons for societal patterns. Bildung concerns the education of humans so that they can be able to take over the development of core
social values, for instance, ethical, moral, social, political, economical, and global values.

Barnett (1994) does not use the word Bildung, but would agree in the above notion. Barnett is concerned about the development of Higher Education in Britain because the tendency in Higher Education is to have all objectives clearly stated and formulated as outcomes and competencies. He does not want to defend the traditional system, but is concerned that the new trends will lead to a much more instrumental and short-sighted learning. He finds that many institutions formulate competencies as operational competencies as the alternative to the traditional academic competence. Thus, he has formulated a third direction, life-world becoming, based on inspiration from Habermas, which can form the basis for a new vision for higher education and which is beyond competence.

The life-world becoming may form a basis for visions. The concept of knowing moves focus from knowledge as a structural concept to knowing as an inner human aspect. Knowing is the internal subjective process of individuals’ cognition and reflective knowing is the capability to relate the inner knowing to its roots, origins, context, implication, and impact and thus make use of all kinds of knowledge (knowledge why, that, how, and who).

The notion of life-world becoming is in line with the socio-cultural dimension and, as such, the concept Bildung as there is an emphasis on shaping reflective individuals capable of reflective knowing.

Barnett (1994) see common pattern in the operational and academic competencies as the students have to learn (individual) external defined becoming– for the operational competence, the students have to learn the “standards”, and for the academic competence, the students have to learn the discipline. “In contrast, the suggestion made here is that we should think of the process of higher education as involving quite a different kind of becoming. Instead of asking the students to respond to and to fulfil the demands of standards externally present, higher education should be conceived as a process of fulfilling internal demands.” (Barnett 1994: 191)

Barnett stresses the meaningfulness of learning and the inner process as a process of self-construction and self-reflection. This approach is in line with the socio-cultural aspect that the shaping of the inner self is getting more and more important in society and that it is also an important task for higher education. Schön (1983) argues that reflection is the key link between knowledge and practice. The reflective practitioner is a person who is capable of analyzing situations, choose and use relevant knowledge and reflect on own experiences. To be able to do this, reflection has to be
learned, and an integrative part of reflection is self-reflection, that one is able to manage an inner world of reflection in the same way, since creativity is closely connected to inner resources and energies.

Learning, therefore, becomes facilitation of the individuals’ understanding of inner resources as well as facilitation of the external scientific and technological knowledge.

Future Engineering Skills

Bildung, competence, and skills are not rigorous concepts. Their meaning will be dependent on the context: the history, society, culture, theories, and values. And the borders between these concepts can be very hard to figure out. However, regardless of these definitions, the previous analysis points out certain areas as being important parts of future engineering skills.

The scientific-technological approach points out the requirement for scientific-technological skills as well as process skills. The scientific-technological skills cover capabilities of problem/situation analysis, problem/situation-solving, interdisciplinary and contextual knowledge. This aspect involves an emphasis on scientific and technological methods that can be applied in analyzing and solving new problems/situation.

Together with the notion of a knowledge society, the scientific-technological approach underpins the need for lifelong learning and individuals’ capabilities to be able to update their own learning, which becomes an important professional skill.

This approach also points out the need for process skills such as cooperation, teamwork, communication, intercultural cooperation and communication, organizational understanding, and project management. Furthermore, the notion of a knowledge society emphasizes innovation and creativity as important elements for developing the society in new directions.

In relation to engineering education, these skills have previously been formulated. What is actually new is that the socio-cultural approach including educational research adds identity work and self-reflection. This becomes more and more important both in relation to cooperation where it is necessary to know oneself before one can relate to others, but also as a social human being in society where it will become more and more important to be able to handle social risks and develop one’s own identity.
Figure 5. Engineering skills.

These areas of the development of skills reflect the concepts developed by Popp Troelsen (2000). She defines the nature of skills (in Danish: kompetence) as a broad notion of the fulfilment of the range of professional and human requirements that the individual meets and has to deal with in an appropriate manner. The notion of skills encompasses three aspects:

- **Comprehension:** the ability to analyze and understand a given situation and not at least to compare it with other relations and oneself. This dimension includes context.
- **Mastery:** the qualifications to master a given situation.
- **Action:** the ability to take action when there is a complex comprehension and the skills to mastering the situation.

Popp Troelsen (2000:114) formulates four core skills for science education: learning and knowledge, collaboration, change, and identity. These four areas correspond to the conclusion that can be drawn from the previous argumentation.

Also Elstrøm (1997) emphasizes in his concept of skills (in Danish: kompetence) the individuals’ potential for analyzing and solving new unknown problems, involving elements of transfer from known knowledge
areas to new and unforeseen situations. Skills therefore include a potential of tacit knowledge that can be brought into action in certain cases.

The above-mentioned skills are inclusive and integrated in their nature, meaning that both innovation and creativity and also identify work and self-reflection can be part of the scientific-technological skills and the process skills, but by pointing them out, they become more visible, which might be needed for future development of engineering education. The questions are if engineering education focuses on these aspects, and how one integrates these skills in the engineering education curriculum?

Objectives for Engineering Education

If engineering education should be properly analyzed, it is necessary not only to focus on formal objectives and outcomes, but on the more specific curriculum level with both contents objectives and the applied learning methods. However, this would be a rather extensive study. Therefore, I have chosen only to look at the very top-level to investigate if there would be any indications of the engineering skills that are formulated? I have chosen to look at American (ABET-criteria) and Danish (Ministry order) education.

As a representative for the American educational system, the ABET-criteria are the most obvious to look at. These criteria were reformulated anew in 2000 with emphasis on more student-centred learning. Furthermore, the criteria are formulated as programme outcomes that engineering educations have to fulfil if they want to get an ABET-certification. Of special interest is criterion three.

Glancing at the third ABET-criterion, it is obvious that there are no outcomes in the areas of innovation, creativity, and identity work. There is of course a strong emphasis on the scientific and technological aspects as well as on process skills, so there are elements of Bildung. Analyzing the criteria in relation to Barnett (1994), there is a tendency to underpinning the operational competency more than life-world becoming.
Criterion 3. Program Outcomes and Assessment

Applied science programs must demonstrate that graduates have:

(a) an ability to apply knowledge of mathematics, science, and applied sciences
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to formulate or design a system, process or program to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify and solve applied science problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern scientific and technical tools necessary for professional practice.

ABET: http://www.abet.org/

Shuman et al. (2005) interpret the development in the ABET-criteria as a strong development of the professional skills, which is a term covering awareness and process skills. Awareness skills cover 3h, 3i, and 3j and are defined by the awareness of the impact of technology, whereas process skills include 3d, 3f, and 3g and are defined by the capability to bring knowledge into action. It is not any obvious categorization since, e.g. an understanding of professional and ethical responsibility normally would be regarded as awareness more than process, and lifelong learning normally would be regarded as a process skill. However, the above categorization does have a point as ethics has to be taught and learned so that engineering students can take action.
Objectives of the B.Eng. programme:
- to qualify the students to handle professional functions, nationally as well as internationally, in which they must:
1. convert the results of technical research as well as scientific and technical knowledge into practical applications, both in connection with R&D projects and when solving technical problems,
2. acquire new knowledge in a judicious manner within relevant areas of engineering,
3. independently solve common engineering tasks,
4. plan, realize, and manage technical and technological plants, i.e. tasks which include the ability to take into account social, economic, and environmental consequences, including consequences for the working environment, in connection with the solution of technical problems,
5. enter into cooperative and managerial functions and relationships at a professional level with people with different educational, linguistic and cultural backgrounds.

Translated by Aalborg University, Faculty of Technology and Science, http://auaw2.aua.auc.dk/fak-tekn/english/framework.pdf

Analyzing the objectives for the Danish engineering education does not leave one with the impression that it is more oriented towards innovation, creativity, and identity work; however, there are elements of social responsibility, interdisciplinary knowledge, and process skills.

Of course, we cannot answer these questions just by superficially analyzing the criteria and objectives as the way these outcomes are learned and taught might have substantial influence on the learning outcome. Felder and Brent (2003) point out educational systems where it is possible to handle all aspects of these new ABET-criteria. The educational systems mentioned are Problem Based Learning and Cooperative Learning system.

Characteristic of these educational systems is that students are motivated to make choices of their own by choosing problems to work with or to argue in teams. Students’ choices in their own learning process raise questions such as why, what, where, what if- and students reflect on their own interest in the subject and might get more motivated to learn.
Self-reflection and identity work in a technological context include one’s ability to relate oneself to history and one’s position in society. As such, the social and societal awareness is present in the ABET-criteria and in the Danish objectives, both in the awareness skills and in the process skills as they necessary have to include a self-reflection in order to understand the relation to other. However, these subjects can be taught in a very teacher-centred way related to external premises instead of internal reflective premises. Only the exact curriculum will reveal the learning outcome and as such the critical and self-reflective part could have been stressed more.

The present formulation might have been modernized and been more in accordance with the techno-scientific understanding of knowledge production and innovation; however, the criteria are mainly formulated on the basis of a scientific and technological regime and, obviously, not on a sociocultural approach.

Perspectives

The original intention with this article was to review literature on the evaluation of problem-based and project-based learning (PBL). After collecting material, I did not know how to analyze these evaluations. Most of the evaluations show that educational systems and students’ learning had improved by utilizing PBL methods, especially the learning environment and motivation for learning. However, the dimension of knowledge seems to be more or less the same—only small improvements can be documented.

When I started to write, I became more and more frustrated, because it seemed that most of the evaluations try to justify PBL in relation to traditional approaches to knowledge and learning. The evaluations did not take into account that PBL is more than a learning method— it is a learning method that only works effectively when it is in alignment with the rest of the educational system. PBL is not an element in the curriculum; PBL is a system that leads to new types of knowledge and skills where the students learn skills from the learning methods they use. Therefore, the platform for an evaluation of PBL should take the goals and philosophy of PBL into consideration, and this lead me to start reflecting on the understanding of future engineering skills.

I think I have offered some basic answers to this question. The traditional engineering education might correspond to the traditional scientific-technological understanding of knowledge; however, societal development caused a need for a new knowledge concept such as knowledge that, how,
and who. The concept of knowledge has become far more complex and, thus, the requirement for future engineering skills will change.

But there is more to it—normally, we define engineering skills on the basis of scientific and technological development. However, the sociocultural dimension becomes more important as globalization and the requirement for full-time flexible engineers increase. Engineers have to be able to cope with the establishment of new life forms and the construction of new identities on both a professional and an individual level.

Looking at engineering education, it is closely connected to a rational scientific-technological paradigm, and the described outcomes and objectives in both the American and Danish engineering educations seem to be a reduction of rationalism within the technological-scientific-economic paradigm. Both the American and Danish engineering educations seem to be on their way towards a techno-science paradigm within the scientific and technological approach—but they have not fully moved there yet. The socio-cultural perspective, however, is missing, and there seems to be no room for students’ doubt, creation of identity, and development of self-reflection. Today’s students have an increasing interest in learning about oneself in order to be ready to function in this very chaotic and complex society. Therefore, the socio-cultural aspect is important to take into consideration for future skills—and room for identity work could be one incentive that could render science and engineering more attractive to women.

From educational research we also learned that reflective knowing, identity, and dialogue are very important elements in life-world becoming or Bildung. Thus, these aspect have to be formulated at a skills level where the learner has to both understand, master, and be able to take action. In a changing world, the ability to master technological knowledge that changes fast depends on engineers’ capabilities to adapt knowledge to context and create their own life forms and life stories.

Creation of life stories and identity work in a technological context might be essential for engineers in order to be able to analyze the impact of technology on other people’s lives. Personal experiences that have been reflected upon in relation to the broader context might give a deeper understanding of the real impact of technology on everyday life, environment, politics, and economy.

From educational research we also learned that both contents and methods are important, and that a deeper analysis of objectives and outcomes has to include both the contents and the learning methods at all levels in a curriculum.
Basically, engineering education has been contents-driven and process skills are a relatively new notion. Especially during the 80’s, a growing awareness that engineers have to act on an interdisciplinary arena and cooperate with other people emerged. Thus, process skills became- and are- important in order to manage technological knowledge. At the same time, there is now a growing awareness that learning methods can be used as a means to achieve process skills, and that engineering education as a whole has to change from a very teacher-centred system to a more student-centred system.

Fragmented educational strategies may lead to fragmented development of skills– therefore, it is important that we approach engineering education as a holistic system. With that approach, it might be possible to meet future demands for skills in very diverse directions, ranging from scientific contents to cooperation and self-reflection, and this conclusion leads us to take a closer look at the efficiency of PBL as a learning system. However, the criteria for assessing PBL should be based on a techno-science notion including technological knowledge and life-world becoming and, at the skills level, encompass both technological contents skills as well as process skills.

References


Ellström, P. (1997) Kompetens, utbildning och lärende i arbetslivet: problem, begrepp och teoretiska perspektiv (Skills, education and learning in
Future Engineering Skills, Knowledge and Identity

working life: Problem, concept and theoretical considerations). Stockholm, Publica Norstedts Juridik AB.


European Commission. The Role of the Universities in the Europe of Knowledge COM, final 05.02, 2003.


