The Design Process as Multiple and Complex Problem Solving Process

Ulrike Englisch, Pierre Sachse, Johannes Uhlmann

Human design processes may be described as productive actions – covering the way beginning with a first idea to an object to its material or virtual realization. Differences as well as common features (e.g. related to the kinds of externalization, the used methods or the criteria leading to the end of the design process) characterize various design processes: Coming from the qualitative analysis of functional/technical and non-technical (artistic) design processes various criteria for comparison were abstracted to enable the description of design processes as a continuum (cf. Englisch, Sachse & Uhlmann 2008). Bounded by the poles of functional/technical and artistic designing individual design processes may be categorized on this continuum. As a so called "mixture discipline" – consisting of functional and artistic aspects – the discipline Industrial Design may be seen.

1 Design Processes in the Field of Industrial Design – Theoretical Implications

Design processes in general may be described as complex problem solving processes consisting of so called "ill-defined problems" (cf. Carroll, Thomas & Malhotra 1980). Because of vague criteria defining the object to be designed and the lack of algorithms leading to it productive thinking (Badke-Schaub 2007) or complex problem solving (Eisentraut 1999) is undispensable. This way of thinking may be described as a non-linear (Goldschmidt 2003), opportunistic (Guindon 1990) action with systematic episodes (Hayes-Roth & Hayes-Roth 1979, Visser 2003, Hacker 2005), as a creative process which presupposes the integration of various fields of knowledge (Sachse & Hacker 1995, Badke-Schaub 2007). In addition to the progressive change of the problem´s characteristics (Badke-Schaub 2007), and the continuous reformulation of the problem (Simon 2007) it is obvious that design problems are solved and externalized on different levels of abstraction (Guindon 1990).

Special interest is given now on design processes in the field of *Industrial Design*. One characteristic of this "mixture discipline" is that for designing an object in this field the working on functional/technical as well as artistic aspects is necessary. The requests on the object in relation to its form and function lead to these various aspects to be worked on. After studying theoretical descriptions of design processes in general and in Industrial Design, the following actions dealing with problems in these fields can be seen: In a first approach to the object the form/Gestalt is externalized in rough outline – called "key concept" (Dorst & Cross 2001), „embodied design" (Roozenburg 2007), or „hypothetical concept" ("Hypothetischer Gesamtentwurf" - Uhlmann 2005). Gradually various sub-problems (cf. Carroll, Thomas & Malhotra 1980) are developing out of this externalized idea to the object. Depending on each sub-problem´s main focus they may be categorized as being rather functional/technical or artistic ones:

Externalizations in connection with the work on *functional/technical sub-problems* consist of calculations or sketches to the function of the object´s parts, and allow - if the solution principle is found - a rather algorithmic action in comparison to the work on artistic sub-problems. The design process to a functional/technical sub-problem is finished when a result is reached which is arithmetical right, and when the object has the aspired function.

In contrast *artistic sub-problems* are to be solved rather by sketches comparing different possibilities of form and colour – leading to the object´s effect. A criterion to end the work on an artistic sub-problem which is in addition valid between various subjects may not be found. The subjective assessment of the designing person and its satisfaction with the result - in relation to the object´s colour or form – leads to the end of the work on an artistic sub-problem.

Therefore there is not only a difference between the strategies to work on functional or artistic sub-problems but between their externalizations and criteria to end the design processes as well. At the same time the sub-problems occurring during the course of designing are interacting with each other: On the one side artistic solutions determine technical realization possibilities, on the other side are special artistic solutions suggested or stopped by functional/technical aspects. This way the complexity of design processes becomes obvious: In addition to multiple goals and inherent dynamics the interdependence of variables (sub-problems) can be seen as a characteristic of complex problems (cf. Dörner, Kreuzig, Reither & Stäudel 1983). The so called opportunistic action with systematic episodes (Hayes-Roth & Hayes-Roth 1979), or hybrid action (Hacker & Sachse 2006) is comprehensible as a typical characteristic of design processes. Furthermore individual design processes in Industrial Design are carried out on various levels of abstraction:

- Functional as well as artistic sub-problems are solved in relation to the initial "key concept".
- The sub-problems´ solutions are compared with the solutions of other sub-problems – related to the possibilities to realize all solutions in the aspired object.
- And they are solved as single problems – in relation to the correctness of the solution or the satisfaction with the aspired effect.

The approach to the "key concept" this way can be seen as a successive and iterative process (Carroll, Thomas & Malhotra 1980). In parallel to the problem solving process – possibly at the end of the process – a material or virtual model is made. In relation to the more simple working models supporting the work on the sub-problems this model includes the sub-problems´ solutions and a more precise assessment of the solutions´ quality in relation to the "key concept". Thus, the design process is finished when functional and artistic demands are fulfilled. As it was shown by describing the work on the sub-problems, individual assessment in relation to the form or colour of the model and the correctness of the solution leads to the end of the whole process.

On the basis of individual design processes´ characteristics individual design processes in the discipline Industrial Design may be seen as *multiple* (related to the sub-problems) and *complex* (related to the sub-problems´ characteristics) *problem solving processes* (Englisch, Sachse & Uhlmann 2008).

2 Design Processes in the Field of Industrial Design – Empirical Findings

Students in the course of studying Industrial Design (Technisches Design, TU Dresden) complete a project-orientated study (cf. Kranke 2009). Thus, they are working in the course of their study on various projects for a period of time. The support given by the university includes amongst other things the instruction for the documentation of the design process. This documentation (called "designer´s diary" or "Entwurfstagebuch") should include all the externalizations made in context with the design process (e.g. sketches, drawings, calculations or models).

As a result of a qualitative analysis of twenty students´ documentations, individual design processes could be illustrated with the help of a criteria´s catalogue. So it was possible to show the individuality of design processes and to compare the courses as well. With the method of the so called "wall paper" ("Tapetenmuster" - Hoyer 2005) individual main focuses in the course of the design process may be illustrated.

Now the contents of the documentations made by two students will be presented. Therefore the “wall papers” abstracted from the documentations are shown, supported by characteristic illustrations, and explained.

Experimental Subject 1: „Construction set for a radio controlled model of an aeroplane suitable for beginners“

The main examination with functional sub-problems is the sign for this documentation: The given problem (with the goal to optimize an existing object in relation to its functional aspects) may be seen as one cause (figure 1).

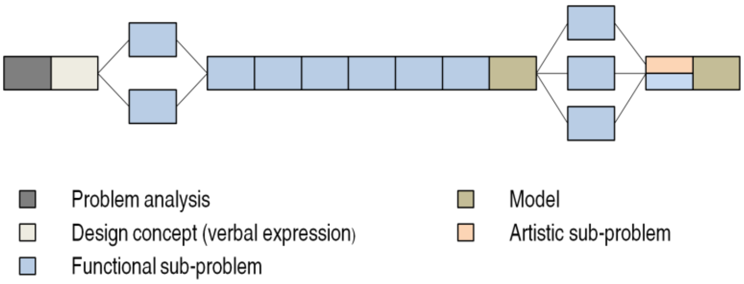

Figure 1: Diagram of the design process for experimental subject 1

The designing student starts by resolving this problem followed by working out a suitable verbal concept: “*The ideal model for beginners flies marvelously (slowly and solidly), is not expensive and easy to build.” (p. 10).* It is obvious that following this verbal approach no approach to the object with the help of sketches – no “key concept” – is documented. Immediately the student starts with working on various functional sub-problems – as there are calculations to the wings´ dimensions or the forces operating on the model aeroplane. Therefore detailed illustrations or drawings of the construction are used to resolve given sub-problems or to illustrate sub-problems´ solutions (figure 2).

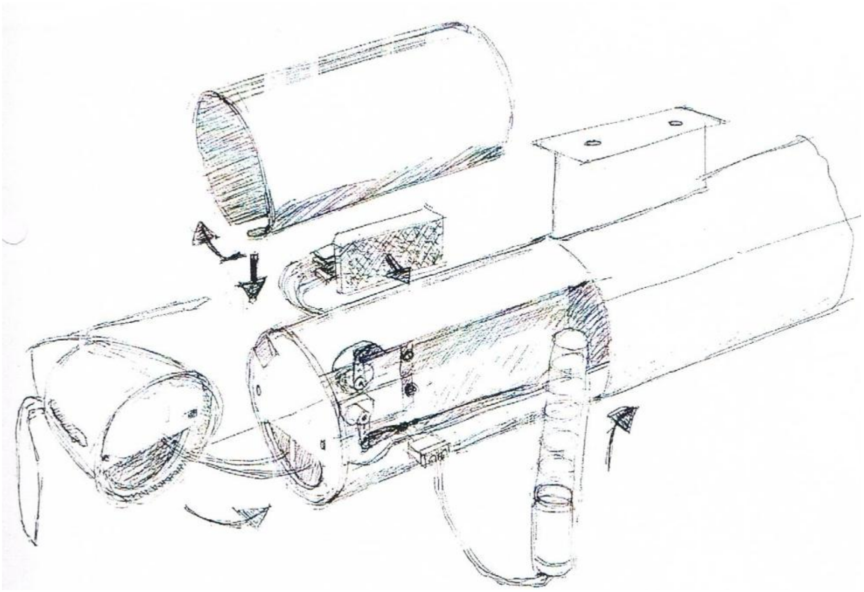

Figure 2: Example for sketches to the work on a functional sub-problem (construction of the front fuselage)

The work on artistic sub-problems – in interaction with functional demands – can only be found at the end of the whole design process – to be precise when deciding on the form of the wings´ finishing: *“The aerodynamic and optical most attractive wings´ finishing is the elliptic curve.” (p. 81)* In relation to the optical effect and functional aspects as well various variants are illustrated in comparable viewpoints (figure 3). At the end of the design process the solutions of the artistic sub-problems and of the functional ones are used to create a material model.

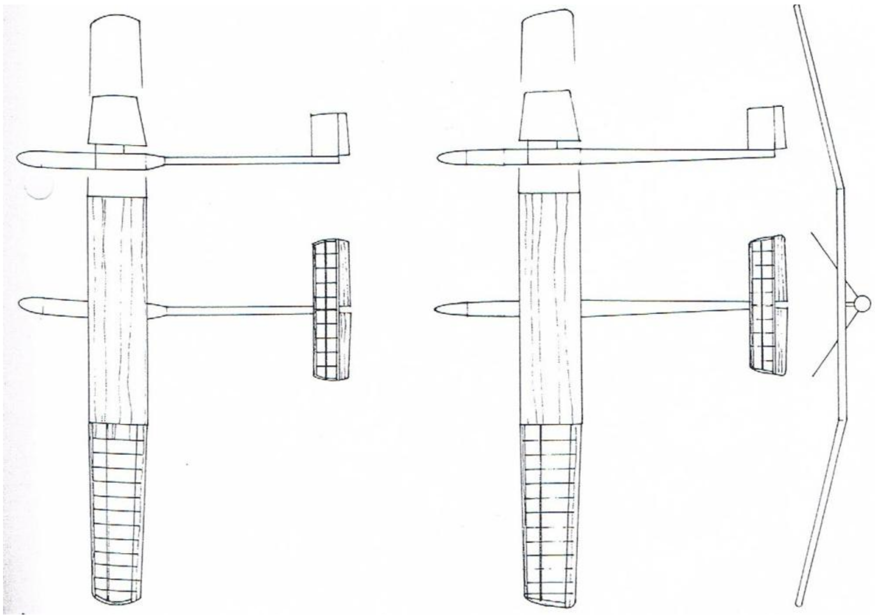

Figure 3: Example for sketches to the work on an artistic sub-problem in interaction with functional/technical demands (wings´ finishing)

Experimental Subject 2: „Functional transportation series consisting of modules for electric vehicles including the fields of leisure time and rehabilitation“

A characteristic for this design process is the main examination with various interacting functional and artistic sub-problems (figure 4).

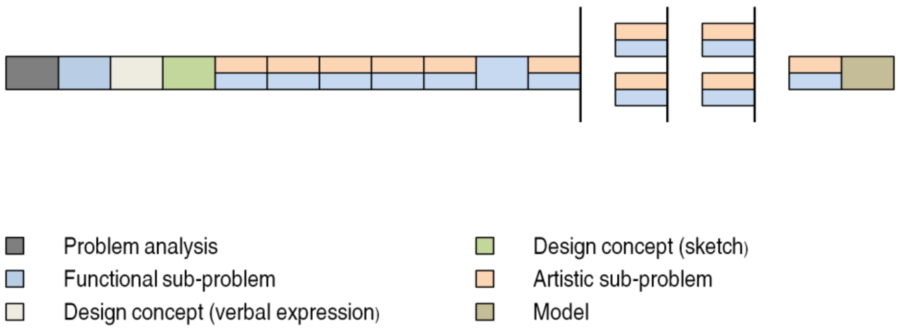

Figure 4: Diagram of the design process for experimental subject 2

A cause may be seen as well in the given problem: Working out a functional transportation series consisting of modules for electric vehicles including the fields of leisure time and rehabilitation. Following a detailed analysis of this problem the student starts by working on first functional aspects. After this initial problem solution the design concept “ally” with the artistic expression “pearl mussel” is worked out. A variety of interacting functional and artistic sub-problems to the front and the back of the vehicle arises in the following time. Again it is obvious that for the decision to an artistic solution – an artistic sub-problem´s solution – the effects of different graphic variants are tested in comparable viewpoints. Added functional aspects to the artistic problem´s solution need to be tested in relation to their technical feasibility in a next step. Verbal comments to the function or the effect help to illustrate and to explain the solutions (figure 5).

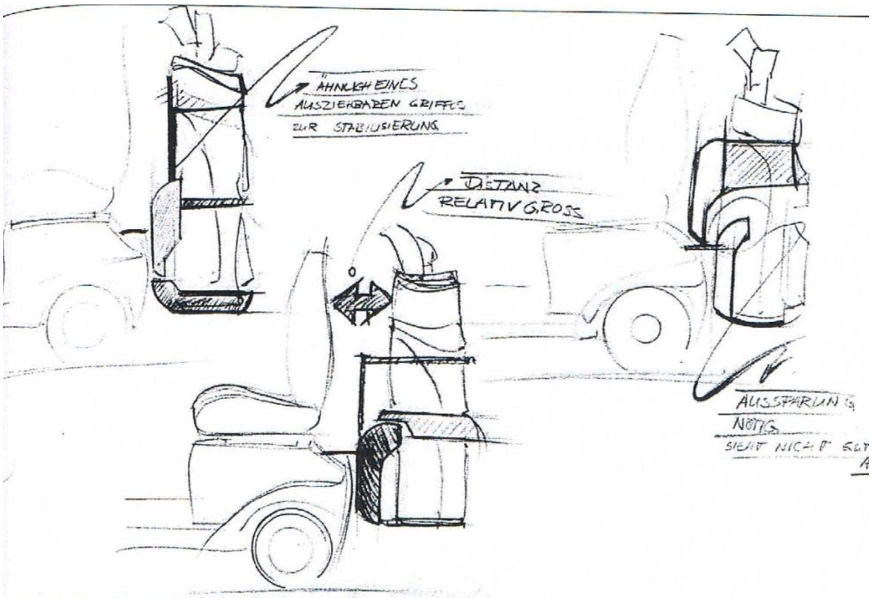

Figure 5: Example for sketches to the work on an artistic sub-problem in interaction with functional demands

Following each other (front of the vehicle) as well as in parallel (back of the vehicle) the sub-problems are dealt with by the student. An integration of the sub-problems´ solutions is made at the end of the design process with the help of a material model. At this time the student reflects: "*Finally the present result is the accessories´ series powerful solution for the transport of consumers´ items with the help of electric vehicles." (p. 100).*

3 Conclusions

It is obvious that there are differences as well as common features characterizing individual design processes in Industrial Design. Causes for the differences may be seen for example in the variety of projects or the individual style of the designing student when working on a design project. Similarities between these individual design processes lead to the assumption that there are generally applicable steps describing design processes in Industrial Design – as there is the initial work on a key concept and its externalization, or the work on various (rather functional or artistic) sub-problems.

Furthermore it can be seen that the usage of an instrument documenting the individual design process is meaningful – this instrument should have a small influence on the process itself (cf. Visser 2003) but it should help to document the course without any gaps. So the documentation is of high importance, on the one hand to control the decisions´ effects in relation to the sub-problems´ solutions (Badke-Schaub 2007), and the possibility to trace back single solutions (in the present project or over different projects), and on the other hand to communicate, and to reflect the design process.

4 Preview

Following the so called „design map" ("Konstruktionslandkarte" Schroda & Sachse 2000) a graphic instrument was developed to support the documentation and the reflection of the individual design process in various projects in Industrial Design. In addition to the design processes´ documentations in relation to the sub-problems this "Map for Industrial Design" includes and supports the reflection of the whole course.

The "Map for Industrial Design" was revised after a pretest and is at the moment in a new state of testing. The main goal is to develop an instrument which supports the documentation as well as the reflection of individual design processes in the study of Industrial Design and in the working life of designers.

5 References

Badke-Schaub, P. (2007). Why designing is best described as complex problem solving and why designers are best described as human beings. In P. Badke-Schaub, C. Cardoso, K. Lauche & N. Roozenburg (Eds.), *Design Theory and Methodology.* TU Delft, pp. 3-26.

Carroll, J.M., Thomas, J.C. & Malhotra, A. (1980). Presentation and representation in design problem solving. *British Journal of Psychology,* 71, 143-153.

Dorst, K. & Cross, N. (2001). Creativity in the design process: co-evolution of problem-solution. *Design Studies,* 22, 425-437.

Dörner, D., Kreuzig, H.W., Reither, F. & Stäudel, T. (1983). *Lohhausen. Vom Umgang mit Unbestimmtheit und Komplexität.* Bern: Huber.

Eisentraut, R. (1999). Styles of problem solving and their influence on the design process. *Design Studies,* 20, 431-437.

Englisch, U., Sachse, P. & Uhlmann, J. (2008). Comparing Actions of Creative Designing. In D. Marjanović, M. Štorga, N. Pavković & N. Bojčetić (Eds.) *Proceedings of the DESIGN 2008,* 10th International Design Conference (1009-1016), Dubrovnik, Croatia: University of Zagreb.

Goldschmidt, G. (2003). Cognitive economy in design reasoning. In U. Lindemann (Ed.). *Human behaviour in design.* Heidelberg: Springer. 53-62.

Guindon, R. (1990). Designing the Design Process: Exploiting Opportunistic Thoughts. *Human-Computer-Interaction,* 5, 305-344.

Hacker, W. (2005). *Allgemeine Arbeitspsychologie. Psychische Regulation von Wissens-, Denk- und körperlicher Arbeit.* Bern: Hans Huber.

Hacker, W. & Sachse, P. (2006). Entwurfstätigkeiten und ihre psychologischen Unterstützungsmöglichkeiten. In B. Zimolong & U. Konradt (Eds.). *Enzyklopädie der Psychologie, Ingenieurpsychologie, Reihe D/ III/ 5,* Göttingen: Hogrefe, 671-708.

Hayes-Roth, B. & Hayes-Roth, F. (1979). A cognitive model of planning. *Cognitive Science,* 3, 275-310.

Hoyer, S. (2005). Warum Robinson Crusoe Katzen dressierte – die Rolle von Motivation und Emotion für die Absichtsregulation. In P. Sachse & W.G. Weber (Eds.). *Zur Psychologie der Tätigkeit.* Bern: Huber, 71-86.

Kranke, G. (2009). *Technisches Design. Integration von Design in die universitäre Ausbildung von Ingenieuren.* München: Verlag Dr. Hut.

Roozenburg, N. (2007). Prescriptive models of the design process. In P. Badke-Schaub, C. Cardoso, K. Lauche & N. Roozenburg (Eds.). *Design Theory and Methodology.* TU Delft, 45-70.

Sachse, P. & Hacker, W. (1995). *Wie denkt, handelt der Konstrukteur?* TU Dresden: Institut für Allgemeine Psychologie und Methoden der Psychologie. Band 24.

Schroda, F. & Sachse, P. (2000). Die Konstruktions-Landkarte. Planung, Dokumentation und Selbstreflexion des Konstruktionsprozesses. *Konstruktion*, 3/2000, 48-50.

Simon, H. (2007). Problem forming, problem finding, and problem solving in design. In P. Badke-Schaub, C. Cardoso, K. Lauche & N. Roozenburg (Eds.). *Design Theory and Methodology.* TU Delft, 27-36.

Uhlmann, J. (2005). *Die Vorgehensplanung Designprozess für Objekte der Technik.* Dresden: TUDpress.

Visser, W. (2003). Dynamic aspects of individual design activities. A cognitive ergonomics viewpoint. In U. Lindemann (Ed.). *Human behaviour in design.* Heidelberg: Springer. 87-96.