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Andreasen, Mogens Myrup; McAloone, Timothy Charles; Hansen, Claus Thorp

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ON THE TEACHING OF PRODUCT DEVELOPMENT AND INNOVATION

Mogens Myrup Andreasen, Tim McAloone, Claus Thorp Hansen

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1 Introduction

Danish industrialists point out, that the importance of product development and innovation in industry is strongly growing, but the focus upon the way we are working is weakening. Therefore there is concern about the necessary number of students and their abilities in the design area. Current efforts related to the teaching of design will be reported in the following.

1.1 Questions and challenges related to design teaching

Around 1960 the first steps in education were taken to show that engineering design was teachable and learnable, not an art or a secondary pattern of dimensioning machines. At the same time it was also recognised, that the human ability to synthesise or create solutions could be influenced by training and stage-setting. Today many universities have chairs in engineering design and product development, but still it is not generally understood or accepted that the area of synthesis is researchable, has explicit methodics and may be taught. "We all design" say the university colleagues, and this is true. But few *reflect* upon designing and aim at making the process better.

The same attitude is dominant in industry. Not surprisingly, industrialists focus upon the products, not upon the process. Here is our challenge. What is the complete agenda for creating such candidates? In our department the overall question for our education and research is:

- How to realise the engineering design and product development of mechanical and mechatronic industrial products and systems in such a way that the process is effective and there is a great chance for success?

In order to be able to answer this we need to identify the dynamic development of industrial conditions, leading to decisions about the education.

1.2 From engineering design via product development to innovation

The development of our department has been an expansion of understanding and scope over a 45 year period, starting with US-influenced interest in human creativity and problem solving, to which we added a mainly German oriented approach for engineering design, influenced by Hubka (1986, 1988). Our industrial activities as consultants lead to the recognition of product development as the context and framework for engineering design (Andreasen & Hein 1987). The concept of Integrated Product Development was later supported in several dimensions by DFX-research, the theory of dispositions (Olesen 1992) and work on designers workbench, design language, product modelling and modular engineering, see Mortensen 1999.

Today the picture has started to alter; as the nature of industry's business has to adapt to a much more complex world in many cases, Integrated Product Development is no longer a sufficient way of describing and understanding design in industry. Causes for these changes include topics, which by keywords may be described as

- enhanced quality
- customer oriented quality, values and perceptions
- environmental concerns
- exploding complexity of technologies, product families, customisation, legislation, product life concern
- multi-product development, platforms, modularisation
- multidisciplinary product conceptualisation
- globalisation of supply, companies and markets
- dynamic innovation of products and organisations
- the handling of product definitions, knowledge and competencies.

In our current research on product development (McAloone and Robotham 1999) we focus upon aspects and approaches which should be added to the current approach to product development in research and teaching:

- organisation: structures, processes, tasks, management systems, teams, individuals
- product development types or tasks: innovation, development, consolidation, variants
- integration of product life orientation and multi-disciplinary work patterns.

In addition, there are important aspects and approaches that should be added, such as:

- techniques for determination and utilisation of re-use patterns of any kind in product development
- identification of the interaction between a method and the related platform of under-standing
- use of visualisation and graphical modelling of complex aspects in product development
- use of the theory of design co-ordination for identification of framework dimensions
- patterns of where and how innovation fits into product development.

Innovation has become a buzz-word and expanded its meaning from creating new products to surprised customers to a dynamic innovation of products and organisations for precise fitting to new situations, markets and technologies. Teaching innovation we see as two distinct tasks:

- to develop an innovation culture for creating innovative concepts
- to react on new conditions by innovating products and organisations.

1.3 Research based and research related teaching

Teaching design and product development on master courses is not only a question of what is teachable and learnable, but also a question of the understanding of the nature and validity of our insight into the methodics presented.

Explaining why and how a multidisciplinary team is able to create a complex design based upon observations, beliefs, values, teamwork, synthesis and engineering analysis tools and experiments, is far beyond the range of engineering. Therefore it is important for students – the future managers and innovators of products and organisations – that they understand the importance of human cognition and drive.

Research based teaching needs a balance in the textbooks between prescriptive and descriptive elements and elements explaining the explorative dimension. Very few books follow this approach, most being (too) prescriptive. It is the long-term aim of our department to experiment with new research based approaches.

It is our experience, that the students’ motivation and interest is positively influenced from gaining deeper insight into the staff's research and industrial problems. Therefore we apply several methods for linking the students closer to our research:

– by letting the students become guinea pigs in our research. For instance 24 multinational students were brought together in a summerschool, as part of our experiments on multi-boards, see section 3.2.

– by letting the students contribute to current research. In the area of modular engineering seven final year industrial projects have until now contributed to our understanding of modularisation and product modelling.

– by letting the students’ projects be a combination of practical work and reflections on the generality. Examples are "Methodics for upgrading secondary products", "Applying DFMA", and "Lessons-learned approaches".

– by letting the students aiming for a PhD perform research-like projects with empirical methods in industry. Examples are "The use of QFD", "Creativity and innovation" and "Man/Machine-Interaction methodics in industry".

2 A design curriculum

The aim of the design curriculum at the Technical University of Denmark is to create a structure of modules, so that the candidates can configure a more or less design/synthesis oriented education. The modules taught at our Department differ radically from most of the rest of the university, by aiming at a profession or métiers, not technical topics or specialisations. In the following we show the comprehensive structure of courses for this purpose.

2.1 A curriculum with design and product development

At the Technical University of Denmark, with a relatively low number of students and the wish to cover many specialisations, the study is made up of 5 credit point modules, currently changing to 10 credit points modules. The authors' department delivers a line of design and synthesis-related modules, from which specialisations in engineering design and product development may be created, based upon the students' choice of core competencies, such as mechanics, processing, robotics, thermodynamics, etc.

In our planning and communication with the students we try to explicitly manage, when the following teaching dimensions are present in the course modules:

- transfer of knowledge about designing
- developing and training skills in synthesis (concepts, structuring, detailed design), modelling, handling information, communication
- developing attitudes concerning quality, cost, environment, reflection and self-criticism, timeliness, interest for technological and societal matters
- developing personal values
- developing personal working techniques (use of computer, reporting, communication abilities, studying technique, etc).

As shown in Fig. 1, the line of course modules related to design is contributing to these teaching dimensions in a complex pattern, which is showing the necessity for a careful follow-up on the broad spectred teaching in each module.

2.2 What makes a product developer?

Due to industrial support and university restructuring the design courses have recently been developed and new courses added. Documents have been worked out for articulating our ideas, see McAloone and Robotham 1999, the document "A vision for the Centre for Industrial Product Development" (McAloone 1999), and the Departments Strategy and Identity document (Andreasen 1998).

A very critical topic is our university's lack of students. The department is therefore making every effort to create a clear, inspiring communication to the students, hoping that the identity of the design will lead to a raise in the student numbers.

Fig. 2 shows the dimensions of the specialisations for engineering design and product development. The left-hand side shows the specialising elements, the right hand side shows what the student may choose of technical competencies to combine with the design specialisation.

2.3 Types of courses for teaching design

Behind the notation of teaching dimensions in Fig. 2 lay some course pedagogics concepts, chosen for each course. The inspiration for our way of teaching comes from more than 25 years of close contact with and following of the solutions chosen by Delft University of Technology's teaching in Industrial Design Engineering and more recently the teaching style at Halmstad University. Recently established courses at the Department of Machine Design at

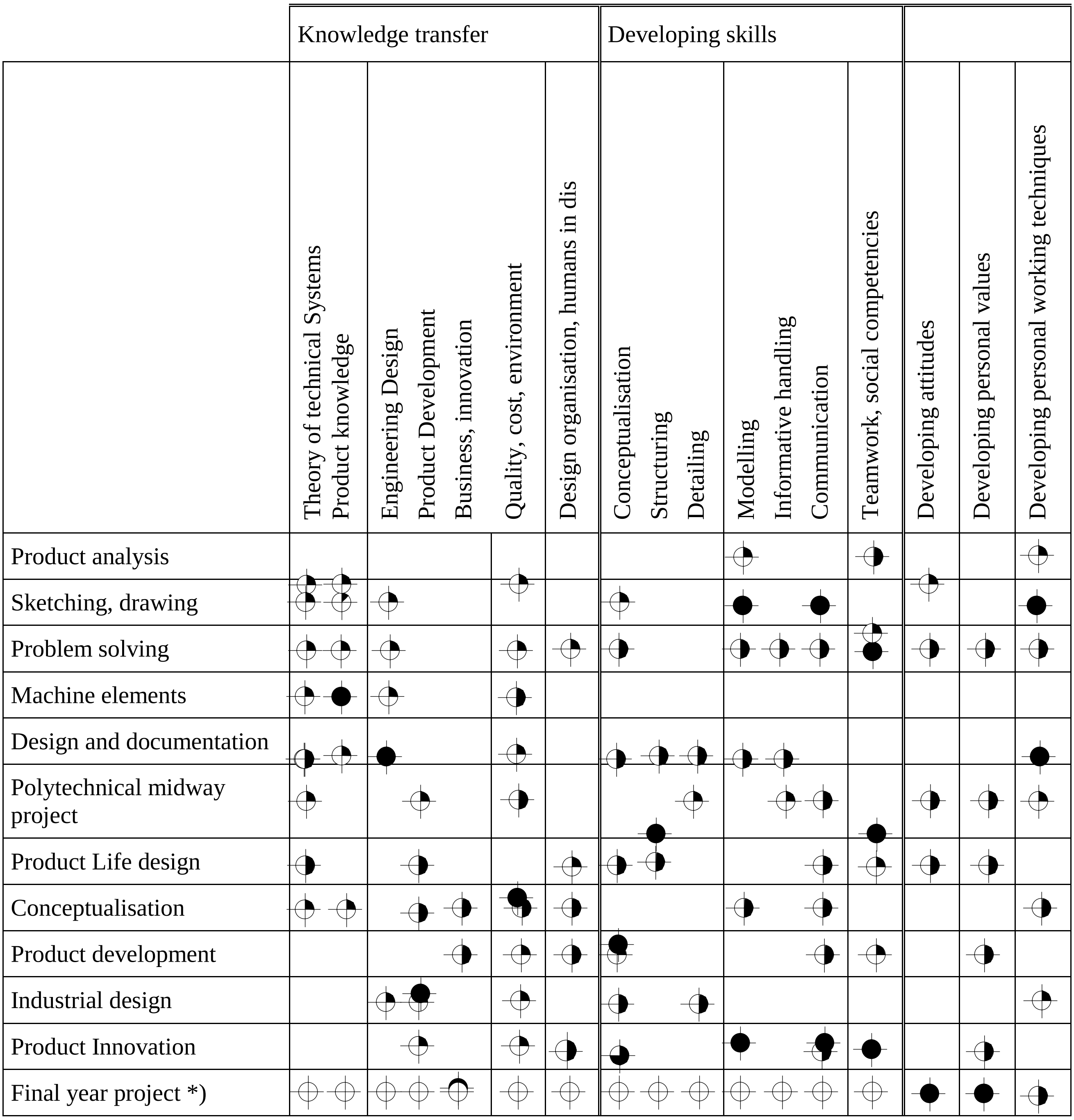

Figure 1. Teaching dimensions and modular courses (5 credit points) in a slightly idealised presentation of teaching design at Technical University of Denmark.
Each circle shows to which degree the teaching dimension is present and focused upon in the module.
*) The final year project may have different foci and contributions.

the Royal Institute of Technology in Stockholm (Norell 2000) and the dialogue at the series of Integrated Product Development workshops in Magdeburg have also inspired us. Some characteristic patterns shall be illustrated in the next section.

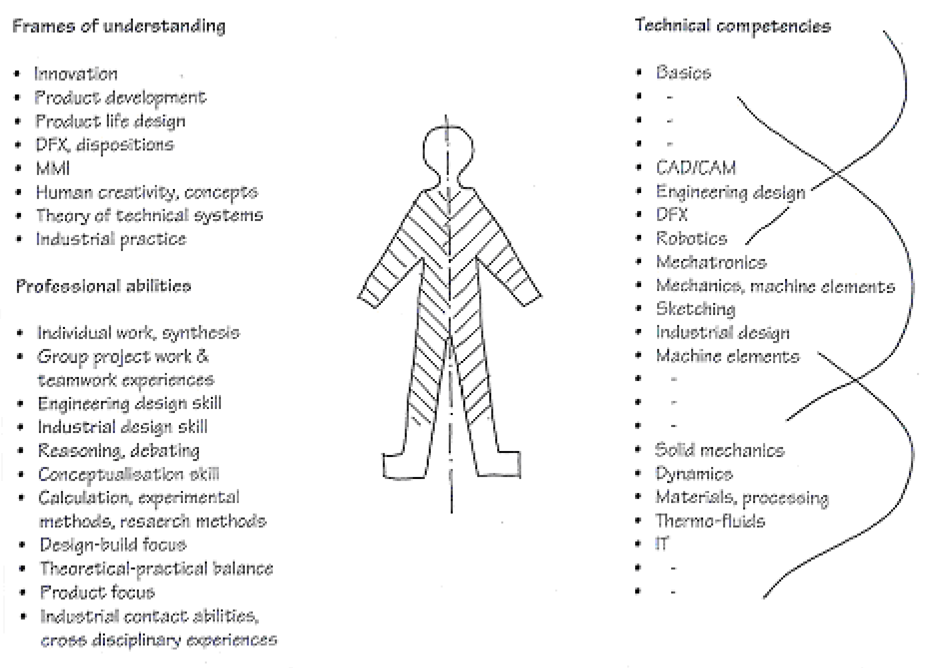

Figure 2. The specialisation for engineering design and product development has a (right hand side) technical dimension and a (left hand side) design and synthesis dimension.

3 The pedagogics of teaching design

In the previous sections we have focused upon the "what" questions related to teaching design and product development. In this section we will focus upon elements, which we believe are constituting the challenging dimension of design: how to make synthesis?

3.1 Frameworks, methodics and mindsets

Design science is a young science still lacking a crystallised theory foundation. Similarly, the knowledge of designing, see Hubka & Eder 1996, has not yet been transformed into agreed course contents, mirroring industrial needs and pedagogic choices. Some teaching institutions have such comprehensive programmes, that we can talk about "schools". Our department is regarded as such a school, based upon the so-called WDK approach, related to the works of V. Hubka, but enhanced with frameworks and theories for product development and innovation.

Our "design school" is at present suffering from a lack of teaching material, reflecting the theories upon which the teaching is based. We focus on the identified limitations in teaching methodics (Araujo 2000), making it necessary to teach the proper mindset for understanding design phenomena. Such a mindset is the quality mindset, currently being investigated by Robotham 2000, and the decision-making mindset, Hansen & Andreasen 2000.

3.2 Capturing and externalising design

The importance of designing for the user and fitting the products to their life cycle activities is evident in today's industry. The great complexity of product development (see section 1.2) and the necessity of applying teams to designing, force us to use new means for designing, for capturing the design and for externalising design.

Several means are currently utilised at our department, mirroring our graphical approach to design: worksheets, multi-boards, presentations by overheads and posters and extended use of modelling. Together with brainstorm- and scenario-techniques this is believed to enhance creativity and teamwork and to create overview and transparency of the designing.

The scientific basis for answering what and how to capture and externalise design stems from the Theory of Technical Systems (Hubka & Eder 1988), from Tjalves modelling approach (Tjalve 1979), from Man/Machine Interaction Theory and the use of scenarios for designing, see for instance Nielsen 1995, or Verplank (1993). Recently we have initiated studies of scenarios and multi-boards for life cycle oriented design and product life quality both in teaching and industrial practise, see Robotham & Hertzum 2000.

3.3 Social competencies

The ability to work in teams and networks, where different disciplines (mechanics, electronics, software, chemistry, marketing, finance etc.), cultures, and nationalities have to co-operate, is crucial for modern design. Teamwork is not obtained by letting 3-4 students share a task, it needs instruction and training. Externalisation and communication is an important part hereof.

In our teaching the students encounter teams of different sizes, from two to ten (see Fig. 1). In some courses the teachers arrange the teams and define that the teamwork has to function, in other courses, for instance the final year project (45 credit points), the student carefully seeks their own partner. Our group had an inspiring challenge in 1999, teaching innovative product development to 24 European students from 17 nations, (arranged through the BEST organisation).

The condition for developing and improving abilities, also in the social dimension, is reflections on ones own performance and contribution. Therefore we request the students to deliver a reflection report after each course module, which gives us precious feedback and at the same time forces the student to make value judgement about their own experiences and performance.

3.4 Balancing teaching and learning

Designing can only be learned by practising, which demands many project-oriented courses and exercises. But design also has systematic, teachable elements, important for building up the mindsets and understanding, which asks for lectures. Besides, the industrial conditions and working patterns must also to be lectured.

We have chosen different patterns to create a proper balance between lecturing and exercises, and in some courses we have adopted a learning-based teaching style, characterised by intensive dialogue, students self-study, students lecturing, industrial guest lecturers and visits to companies. A couple of our patterns are illustrated here:

– "Product Development": In this course we actually do not make a product, but six important aspects of product development are studied, based upon textbooks, exercises, role-plays, discussions etc. The students work out a report related to each topic, answering questions related to the topic. An examiner evaluates the reports.

– "Product Innovation": The course has a teaching part and an industrial part. The teaching part is based upon case material from Open University, which is studied and presented by small groups of students, mixed with discussions, short introductions from the teacher and industrial guest lecturers. The industrial part aims at developing new business and product concepts for companies. In the semester-start the students work in teams of 10 making intensive use of multi-boards and brainstorms. Later they split up into groups of two for detailing their innovation concept outline. The concepts are presented to the company and an industrial examiner.

– "Final year projects": Here the students work on an industrial task in groups of two, related to conceptualisation, cost reduction, DFMA, environmental design, modularization, product modelling etc. The students present their proposals to a group from the company and at the end of the study they present their results to the company and the examiner, and their reports are evaluated.

Unfortunately our teaching ambitions easily lead to a higher number of lecturer hours in the courses, while university management's aim is rationalisation. We believe that the element of craft's apprenticeship in design necessarily has to be respected.

3.5 Attitude, values and personality

The students' development and maturing is determined by aspects, which are not normally in the curriculum and course descriptions. The way they are influenced is very important for their future life as engineers and their life in society.

The ideal study is based upon:

– students having interest and being inspired
– comprehensiveness, cross-disciplinarity and relevance for the society
– exciting working- and learning-methods
– time for absorption
– examinations which are supporting the learning
– an international environment.

We believe, that we do a better job as teachers, if the students are developing professional attitudes, personal values, and interest for technical solutions and their effects for the society. The students shall be trained for innovative, responsible jobs, where co-operation and joint development in teams are typical.

The means for supporting these dimensions are multiple. For instance *"the consequences of using the multi-board concept are shared understanding of quality goals amongst the design team, changed attitudes towards customer-focused product quality, team building and ownership of the project task, resulting in designs with improved product quality that will enhance the satisfaction of the customer"*, say Robotham & Hertzum (2000).

4 Conclusion

This paper is reflecting experiences and steps taken in teaching design, product development and innovation at the Technical University of Denmark. Our teaching has not been an object for systematic research, therefore many statements are beliefs and opinions.

As a conclusion our teaching *mission* may serve, for summing up what we believe is important:

"Active participation in the education we see as an important instrument for technical and personal development. Our teaching handles many aspects of engineering design and product development. We teach the students to think, to work and to create products in a systematic way.

The systematic approach for synthesising mechanical products and systems regarding their utility and fit for humans, society and ecology, is of high importance for the future engineering profession.

The candidate from our department is professional. He or she has achieved such skills, knowledge and attitude, related to conceptualisation, embodiment and detailing, and understanding for the industry's conditions and operation, that he or she can contribute to industry with a competitive edge".

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Professor Mogens Myrup Andreasen, Department of Control and Engineering Design, Technical University of Denmark, Building 358, DK-2800 Kgs. Lyngby, Denmark, +45 4525 6258, +45 4588 1451, myrup@iks.dtu.dk.

Associate Research Professor Tim McAloone, Department of Control and Engineering Design, Technical University of Denmark, Building 358, DK-2800 Kgs. Lyngby, Denmark, +45 4525 6270, +45 4588 1451, tim@mcaloone.com.

Associate Professor Claus Thorp Hansen, Department of Control and Engineering Design, Technical University of Denmark, Building 358, DK-2800 Kgs. Lyngby, Denmark, +45 4525 6273, +45 4588 1451, cth@iks.dtu.dk.