

# **THE CHALLENGE OF CONCEIVING: APPROACHES TO PROBLEM IDENTIFICATION AND FRAMING**

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## **ABSTRACT**

One of the big challenges in the CDIO approach to engineering education is the first part focusing on conceiving problems to be handled and eventually solved. Traditional engineering education has been dominated by its focus on technical disciplines emphasising their individual tool box of problem solving and optimization methods. Going back to the earlier days of engineering education problems were defined through the repertoire of existing technologies and solutions taken up and handled as given cases in the education. With the growing emphasis on scientific methods leading to a continued change in engineering disciplines throughout the mid 20th century the focus changed and problems were defined in more theoretical terms. Engineering education remained dominated by its introduction of a more and more dense repertoire of methods and theoretical models.

In this paper we will approach this problem from the perspective of engineering design challenges where the need for problem identification is obvious to avoid the pitfall to reproduce and piecemeal engineer already existing product or service concepts. Problem identification is not a simple desk research task as it often involves a multitude of actors having different or even not very well established ideas of what might be a good design result.

We present two mutually supportive approaches to problem identification that we have developed, applied and refined. The first is providing an approach to map the arenas of development that influence the context of materials, visions and actors providing the basis for analysing problems related to a design task. The second is providing an approach to the co-evolution of problem space and solution space into a matching pair, which constitutes a good starting point for synthesising design concepts. The two approaches have a solid grounding in existing theories of the socio-technical nature of engineering and the process of synthesising solution spaces in engineering design.

## **KEYWORDS**

Conceiving, problem identification, development arena, conceptualisation.

## **INTRODUCTION**

One of the big challenges in the CDIO approach to engineering education is how problems are conceived. Though 'conceiving' seemingly constitutes the first of four components in the CDIO concept: Conceive, Design, Implement and Operate, this element is not given much attention in

the standards and syllabus of CDIO in practice. It is as if this element at the end is not too much of a concern for engineering training which is contradictory to the literature on the anticipated character of engineering problems often identified as open and wicked. Also in the CDIO concept problem identification seem to be given a backstage position compared to the methods and theories used to handle and solve problems in the view of engineering disciplines. Traditional engineering education has been dominated by its focus on technical disciplines emphasising their individual tool box of problem solving and optimization methods. Going back to the earlier days of engineering education problems were defined through the repertoire of existing technologies and solutions taken up and handled as given cases in the education. With the growing emphasis on scientific methods leading to a continued change in engineering disciplines throughout the mid 20th century the focus changed and problems were defined in more theoretical terms. Engineering education remained dominated by its introduction of a more and more dense repertoire of methods and theoretical models.

In this paper we will approach this problem from the perspective of engineering design challenges where the need for problem identification is obvious to avoid the pitfall to reproduce and piecemeal engineer already existing product or service concepts. In many engineering design courses the specifications of a new product already seem to imply a certain concept and solution space, though often these specifications may be contradictory and open for returning to the more basic question of what are the problems in the minds of involved actors that an intended design should solve?

Problem identification is not in all situations implicitly given by the practice domains of engineering though they provide a framework in which known concepts and solutions can be reproduced thereby simplifying engineering practices. It is also not a simple desk research task as it often involves a multitude of actors having different and sometimes not very well established ideas of what might be a good design result. With the complexity of engineering problems also within a given domain may ask for re-considerations of what problems are involved and thereby opening for a much wider solution space even inside a company with well established product portfolios.

Without claiming that we have the solution to all facets of the problem conception phase of engineering design we present in this article two approaches to problem identification we have developed, applied and refined. The first is providing an approach to map the arenas of development that influence the context of materials, visions and actors providing the basis for analysing problems related to a design task. The second is providing an approach to the co-evolution of problem space and solution space into a matching pair, which constitutes a good starting point for synthesising design concepts. The two approaches have a solid grounding in existing theories of the socio-technical nature of engineering and the process of synthesising solution spaces in engineering design.

## **CONCEIVING AS PROBLEM IDENTIFICATION**

This problem of how problem identification and conceiving problems in the terminology of CDIO has been downplayed in engineering education has been taken up by e.g. Downey [1] emphasising the need for engineering training to focus much more on problem identification to sustain engineering as an innovative and creative profession. While this might be considered obvious from the point of view in attempts to characterize engineering problems as open ended and 'wicked', only few analytical texts deal with this phase of engineering activities. The activities involved in problem identification seem to be black-boxed in either established technical

concepts or solutions implicitly reflecting the problems solved or to be left to creativity and ideation often seen as outside the realm of engineering science. Even in the very comprehensive book of Vincenti [2] which puts emphasis on the role of designs and problem analysis there is a tendency to take both the character of engineering problems and the division of labour among engineers as a given. Vincenti presents a typology of phases or elements that engineering practice comprise of where design concepts are provided from the field of practice.

That engineering design concepts can be taken for granted as a pre-given repertoire may be the case for very established fields of technology and operational in large engineering corporation working in well established product areas, but even here the challenges of 'wicked' problems shows, demonstrating that even seemingly well known problems can turn out to be challenging and need careful analysis and deconstruction not taking the problem for granted and just applying known methods and designs. This comes from a basic experience that many engineering problems have elements that challenge existing designs and operate at the limits of existing and well established knowledge [3].

In a longer historic perspective some basic engineering solutions may have occupied a large part of what constituted engineering work, but the movement toward a science base was concurrent with a massive post-war expansion of government-funded research in the United States expected to result in many new technological solutions. Sponsorship of fundamental studies in a variety of areas supported the trend away from practice-oriented research and education. Successes in fields such as high-speed aerodynamics, semiconductor electronics, and computing confirmed that physics and mathematics, conducted in a laboratory-based environment, could open new technological frontiers. Military research during these years also tended to focus on performance – increased power, higher altitudes, more speed – goals that were conducive to scientific approaches. They at the same time emphasized improvement in existing design concepts, but they also asked for new ideas and solutions resulting from a multitude of new problems and challenges to engineering.

Electrical engineering, for example, no longer focused on electric power and rotating machinery, but instead, on electronics, communications theory, and computing machines. As historian Bruce Seely [4] wrote:

*Theoretical studies counted for much more than practice-oriented testing projects; published papers and grants replaced patents and industrial experience as measures of good faculty. By the mid-1960s, the transition to an analytical and more scientific style was largely completed at most American engineering colleges.*

Yet today, many engineering departments still have their core activities defined by technical disciplines, such as mechanics, energy systems, electronics, chemistry, building construction, or sanitary and civil engineering. Many of these disciplines have specific problems and industries that relate to their founding years, but as the demand for science-based research and teaching became prominent, the original roots to practice and industry lost their significance. With the changing demands, more abstract courses, and courses defined by scientific fields, were developed. This process may have been supportive of focusing on theories and science as the new omnipotent problem solving toolkit supporting the view that engineering problems were identified within the realm of scientific activities. A position obviously contested by new problems arising from the complexity of technological systems, environmental impacts and social reactions to technology.

The post-war decades saw the rise of systems engineering and thinking as broadly applicable engineering tools [5]. Systems sciences that include control theory, systems theory, systems engineering, operations research, systems dynamics, cybernetics and others led engineers to concentrate on building analytical models of small-scale and large-scale systems, often making use of the new tools provided by digital computers and simulations [6,7]. Techniques range from practical managerial tools, such as systems engineering, to technical formalisms, such as control theory, to more mathematical formulations, such as operations research. A broad-based movement within engineering found that these tools might finally provide the theoretical basis for all engineering that goes beyond the basic principles provided by the natural sciences. Whereas systems engineering of the 1950s could be narrowly analytical and hierarchically organized, new ideas of systems in the 1980s and 1990s focused on the relationship between technology and its social and industrial context. This new relationship and understanding of the natural and technical sciences is reflected in the notion that engineering as techno-science developed in the field of sociological studies of science and technology to reflect the new intimate relationship between these fields of science [8].

From within the technical universities, voices were raised against the consequences of a too-narrow focus on science-based teaching that lacked interest in the practical aspects of engineering work and competence [9]. Educational programs focusing on project work and problem-based learning, introduced in some experimental engineering education programs during the 1970s, spread broadly during the 1990s. They attempted to address the problems from a pedagogical and didactic point of view. In both Denmark and Germany, a few radical reform universities made project-oriented study the trademark of their education, stating that the projects could both cater to the interdisciplinary aspects of engineering methods and problem solving, and to the integration of the practical and theoretical elements needed in engineering [10].

One response to the complexity of engineering practice has been reflected in the general pedagogical reform based on project-oriented work. Project activities are also argued to provide students with a broad understanding of engineering work and problem solving, with less emphasis on theoretical knowledge represented in the courses and disciplines which is also found in e.g. the CDIO initiative [11]. In a less radical manner many engineering schools have tried to add certain new personal skills to their requirements and curriculum by complementing the natural and technical science teaching with training in communication skills, group work, and project management. These are competences that are implied in the project-oriented model and in the less demanding problem-based learning model.

The description of an engineer's contemporary competencies might include the following: 'scientific base of engineering knowledge', 'problem-solving capabilities', and the 'adapt knowledge to new types of problems'. The focus is more often on problem solving, and less on problem identification and definition [1]. This is ideally taken up in the CDIO standard as conceiving, but not explicated were much in the latter detailed curriculum plans presented [11]. This focus emphasizes the problem of engineering identity in distinguishing between engineers as creators and designers versus analysts and scientists raising question about the foundation of synthesis knowledge and design skills. The underlying assumption in most training given by engineering schools on engineering problem solving is that engineers are working with well-defined technical problems and methods from an existing number of engineering disciplines. This assumption does not answer the question as to whether engineers are competent in handling the social implication of complex technologies, and the even non-standardized social and technical processes where the problems are undefined and involve new ways of combining knowledge.

In this relation the limitations to engineering sciences and their models become a crucial part as does the understanding of technologies as hybrid constructs building on several both disciplinary and practice based knowledge components and embedding assumptions of use and social relations related to specific localities and historical settings even though these may become part of standardized socio-technical ensemble [12]. The other crucial aspect for engineering technology of the future is the handling of design challenges coming from the even more dominant role of technology in society and for the environment.

## **DESIGN & INNOVATION AT DTU**

Since 2002, the Technical University of Denmark (DTU) has offered a new engineering education in design & innovation. This new bachelor and master program of 3 plus 2 years length represents a fundamental rethinking in engineering education. With an enrolment of 60 new students per year and twice as many qualified applicants, this new initiative is considered as a success by DTU. The new curriculum is targeted to meet the demands for competences from industry and society in the context of globalization and new cooperation structures in product development and innovation. The design & innovation education contributes to the renewal of the educational profile of DTU and is regarded as one of the recent major successful strategic developments.

Within this program several course activities focus on the process of problem identification as the important first step in working with design tasks. We will illustrate the process of problem identification from the experiences in two different courses: 'Scenarios and concepts' held in the 6<sup>th</sup> semester in parallel to the students' bachelor projects, and in 'Conceptualization' given to master students both in design engineering and in mechanical engineering. In 'Scenarios and Concepts' two approaches are core and taught in an integrated manner as the students apply the approaches on their bachelor projects. The course has been running 6 years with approximately a total of 360 students having followed it giving a rich material from the student assignments to be used as empirical material to justify and illustrate the approaches. We use this case to demonstrate that there are theoretically grounded methods and tools available that can support the students work within the process of 'problem identification' or in the terminology of CDIO in the process of 'conceiving'.

## **ARENAS OF DEVELOPMENT**

The dominant role of technology demands multidisciplinary approaches, and challenge the science-based, rational models and problem-solving approaches. The 'arenas of development' approach is such a multidisciplinary approach having its theoretical grounding in the sociology of technology but emphasizing the role of material objects as well as social for the understanding and mapping of actors engaged in idea generation and innovation [13]. Arenas of development operate in this context of engineering problem identification as a tool to be used to map the actors and the object operating and configuring this space of change. It must cater for both the already existing solutions and configurations that sustain given concepts and solutions but also for the fluid and still open-ended and performance driven initiatives for renewal. As such it represents an initial step into the design process.

Innovation has been studied from within a number of different disciplines, and several aspects may have been caught in these approaches. Experiences demonstrate, however, that

developing new technologies involves a number of very dissimilar processes held together by various linkages and inter-dependencies. This has resulted in a definition of an arena of development being a characterized and delimited as a space holding together the settings and relations that comprise the context for product or process development that includes:

- *a number of elements such as actors, artefacts, and standards that populate the arena,*
- *a variety of locations for action, knowledge and visions that define the changes of this space, and*
- *a set of translations that has shaped and played out the stabilisation and destabilisation of relations and artefacts.* [13,p.190]

The definition emphasizes the different and dispersed elements of the space that comprise various localities of both a cognitive and physical nature. A 'development arena' does not generally have a specific locality or one single geographical space of existence or of central importance. However, a number of specific locations will form the stages for action in relation to each other. They do so without any pre-specified order of importance or set of relations. As a pure abstract notion 'development arena' remains metaphorical.

Companies enter arenas and specific situations when they start developing technologies and products. They may already be in an arena as a result of earlier activities. Actors might unintentionally be present in an arena. They might be represented in reduced form as competitors or users. In this paper, we limit the discussion to the analytical perspectives, although our attempt may include, as a future perspective, a discussion of managerial methods and problems.

Phenomena such as markets, customers and costs are placed into a new perspective when seen through the arenas perspective. Customers, markets etc. cannot stabilize before technologies and artifacts are stabilized as commodities. Arenas define and characterize a space and consequently also constitute the boundaries for the activities carried out on the arena. The arena is deliberately defined as an open-ended space, where certain actors and locations can be inscribed either by the actors themselves or by others engaged in the arena. The development arena should thus give us a frame for understanding and researching processes in which companies and other actors attempt to master technologies, products and markets. It includes both the static elements of locations, knowledge and artifacts, while it also frames a space for continuous action.

The 'arena' is a metaphor taken from political and social theory. It provides a tool for mapping activities that are temporary and actor-dependent within a field that structure social orderings and in which change and transitions take place. The metaphor 'arena' refers to the word's original meaning in Arabic, 'sand on sand', to indicate the special temporality and fluidity of the phenomena for which the approach provides the analytical framework. Arenas provide the place and space for socio-material interactions.

In accordance with actor-network theory, actors comprise a heterogeneous set of entities, including humans, technologies, institutions, visions and practices, which are given specific social meaning and identity through their inter-connectedness in networked relations. The structuring and stabilization within networks result from alignments and mediations that give the entities their specific meaning. These processes of alignment and mediation are core to the configuration of networks and lead to the creation of temporarily stable actor-worlds, ordering the included objects, knowledge, visions and practices [14]. Actor networks and, in their more specific and stabilized form, actor-worlds, are sense-making, semiotic networks, which in parallel

produce arenas' focus, boundaries and dynamics through their internal relations and the tensions created between the different actor-worlds and the continued processes of re-structuring and re-adjustments following them. Arenas are re-structured and eventually expand or shrink depending on the performances that actors engage in when attempting to stabilize, transform or even destroy existing actor-worlds present on the arena. The performance dimension maintains focus on actual events – whether they are discursive, organizational or material. While actors may have visions and goals that justify their actions, they often first build alliances and then, along the way, make sense of the actions and re-structuring.

Actors can even have multiple identities and engagements on an arena and being enrolled in more than one network and actor-world at the same time. Although knowledge and practices may be constrained and framed within a specific actor due to the sense-making relations that dominate within the network, other meanings might be assigned in other networks. Actors may even be engaged in several arenas at the same time and not necessarily need to coordinate and solve either conflicting views or practices.

## CONCEPTUALIZATION

Text books in engineering design are in agreement about how to structure the design process. First phase comprise of an analysis that leads to a design goal after which the synthesis work starts. A concept is in this context described as an 'early suggestion for a solution' characterised by a low degree of specificity though a more precise account of what these characteristics are is not detailed. Roozenburg and Eekels [15] tend to characterise concept in terms of a solution defining the main principles of the intended design, which does not really help as this eliminates the need for a notion of concepts as they just could be characterised as principal solutions.

Dorst and Cross [16] emphasise the design process as a co-evolution of problem space and solution space as a matching pair which is in light with the understanding of these as closely related. But in the view of Hansen and Andreasen [17] this is not satisfactory either as a concept in their view must include some specific and relevant characteristics. Consequently they suggest that a concept must include some relevant and specific characteristics relating to the actual situation and stage in the design process and its context. The result is a two-dimensional definition of a concept comprising of the idea with and the idea within the concept, where the idea with must reflect the use, need and market context while the idea within reflect the specific technical aspects related to the concept realisation and the working of the design.

This definition of a concept is characterised by Hansen and Andreasen:

*A conceptual design, i.e. the concept for a new product, may be seen from two sides, a need/market-oriented and a design/realisation-oriented. The need/market-oriented side explains the conceptual new way the design solves its task. The design/realisation side explains how the concept creates the necessary functionality and structural realisation for doing so.*

*What is seen as conceptual depends upon what is already created in the actual area concerning solving the task or concerning the principles or design of the artefact. So the conceptual new aspect could very well be e.g. man/machine interaction, form features, or choice of material. [17,p.1]*

The combination of this take on conceptualisation is that it in conjunction with the arenas of development provides an approach to the demand for co-evolution as outlined by Dorst and

Cross. An approach they themselves do not provide for. The designer must in parallel identify the development arena and create new concepts to conceive and identify the problems at stake.

Within the rational problem solving paradigm and based on an empirical study Cross and Dorst develop a model of creative design as the co-evolution of problem and solution spaces towards a matching pair [16,18]. Dorst [19] explains the model as follows:

*Creative design seems more to be a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis and evaluation processes between the two notional design 'spaces' – problem space and solution space. In creative design, the designer is seeking to generate a matching problem-solution pair, through a 'co-evolution' of the problem and the solution.*

## **CASE STUDY: LIFE-SAVING IN THE PUBLIC SPACE**

To illustrate the open-ended character of the process of 'conceiving' a case study is taken from the master level course 'Conceptualization' where 8 student design teams (in total 43 students were participating autumn 2010) worked on a project entitled: 'Life-saving in the public space – products, services or systems.'

We observe the project title opens the solutions space towards products, services or systems. In this sense there is no restriction of the type of solution for the student design team to conceive.

The design task was formulated as two questions for the teams to answer:

*What if life-saving in the public space should be improved? Which concepts can we propose?*

We observe this is a very open formulation of a design task, in the sense that neither a need nor a problem is specified. Each student design team has to identify a need and define its own design problem.

The design task formulation was supplemented with a description (to inspire the students) of some current situations in Denmark, where a possibility for improved life-saving is evident:

*TrygFonden has in recent years sponsored installation of defibrillators in public places to make it possible to render an instant life-saving effort until ambulance arrives. Although the installed defibrillators are assessed by professionals to be user-friendly, early experience indicates that they are seldom used in practice. This might be fatal for a person having cardiac arrest, because the survival chance decreases for every minute the life-saving effort is postponed.*

*During summer 2009 10 persons died by drowning at the Danish beaches. Several holiday-makers drowned when they went for a swim. Some holiday-makers probably go bathing ignoring - or not aware of - wind and weather conditions. Others are unlucky and may be hit by a wind surfer. In any case fast life-saving effort is a precondition for survival. Ambulance men complain that the conditions for carrying through their work at road accidents are becoming more difficult. Road users passing by do not accept waiting time and delays, and nosy people crowd around the scene of the accident. Road users and*

*nosy people ignore requests from police and ambulance men, and therefore the injured persons and the ambulance men are subjected to danger.*

What perspective develops each student design team on the design project?

First of all we observe that 5 of 8 student design teams deliberate the term 'public space':

- *When brainstorming and debating about the subject the team found it necessary to reach an understanding of what constitutes "the public space". Here the team found subject of responsibility especially interesting, for instance with concerts in public fields. In such cases there can be several different stakeholders each with their responsibility and agenda, which might not always contribute to secure activities.*
- *Every person spends some time of the day in public spaces, when going to work or to school, shopping, traveling, going for a walk or doing any other kind of activities outside home. ... But the fact is that people may encounter many dangers every day such as traffic accidents, fires, falls, extreme weather conditions and many other things, which cannot be controlled or predicted in advance. ... sometimes unplanned things can happen when a person's life is threatened and he or she cannot help themselves and become dependent on help from outside.*
- *Public space is an area or place that is open and accessible to all citizens.*
- *Among other issues concerning life-saving, a thorough and intense discussion among the team members took place of articulating what a public space stand for. ... Part of the first information search took place regarding institutional and constitutional terminologies of 'public space', according to which a public space is 'in theory what is open to everybody' as well as it can be interpreted as a social space such as a town square that is open accessible to all, regardless of gender, race, ethnicity, age or socio-economical level. Other examples of public spaces are squares, city beaches, fields, parks, quays as well as plazas, town squares, parks, marketplaces, public commons and malls, public greens, piers, special areas within convention centres or grounds, sites within public buildings or so on. ... Soon enough it became clear that public space has a multifarious meaning related to existing social activities, architectural features, community involvement, local culture and history and so on. Thus, it has to be seen in relation to life saving not as an issue to-be-deconstructed individually. Based on the primary research public spaces were categorized with regard to volumes and whereabouts. It seemed beneficial to further categorize into small and great, as well as, into created by nature itself and designed by man too.*
- *During and through the latter process some characteristics were also defined by the group for the context of the public space. These general characteristics were: Urban environment, densely populated, accident occur often, high energy traumas. High energy traumas are defined as accidents that involve the release of high kinetic energy causing massive damage to technical objects and humans.*

We observe that the student design teams have different interpretations of the term 'public space'. The first team focuses on responsibility in relation to concerts in the public field. This team found a challenge to work with life-saving in crowds being inspired by the accident at Roskilde Festival year 2000 during a Pearl Jam concert, where 9 young men were killed, and the accident at Love Parade in Duisburg, Germany year 2010 where 21 were killed and more than 500 injured. The second team sees public space as 'outside home', and an accident in public

space is a situation where a person's life is threatened and where the person is dependent on help from others. Whether these others are professionals (ambulance men, firemen or police officers) or civilians passing by is not discussed. The third team defines public space as open and accessible. The fourth group has the most elaborated discussion of the term and identifies four attributes of public spaces, viz. accessibility, volume and whereabouts, created by nature or man. The fifth group's interpretation of 'public space' is closely linked to accidents happening in cities, especially traffic accidents, where a car runs into a pedestrian or a cyclist.

The 8 student design teams formulated the following design problems:

- The first team defined their problem as life-saving in crowds. This group sees a solution space consisting of flexible barriers, which will not result in accidents (crush hazard) when a crowd goes into panic.

Four other student design teams focus on ambulance response in case of an accident:

- One team defines their task as *Alarming road users*. The team sees the answer to response of ambulance in a cleared road for the ambulance, so it is possible for the ambulance to drive fast. In order to obtain a cleared road the road users shall be warned about the fast ambulance as early as possible and the aim is to design an alarming system to alarm road users. The system should provide the road user more awareness of the ambulance coming and where it is coming from and in this way take into account the safety for the paramedics and road users.
- One team formulates a mission statement: *The Ambulance/Victim Protection must quickly ensure safe working environment for the paramedics as well as improving their working conditions without the need for involvement of other rescue units*. The team sees the answer to ambulance response in the fast establishment of a safe workspace for the ambulance men at the scene of the accident, i.e. ensuring that road users passing by the accident do not disturb or expose the ambulance men for danger.
- One team writes a short problem formulation: *When looking at cross-sections, how can the transport of an emergency vehicle be improved?* The team sees the answer to response of ambulance in cleared cross-sections, which means that ambulance drivers do not have to lower speed when approaching cross-sections.
- One team writes: *In case of a car accident, help is called for manually. The caller in question will have to state the location and then wait for help to arrive. If the person involved in the accident is not able to call for help, the person will have to rely on by-passers taking action. If there are any!! In case the driver is unconscious the driver cannot make the call. And if no one is around the driver can risk waiting for a long time. Simultaneously, when help is called, the emergency team does not always get the exact location from the caller, which will delay the arrival of the help*. This team sees the answer to ambulance response in an alarm call immediately after the accident has happened and an alarm call containing information of the exact location of the accident. The team focuses on automatic GPS systems in the car being activated when the airbags are activated.

We observe that although the four student design teams focus on the same issue, the ambulance response in case of an accident, they find four different matching pairs of problem and solution space. One team defines their problem statement as: *How can the awareness and localization of a man overboard be improved?* This team sees the problem related to rescue

missions at sea, where the helicopter crew today depends on vision to localize a person overboard. Rescue missions are often in rough weather conditions, and vision systems, e.g. infrared camera or a flashing light on a life jacket, are not optimal. The team focuses on the life jacket having a GPS device to signal position.

## CONCEIVING IN THE CDIO VERSION

The CDIO concept is detailed in the following table where more details are provided concerning the content of the four acronym letters:

<i>Conceive</i>	Defining customers needs, considering technology, enterprise strategy and regulations, and developing conceptual, technical and business plans.
<i>Design</i>	Focusing on creating the design; the plans, drawings, and algorithms that describe what product, process or system to be implemented
<i>Implementation</i>	Refers to the transformation of the design into the product, including hardware manufacturing, software coding, testing and validation.
<i>Operate</i>	Uses the implemented product, process or system to deliver the intended value, including maintaining, evolving, recycling, and retiring the system

Figure 1. The Four elements of the CDIO concept [20,p.8].

The dilemma related to these elements is that they seem to neglect the socio-technical competences as well as competences to work with synthesis as also demonstrated in the following definition of the CDIO goals:

*Master a deeper working knowledge of technical fundamentals defined by: Engineering education should always emphasize the technical fundamentals ...deep working knowledge and conceptual understanding is emphasized to strengthen the learning of technical fundamentals ...In a CDIO program, the goal is to engage students in constructing their own knowledge, confronting their own misconceptions". . Instead the CDIO concept with its three overall goals seems to be enrolled in a classical techno-science discourse, emphasizing the 'technical fundamentals'. [206,p.20]*

While in the DTU program the phase of conceiving the problems and demands that can be identified in the use context of designs of products, services or systems has been given a very high priority in accordance with the earlier stated imbalance in engineering education between (socio-technical) problem identification and (technology-driven) problem solving not much can be found elaborating of the meaning of 'Conceiving' in CDIO. In fact this 'letter' has only been given a few lines in the complete book outlining the principles, goals and standards. In the listed priorities of the syllabus point 4.3 detailing what is meant by *conceiving* includes: 'setting systems goals and requirements; defining function, concept and architecture; modeling of systems and ensuring goals can be met; project management' [21,p.56]. At another place *conceive* is understood as 'interaction and understanding the needs of others' [20,p.28]. Nicely followed up by this general statement:

*In a CDIO program, experiences in conceiving, designing, implementing and operating are woven into the curriculum, particularly in the introductory and concluding project courses.*  
[20,p.28]

This underpins that the focus in CDIO still is on engineering as a self-contained and complete discipline of both knowledge and skills implying that no other types of knowledge is given a similar status.

## CONCLUSION

The role of engineers in technology and innovation is often taken for granted. Even in future-oriented reports on engineering, there is a tendency to expect problem-solving abilities in societal and environmental issues from engineering, without challenging contemporary foundations of engineering curricula. Innovations during the last decade are leading to changes that may make the role of engineering less central in the future. Policy and management attempts to govern innovation processes have also broadened the scope and shifted the focus from technological development and breakthroughs to a broader focus on market demands, strategic issues, and the use of technologies. At least in the context of a design engineering education much more emphasis should be put on methods to handle the conceiving phase of engineering work. This includes a need for taking up approaches inspired from the field of science and technology studies (STS) like the arenas of development approach as well as advanced approaches to conceptualisation as e.g. developed in relation to the processes involved in design ideation and synthesis.

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