

A Design Theoretical Approach to Learning in Technology

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Introduction

At least in Scandinavia and likely in the rest of the industrialized world, higher engineering education is not among those careers that young people turn to as their first choice today. This is even truer among young women. There are however some exceptions besides booms of interest in information technology and other “new areas”. In Sweden we can see how schools of architecture as a part of technical universities, attract many times the number of students they can accept. The situation is similar with new engineering educations that combine disciplines like economy and technology or take new standpoints like engineering for sustainability or combinations of styling and engineering.

Our economy is less and less dependent on manufacturing of things and hardware. Our future lies in production of soft qualities like advanced services, systems design and management, innovation and research in areas where vast intellectual and economic recourses are needed to compete. These new areas do need a qualified engineering education but also a new kind of engineer that can handle new type of problems that were out of reach of the traditionally educated engineer.

From time to time pedagogues and educators in engineering turn to architecture practice and schools of architecture to find inspiration in their methods of learning and addressing design problems. Also many design theorists use architecture practice, as an example of design behavior and quite a few theorists in the area are architects by training.

In this paper I will try to investigate the problem field of learning in technology from a *design theoretic* point of departure and try to elaborate if this could add something to the epistemological and didactic aspects of future engineering education. I will also try comparing architects practice with that of engineers and maybe modify a sometimes-glorified view of architects practice. I will also show how different professional education might learn from each others and give my view on how they could be

developed and maybe more attractive to young people. My empirical foundation^{*} for the discussion is almost three decades of very inspiring practice in design, research and education with architects and engineers of different specialties.¹ As a genuine believer in design as a learning method, my insight in the subject is a result of constant loops of action and reflection combined with theoretical studies of other experienced designers, teachers and theorists.

Engineers and architects – two design professions

Engineering and architecture are both design professions. I will demonstrate important similarities between the way professionals think in action² but also describe some obvious differences. In his book “*The Reflective Practitioner*” the American design theorist Donald Schön distinguished between a *technical rational* and a *reflective* way of connecting knowledge to practice. Schön argues that both engineers and architects take advantage of both ways in their practice but the engineers are taught to treat knowledge in a technical rational way while architects mostly depend on reflective behavior in their practice. I come back to this later in the paper.

Artisticalness and engineering construction

I am attracted by Herbert Simon’s view that “*Everybody designs who devises courses of action aimed at changing existing situations into preferred ones*”.³ In this paper I will however, for the sake of reasoning, focus on certain aspects of the design of artifacts[†]. Artifacts are always designed for a *purpose* in the *real world*[‡] and have therefore always an intended or sometimes not intended effect on human beings and society.⁴ Both architectural and engineering practices are design professions in this sense.

Artisticalness and architectural design

Many professionals have an urge to artisticalness. By this I mean and urge to express oneself through professional performance beyond what most others can do. This urge is mostly an ambition due to the personality and the talent of the professional. In training of architects this is however a central aspect of the curriculum like in training of performing

^{*} This is described in more details in my doctoral thesis *Architecture, Technology and Human Factors: Design in a Socio-Technical Context*, Chalmers University of Technology, Gothenburg, Sweden, 1991. Also available on <http://granath.arch.chalmers.se/guestbook.php>

[†] The traditional definition of *artifact* is closely connected to *things*. It is something manufactured by man. My view is however that this definition is not sufficient in the modern society there so many things created by man are non-physical, virtual or mental products. I therefore focus on the other part of the traditional definition, namely artifacts as not being natural phenomenon. My definition of *artifacts* therefore includes anything created by man, also those that originally lack physical form like ideas, theories and mental models.

[‡] I use the expression *The Real World* to distinguish it from the Cartesian division into disciplines that is the tradition in engineering and natural sciences, and other sciences too for that matter. The Real World means a more holistic approach to the problems at hand there we can cross over between traditional disciplines and take on problems that traditionally have been difficult to deal with. The concept is not new as it was used by the American designer Victor Papanek in his book “*Design for the Real World*” already 1985. He however focused more on the appropriation of the artifacts than on the knowledge behind its design.

or fine artists. For some architects this becomes the paramount driving force of their work. Even if the purpose of artisticalness in architecture, in most cases, is to make something pleasing, I do not only connect this to *aesthetic* dimensions of three reasons. The first reason is that my experience from co-operation with engineers, and other professionals, has convinced me that any serious professional has an aesthetic dimension in the way they design or perform. This is often implicit and often even denied by them though. The aesthetic ambitions are therefore not only restricted to artistic work. The second reason is that engineering designers often look on aesthetics as a part of the functional properties of the artifact rather than as a quality in itself or a way of expressing themselves. The aesthetic form in product design is i.e. a semiotic property of the artifact aiming to communicate with society and individuals.

In this sense I think of artisticalness as an important aspect of designing. The driving force for the artist is often to have an impact on the real world but this is not an absolute necessary condition. The driving force could be merely introvert. Some philosophers would argue that this urge to fulfill your own dreams or express yourself is the only valid driving force among human beings. Research done in USA by Robert Gutman, the sociologist and professor of architecture at Princeton, shows that architects' main goal is to get appreciation from the fellow architects rather than users and society as a whole.⁵

Engineering construction and engineering design

On the other hand we have what I call *engineering construction*. Here I do not talk about construction in the sense of erecting or manufacturing something but the activity of giving the artifact its normative qualities, properties and dimensions due to good professional standards. This reminds of a common definition of design, but in this case I will suggest *engineering construction* as a more restricted view on design in the same way as I distinguished *pure artistic work* as a special aspect of design.

In my conception of design there is a dimension of uncertainty and ambiguity in both the problem definition and the process and of the outcome to be. What I call *engineering construction*, different to *engineering design*, lacks to a large extend this uncertainty and ambiguity. I talk about engineering construction as a design situation there the engineer know very much what the outcome will be of his/her construction efforts. The intellectual process is mostly about defining quantities rather than qualities. The process of construction is often linear and predictable and it is quite obvious when the problem is solved. The engineer uses methods and theories from his/her professional education in a formal way to solve the problem. And most important, the mastering of these theories and methods makes it clear from the start that the designer is proficient to solve the problem and that an acceptable result will be arrived at in the end.[§]

So, on one hand I have distinguished *artisticalness* in terms of *pure artistic design* as a design activity in cases there the urge of the creator to express him/herself is of paramount importance. On the other hand I have described what I call *engineering construction* as a special aspect of design where the lack of ambiguity and uncertainty in the problem definition and a linear cognitive process is favored. It is however important to point out that we find very few professionals that fit into these two categories, if any.

[§] Swedish professor in Informatics Bo Dahlbom suggested a distinction between the Swedish concepts of "konstruktion" and "design" in a contribution to a design seminar at Chalmers University of technology in early 90th. I have elaborated this suggestion in my own way since then.

When we discuss education in engineering and architectural design I however find it useful to make these somehow “artificial” distinctions as the two opposite ends of what we think of as design activities.

Real life problems and “scientific” problems

The most demanding area of design is that dealing with *poorly defined or wicked problems* ^{**}.⁶ In these cases the ambiguity and uncertainty is always present concerning the problem definition, the relevance of theories and methods and often even the actual conceptual context of the solution. In these cases design can be described as a simultaneous and iterative process of i) decision-making, ii) problem solving, iii) communication and iv) considerations on aesthetic and ethic values.

The *decision making* process involves *rational logic*^{††} This involves the ability to master professional methods to collect, and structure data, set up and evaluate alternative actions and be familiar with concepts, rules and regulation of the profession and finally have the professional skills to follow them. These skills depend mainly on what Schön calls *technical rationality* in its view on knowledge and professional design behavior.

Problem solving on the other hand involves a more *intuitive logic*^{‡‡} there questioning rules, bending and breaking rules and developing of new rules are essential aspects of design. The *problem solving* process involves very much the ability to look at thing as if it were the other way around.

Communication in design has two important dimensions, the communication with the real world in terms of users, co-designers and other actors and the dialogue with the design situation itself. Schön describes the dialogue with the design situation in terms of assessing provisional structures and solutions to the situation and how the design situation “talks back” to the designer. We all recognize this from everyday design situations. We only have to think about one way to solve a problem to realize that it was not such a good idea and we immediately modify our thinking and try it another way. The idea of communicating with co-designers and user has two main purposes. One is to collect information and learn about the situation; the other to make sure the solution will

^{**} Architect Peter Rowe identifies three categories of problems: 1. Well-defined problems, 2. Poorly defined problems and 3. Wicked problems. In the case of poorly defined problems you know essentially what the problem is, but during the course of your work you are forced continually to gather more information and redefine and specify the problem further in order to reach a viable solution. "Wicked" problems are those, which elude clear definition. Further, you cannot be certain you have found a solution. Rowe, Peter H. 1987. *Design Thinking*. Cambridge, MA: The MIT Press: 39-41. Rowe's points of departure are: Churchman, 1967, Rittel, 1972 and Bazjanac, 1974. Cited from Granath, J Å. 1991. *Architecture, Technology and Human Factors: Design in a Socio-Technical Context*. Diss. Chalmers University of Technology, Gothenburg.

^{††} I here allow myself to use an expression that with a special meaning of *rational* could be a tautology. I use the term *rational logic* to distinguish from *intuitive logic* used below. Intuitive logic would by some be regarded a contradiction so, by combining a “hard” tautology with a “soft” contradiction I try to make a pedagogical point about the difference between the aspects of *decision making* and *problem solving*.

^{‡‡} By intuition I mean the ability to recall earlier experiences that is understood by the designer. Refereeing to Simon and to discussions with Rudolf Arnheim (Ann Arbor, MI. 1988) I see intuition as something individuals experienced from certain situations can use to solve problems within similar situations.

be satisfying to the real world situation. Simon's statement above that everybody being a designer indicates a *collective design process*^{§§} as something that not just involves professional designers like engineers or architects.

The problem solving and communication dimensions of design could, in Schön's terms, be described as a reflective behavior. The reflective behavior is well suited to situation where we do not or cannot, due to the character of the problem, fully defined it initially. The problem becomes gradually understood and changes character with closer contact with and growing understanding of the design situation. This also means that the uncertainty of the relevance of theories and methods and the development of theories and methods is a part of the reflective design behavior.

Due to Schön every designer uses a combination of technical rational behavior and reflective behavior in their professional practice. Technical rational way of thinking is however more predominant and regarded as norm in engineering education in the same way as reflective behavior is in architect education. As a result of this those engineers occupied mainly with engineering construction often feel less professional when they "degenerate" to what they feel is a "sloppy" reflective behavior. Artistically inclined architects on the other hand do not develop too many normative methods and general solutions in their work. To do so would be regarded uncreative and a hindrance for artistic quality. As detailed data and normative methods is crucial to the traditional engineer, too much knowledge and information sometimes makes the design too complicated for those architects seeking merely for the artistically consistent solution.

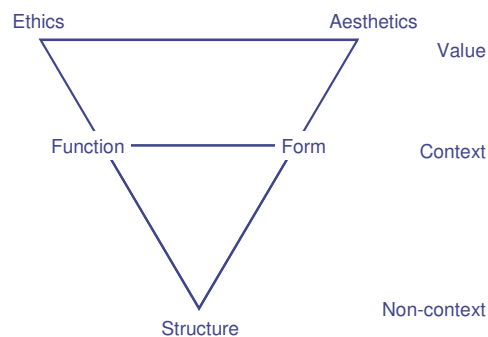
A reflective behavior is essential to solve poorly defined problems and to innovate and technical rational behavior is needed for taking advantage of know-how and scientific knowledge and above all as a controlling behavior of intuitive suggestions. Reflective and technical rational designers have different strategies to deal with overflow of information and ambiguity in the design situation. Technical rational behavior delimit the problem to a safe area there the methods and theories at hand is relevant for the reduced problem.^{***} This makes it difficult to deal with true real life problem that per definition does not easily are reduced to fit into single professional areas. This restriction is no problem for the reflective designer. He/she instead relates the collection of information and data to the actual design situation, which sometimes can be quite opportunistic and ad hoc. Architects include more general information and data in the form of rules and regulation set up by authorities or taken from handbooks and manuals. The presence of such normative data is however controversial among architects. It is argued that such norms is a help to guarantee certain qualities that are essential to users and society and still give the architects a large freedom to concentrate on the artistic aspects of the design. A common view is however that these normative regulations are a restriction to the creativity.

^{§§} Inspired by Schön I suggested the concept *collective design* as a reflection on the process of designing a new automotive assembly plant for Volvo. The process showed all the properties of what Schön would call a reflective design activity but while Schön mainly spoke about individual professionals my experience involved groups of designer like assembly workers, engineers, architects etc.

^{***} There is a popular say that "as soon as you have defined the problem you know the solution". As I see it this is a *technical rational* say. A reflective designer could agree, but he/she would not know all the facets of the problem until late in the process when a satisfying solution is close. I do not think this is the message the say will communicate.

In an ideal situation the collection of data should however be retrieved from the context and through communication with the other actors and the situation. A combination of good methods of taking advantages of scientific knowledge and earlier personal experiences could make many of these normative regulations obsolete and let the design be trusted to reflection and creative thinking. The situation is however far from ideal in architectural practice when it comes to feedback from earlier design situations and procedures and methods that enhance the ability of reflection-on-action. This is an area where engineering practice have a lot to offer.

The last aspect of design I mentioned above was *considerations on aesthetic and ethic values*. For this purpose I introduce a diagram that I have modified from a model originally presented by the Swedish design theorist and architect Jerker Lundeqvist and also modified in other contexts by the design theorist and informatics scientist Pelle Ehn. The original ideas are related to the elements of architecture; *commodity, firmness and delight* by the ancient Italian architects Vitruvius⁷ (last decades B.C).^{†††} Ehn used the model to describe properties of artifacts in general. I have modified the model to discuss the education of architects and engineers.



Schön argues that knowledge based in science is the sole basis to build technical rational behavior on. Skills are something coming after knowledge and not really regarded as knowledge at all. We know that discussions in pedagogic on *life long learning* and *problem based learning* on one hand and discussion on *practice generated theory* and *hermeneutic sciences* on the other hand has put this in question as the sole basis for professional education.

Engineering education is of natural reasons based on *structural knowledge* (se figure above). Structural knowledge is here defined as scientific knowledge, not dependent of the context i.e. rules for how to calculate a concrete beam are the same regardless if it supports a church or a football stadium.

To relate the professional knowledge to the *context* has traditionally been left to after the professional degree. In practice the engineer has acquired true engineering design skills, including reflective behavior in his/her design practice. With a growing awareness

^{†††} This is an interpretation of the original Latin text in *De architectura libri decem* where Vitruvius presents his ideas of the elements of architecture; originally from an English translation by Sir Henry Wotton (1568 - 1639)

among engineers of the need to deal with poorly defined and wicked real life problems without delimit them to abstract pieces of a problem field, the contextually related training has been more and more important in engineering education.

The first experiments with developing a method for using real life problems in graduate and post-graduate training in Sweden was made at the School of architecture at Chalmers University of Technology in late 60th and is still an important part of the pedagogic in the school.^{†††} Unlike some modern problem based courses the basis has always been real real-life problems where the students have intervened in and co-operated with people in their every day situation whereas it has been workplaces, housing projects or redesign of public facilities or communities. Several projects has seen its realization or contributed ideas to later realization.

Engineering education has still its basis in structural knowledge but adopts more and more the ideas of using real life contexts or at least simulated such as basis for professional training.^{§§§}

Aspects of *ethical* or *aesthetical* values was for long “off limit” in engineering education. Scientific knowledge is neutral and a stands above political or moral considerations has been a strong standpoint. This is supported by the conception that all problems are or can be reduced to well defined problems with optimal solutions. There is a growing awareness that this might not be a preferred standpoint in all situations. New cross-disciplinary areas of research closer to real live have also appeared. This has made also the scientific truths of natural sciences subject to discussion and considerations based on values among individuals and society.

We can find two main lines of development in architectural education. The “académie de beaux-arts”, where the architect’s education is mainly artistic. This tradition has always been and is still strong in some countries. In other countries the architects training is part of an engineering school. The Swedish Architects education was traditionally more similar to engineering education and had a larger part of the curriculum than today in the area of structural knowledge. The contextual aspects and training on real life problems has however always been important. Before the change in the late 60th the real life project were more mono-disciplinary and formed the basis for exercises in interior design, landscaping, housing design or structural design. They were also often made up problems that simulated real life situation or fantasy problems just formulated to stimulate creativity or challenge the students without feeding any useful solutions back to those who lent their reality to students’ exercise, if they at all existed. This later use of real life or fantasy in architects training still exists and has a value but the importance of interaction and usefulness is predominant today. It is interesting to note that in school of the “académie de beaux-arts” tradition real life problems and communication with laymen often are regarded not preferable. The argument is that reality will restrict creativity and a need to adjust to users demands and wishes, other than in the architect’s own interpretation, will harm the artistic quality of the result. Real life restrictions will come soon enough in real practice anyway.

^{†††} This is reported in Kjellgren K, Ahlner J, Dahlgren LO, Haglund L (eds) Problembaserad inläring - erfarenheter från Hälsouniversitetet. 1993, Lund: Studentlitteratur.

^{§§§} I distinguish between real real life problems as those solving an existing problem together with people affected by the problem setting, and simulated real life problems where the situation is realistic but not real.

Values have never been a problem to deal with in architecture education and practice when it comes to aesthetics. On the contrary, the artistic aspects of the profession put values among designers, tutors and fellow professional in focus as something of major importance. It is clear that the balance between focus on the of context and real life considerations on one hand and the artistic values of the designer on the other hand changes over time both in education and practice.

It is interesting to observe how traditional engineering education is based in *structural knowledge* but more and more tend to involve *contextual* and *value* based aspects in education. Architect education is traditionally founded on learning from the context and embracing values in terms of aesthetics. In co-operation with engineering schools like civil engineering there are at least at Chalmers University of Technology efforts to marry structural knowledge in technology with the context of architecture and the build environment.

Closing reflections

The attractiveness of technical careers among young people of both genders could be improved by presenting engineering in a more realistic way than the last decades of “bad publicity” has done.

First I would like to suggest emphasizing engineering as a *design profession*. It would be wise to make a point of the fact that being a designer means that the professional creates solutions that have an impact on contexts in *the real world*, i.e. people and society. It also means that the professional does not necessarily have to delimit the problem definition to *well defined problems*, but can through a combination of a *technical rational* and a *reflective* behavior take on those much more demanding *poorly defined and wicked problems* that depend on both *rational* and *intuitive* skills. This means in turn that many of the problems that many young people, critical of technology, think are essential like ecology and third world problems with over population, health and nutrition comes on the agenda for future engineers. It also presents technology as something for the creative and not so conform students to take interest in. Furthermore *artistic and aesthetic* aspects are important to professional engineers in the real world as well as *normative methods and scientific theories*. Above all *ethical responsibility and consideration* is not off limit in the engineering profession. On the contrary it is an essential part of the design behavior in many of the areas that will be important for the future. One example is the questions of integrity that occurs with new “intelligence” in artifacts like cars, household products and communication tools.

Experiences from Chalmers University of Technology shows that cross-disciplinary approaches to engineering design like product design education in mechanical engineering, sustainability in engineering and architecture and combinations of management and technology are attractive to many students and among them many women. Also subjects that could be regarded more technical and dull in their context attracts women under certain circumstances. We have noticed that facilities management studies that is a cross-disciplinary program involving the schools of architecture, civil engineering and management of technology is very attractive to the female students of architecture. The students that choose these courses are almost hundred percent women. This is quite interesting to note in an environment there artistry and “soft issues” is a virtue much more prestigious than any other. Informal interviews with the students give

some explanations to this. One of the reasons is the holistic approach to design combined with the strong emphasis on usefulness for users and society.

Learning through design

As I see it design is a mutual learning process that involves stakeholders in the process and of the outcome. Engineering design seen through a design theoretical perspective therefore emphasize pedagogical and communicative skills, but also the ability to grasp design situation in a multi faceted way.

One way of getting young people interested in and to prepare them for technical professions would be to use design as a method of learning. This implies using more real life problems in education and above all deal with more poorly defined problems. It also means not looking only for the right answers but encourage the students to construct relevant problems and value the process of connecting the problems to the results more than reaching an end result. It also means encouraging the students to “try the opposite”, to question rules and constructing new rules. Training of architects in Sweden has explored this method for some decades now with quite good results even if we still could improve our methods a lot with more resources. The balance between traditional teachings of structural and that of contextual knowledge might be different from architecture training, but I am sure there are lessons to be learned between different areas of design.

We could show the students that technology can house not only structural knowledge, but also deal with contextual and value based subjects in a creative way. In this way we might be able to channel young people urge for free and creative careers and their seeking for alternative world of knowledge and values into a new interest in technology. I also think that we will educate many more creative engineers in this way.

¹ Granath, Jan Åke, 1991. Architecture, Technology and Human Factors: Design in a Socio-Technical Context. Diss. Chalmers University of Technology, Gothenburg.

Also to download: <http://granath.arch.chalmers.se/guestbook.php>

² Schön, Donald A. 1983. *The Reflective Practitioner: How Professionals Think in Action*. New York, NY: Basic Books.

³ Simon, Herbert. A. 1984. *The Science of the Artificial*. Cambridge, Mass.: MIT Press.

⁴ Papanek, Victor. 1985. 2nd ed. *Design for the Real World: Human Ecology and Social Change*. Reprint. Chicago, Ill: Academy Chicago Publishers. 1985.

⁵ Gutman, Robert. 1988. *Architectural Practice: A Critical View*. Princeton, N.J: Princeton Architectural Press.

⁶ Rowe, Peter, G. 1987. *Design Thinking*. Cambridge, Mass.: The MIT Press.