

Historical background and aims of interdisciplinary research between Bamberg, Darmstadt and Munich

Gerhard Pahl, Eckart Frankenberger, Darmstadt University of Technology, Department of Machine Elements and Engineering Design, Magdalenenstraße 4, D-64289 Darmstadt, Germany
Petra Badke-Schaub, University Bamberg, Department of General Psychology and Methodology, Markusplatz 3, D-96045 Bamberg, Germany

This paper on interdisciplinary research between Bamberg, Darmstadt and Munich focus on three main aspects: First, a short survey is given on the historical development of design research in Germany and on the motivation for collaboration with psychologists; second, the main targets of the interdisciplinary research with psychology are discussed; third, the chronological process of the interdisciplinary research project between the work-groups in Bamberg, Darmstadt and Munich is presented. © 1999 Elsevier Science Ltd. All rights reserved

Keywords: design research, design studies, engineering design, psychology of design, systematic design

This Keynote paper was updated and modified by the editors based on elements of a paper by Gerhard Pahl¹.

¹ Pahl, G Historical background and selected results of interdisciplinary research between the universities of Bamberg, Darmstadt and Munich. In Frankenberger, E, Badke-Schaub, P and Birkhofer, H (eds) *Designers—the key to successful product development* Springer, London (1998)

² Kesselring, F 'Die 'starke' Konstruktion. Gedanken zu einer Gestaltungslehre' *VDI-Zeitschrift* Vol 86 No 21–22 (1942) pp 321–330



The field of engineering design implies processes in complex and networked situations. Processes of thought and activity are closely interrelated and defined by both individual abilities and the respective external conditions. During these processes, various paths towards a solution are pursued with varying efficiency, and mistakes cannot be excluded. The designers have to deal with incomplete information and contradicting target specifications, they have to consider side-effects and far-reaching decisions.

With the shift from judging engineering design as an artistic activity to the idea that designing can be taught², methodical design research was established. Particularly during the last few years, engineering design

research has been instituted as an important discipline with broad expectations from theory and practice. The investigation of engineering design processes is equally interesting for engineering design scientists aiming to support the daily design work and for psychologists aiming to understand general aspects of problem-solving of human beings. What is the historical background of the interdisciplinary research between Bamberg, Darmstadt and Munich?

1 Historical background and motivation

The Ilmenauer school in former East Germany first demonstrated methodical work in the area of precision mechanics with the fundamental work of Hansen, Bock and Bischoff in the 1950s^{3,4}, and this was further developed in the following years.

From about 1965 to 1980, design research worked out a more general design methodology in accordance with systems technology and by observing successful as well as unsuccessful procedures in the practice of the developing of technical products. It was an answer to the problem which was named in an article in 1967 'Bottleneck Engineering Design'⁵, coined by university lecturers who had, without exception, previously experienced successful and responsible design activities in industry.

The methodology was based on own observations, from which a more or less normative procedure was abstracted. Within the framework of the German Society of Engineers (VDI), professors came together and worked as a team under the direction of Kesselring, and as a result, in 1973 this group presented the VDI Guideline 2222 in a draft form⁶. Besides that, design method-oriented works of Rodenacker (1970)⁷, Hubka (1973)⁸, Koller (1976)⁹, Pahl/Beitz (1977)¹⁰, Schregenberger (1981)¹¹ and Roth (1982)¹² emerged and preceded well in advance by numerous lectures and magazine publications.

At the International Conferences on Engineering Design 1981 and 1983 criticism was expressed, mostly by Anglo-American scientists, concerning two aspects:

- The methods presented in line with VDI 2222⁶ and those of the individual schools are too rigid in their proceeding.
- Empirical investigations confirming the efficiency of the design methods are lacking.

Further, the publications were written in German and received little international attention, or were only partially recognised. Also, poor translations

3 Hansen, F *Konstruktionssystematik* VEB-Verlag Technik, Berlin (1956)

4 Hansen, F *Konstruktionswissenschaft—Grundlagen und Methoden* Hanser München (1974)

5 VDI-Fachgruppe Konstitution (ADKI) Engpaß Konstruktion Konstruktion 19 (1967) pp 192–195

6 VDI-Richtlinie 2222 *Konzipieren technischer Produkte Blatt 1 (Draft)*, VDI-Verlag, Düsseldorf (1973)

7 Rodenacker, W G *Methodisches Konstruieren* Konstruktionsbücher Bd. 27 Springer, Berlin (1970)

8 Hubka, V *Theorie der Maschinensysteme* Springer, Berlin (1973)

9 Koller, R *Konstruktionsmethode für den Maschinen-, Geräte- und Apparatebau* Springer, Berlin (1976)

10 Pahl, G and Beitz, W *Konstruktionslehre—Handbuch für Studium und Praxis* Springer, Berlin (1977)

11 Schregenberger, J W *Methodenbewußtes Problemlösen—ein Beitrag zur Ausbildung von Konstrukteuren* Haupt, Bern (1981)

12 Roth, K *Konstruieren mit Konstruktionskatalogen* Springer, Berlin (1982)

and several extreme theoretical presentations at conferences contributed to the misunderstandings.

With the onset of the 1980s, in spite of continued intensive work on design methods, no essentially new insights into methodology appeared. Instead, so-called ‘white fields’ were worked on, such as the completion of catalogues, creation of systematic representations of narrower fields of knowledge, and the refinement of evaluation methods, etc. Early cost recognition, which was promoted especially by Ehrlenspiel in his design book ‘Constructing Cost-effectively’ (1985)¹³, proved a valuable addition to the field. In this area, productive co-operation developed between the institutes in Munich and Darmstadt in the early 1980s.

What had been achieved up to this point had clearly shown the technical processes and partial goals necessary for the development of a technical product. It also produced a series of useful singular methods. However, we did not recognise how man, with his creative capabilities, can optimally contribute to such a process. We came to the conclusion that new impulses and insights into the further development of design methods could only be obtained if we escaped the boundaries of our profession and sought collaboration with cognitive psychologists. Research on ‘Design as an Intellectual Process’ by Ehrlenspiel and Rutz¹⁴ and papers on dealing with uncertainty and complexity in the ‘Lohhausen’ project¹⁵, developed under Dörner’s supervision in Bamberg, provided the crucial starting point for this undertaking.

2 *Targets of interdisciplinary collaboration*

The much cited, but not very well understood process of synthesis during design, requires close investigation of the designer’s behaviour in thought and action. The ability to solve problems is not determined by knowledge of the technical system alone but also by experience with problem-solving strategies and by personal traits, for example, by individual heuristic competence.

In an attempt to penetrate the design process from a psychological point of view, the following targets were set for the interdisciplinary empirical research:

- Clarification of the process of thinking, i.e. how do designers think during problem-solving? How do they arrive at a good solution?
- Which intellectual and procedural barriers exist and how are they overcome?
- Which mistakes in thought and action dominate?

13 Ehrlenspiel, K *Kostengünstig Konstruieren* Springer, Berlin (1985)

14 Rutz, A *Konstruieren als gedanklicher Prozeß* Diss. TU München (1985)

15 Dörner, D, Kreutzig, H W, Reither, F and Stäudel, T (eds) *Lohhausen. Vom Umgang mit Unbestimmtheit und Komplexität* Hans Huber, Bern (1983)

- Can a successful process of thinking and reasoning be described and how can it be supported?
- Are the proposed procedures and methods of design methodology according to VDI 2221 or, respectively, Pahl and Beitz¹⁰ a reasonable foundation on which improvements should be made?
- How should design procedures and methods be fashioned, adapted or changed to realise a more effective creative process?

With these stirring questions in mind, we made a conscious effort to move beyond the design methodology as it existed at the time. It was also clear that in doing so, the design methodology and our own methodical attempts could come under fire. But this risk had to be taken if we were to further develop design methodology.

Initially we received quite massive objections from referees, who were sceptical about the prospects for success of our unconventional collaboration. In particular, our colleagues who concentrated specifically on systematic methods could not understand how this interdisciplinary research could lead to new knowledge on physical effects, catalogue contents, and systematic methods. The aspect of a better understanding of the designer as the person who instigates action, and the idea of supporting the process of thinking and reasoning of the designer seemed to be suspect and unnecessary. We referred to the fact that processes in the designer's head could not be grasped and understood by only focusing on the technical system.

3 Short survey of the design thinking research projects

Thanks to the financial support of the German Research Council (DFG), thought and action behaviour of engineering designers have been investigated, since 1986, in a co-operation of cognitive psychologists (Prof. Dr D. Dörner, Psychology II, Bamberg University) and engineering design methodologists (Prof. Dr -Ing. K. Ehrlenspiel, Engineering Design in Mechanical Engineering, University of Technology Munich, and Prof. Dr -Ing. G. Pahl, Machine Elements and Engineering Design, University of Technology Darmstadt). On retirement of Prof. Pahl and Prof. Ehrlenspiel, their successors, Prof. Dr-Ing. H. Birkhofer (1990) and Prof. Dr -Ing. U. Lindemann (1995), became involved in the projects.

The first research team consisted of the engineers Norbert Dylla (Munich) and Gerd Fricke (Darmstadt) and the psychologists Walburga Preussler and Rüdiger von der Weth (Bamberg). Also, Peter Auer, Petra Badke-Schaub, Renate Eisentraut and Kerstin Härer from Bamberg, Joachim Günther from Munich and Eckart Frankenberger from Darmstadt joined the group in the

time to follow. A chronological table of the historical background of our design research is added at the end of this paper.

Twice a year the whole working-team met to discuss the results obtained in the interval. These meetings always took place in a very collegial and friendly atmosphere. Initially we needed time to clarify the technical terms that each of us used. Soon, however, very fruitful insights emerged, which we perceived as a strong enrichment to our own ideas. The concerns initially expressed by the referees that psychologists and engineers would have nothing to say to one another were quickly dispelled, and none of today's participants would like to miss the constant exchange of thoughts and ideas.

Observations on more than 40 engineering designers during individual work in a laboratory situation and investigations of six projects in industry gave rise to a large number of publications, joint symposia^{16–18} and several dissertations. The research methods used to assess individual behaviour can be inspected in Refs^{19,20}, and those in view of teamwork design process assessment in Ref.²¹. Apart from the publications by Badke-Schaub²² and von der Weth²³, the essential basis for the results of our research can be found in the dissertations by Dylla¹⁹ (1991), Fricke²⁰ (1993), Frankenberger²¹ (1997) and Günther²⁴ (1998).

From our point of view, our interdisciplinary work was successful in two ways: first, we had an interesting and significant output involving the two professions, psychology and design. Second, the ongoing project is a positive example that interdisciplinary work can proceed in a productive way over a reasonable period of time.

4 Chronological table

Listed here are only main events and completed works. The latter have many precursors in journals and public lectures.

16 Strohschneider, S and v d Weth, R (eds) *Ja, mach nur einen Plan. Pannen und Fehlschläge—Ursachen, Beispiele, Lösungen* Huber, Bern (1993)

17 Pahl, G (ed) *Psychologische und pädagogische Fragen beim methodischen Konstruieren. Ergebnisse des Ladener Diskurses* Verlag TÜV Rheinland, Köln (1994)

18 Frankenberger, E, Badke-Schaub, P and Birkhofer, H (eds) *Designers—the key to successful product development* Springer, London (1998)

19 Dylla, N *Denk- und Handlungsabläufe beim Konstruieren* Hanser, München (1991)

20 Fricke, G *Konstruieren als flexibler Problemlöseprozeß—empirische Untersuchung über erfolgreiche Strategien und methodische Vorgehensweisen* Fortschrittberichte VDI-Reihe 1 Nr. 227, VDI-Verlag, Düsseldorf (1993)

21 Frankenberger, E *Arbeits-teilige Produktentwicklung—empirische Untersuchung und Empfehlungen zur Gruppenarbeit in der Konstruktion* Fortschrittberichte VDI-Reihe 1 Nr.291, VDI-Verlag, Düsseldorf (1997)

22 Badke-Schaub, P *Gruppen und komplexe Probleme* Peter Lang, Frankfurt am Main (1993)

23 von der Weth, R *Wie entstehen individuelle Vorgehensstile beim Konstruieren—die Rolle der heuristischen Kompetenz.* In **Pahl, G** (ed) *Psychologische und pädagogische Fragen beim methodischen Konstruieren* Verlag TÜV Rheinland, Köln (1994)

24 Günther, J *Individuelle Einflüsse auf den Konstruktionsprozeß. Eine empirische Untersuchung unter besonderer Berücksichtigung von Konstrukteuren aus der Praxis* Shaker, Aachen (1998)

| | |
|---------|--|
| 1956 | Hansen: Systematic Design ³ |
| 1967 | Bottleneck 'Engineering Design' ⁵ |
| 1970 | Rodenacker: Methodical Design ⁷ |
| 1972–74 | Pahl/Beitz: For the Practice of Design. Journal Series Design |
| 1973 | VDI-Guideline 2222, Part 1 (draft) Conception of technical products ⁶ |
| 1973 | Hubka: Theory of technical systems ⁸ |
| 1974 | Hansen: Design science ⁴ |
| 1976 | Koller: Design methods for machine, instrument and apparatus construction ⁹ |

25 Archer, Bromme, Ehrlenspiel et al (17 contributions in the section: 'New impulses for systematic engineering design'). In **Hubka, V** (ed) *Theory and practice of engineering design in international comparison. Proceedings of ICED 85* Edition Heurista, Zürich (1985)
26 Müller, J *Arbeitsmethoden der Technikwissenschaften—Sytematik, Heuristik, Kreativität* Springer, Berlin (1990)

- 1977 Pahl/Beitz: Engineering design¹⁰
- 1977 VDI-Guideline 2222 Part 1, Conception of technical products
- 1981 Schregenberger: Methodical conscious problem solving ¹¹
- 1981 Dörner et al.: Lohhausen. About dealing with uncertainty and complexity¹⁵
- 1982 Roth: Designing with design catalogs¹²
- 1984 First Meeting in Bamberg between Professors Dörner, Ehrlenspiel and Pahl
- 1985 VDI-Guideline 2221 (draft) Methodology for the development and design of technical systems and products
- 1985 Dissertation Rutz: Design as an intellectual process¹⁴
- 1985 ICED 85 in Hamburg with section, 'New impulses for systematic engineering design'²⁵
- 1985 Joint DFG proposals for the project: Processes of reasoning during design
- 1986 Acceptance of the proposals and start of the co-operation in a project
- 1990 Müller: Working methods of the technical sciences²⁶
- 1991 Dissertation Dylla: Thought and action during design¹⁹
- 1993 Strohschneider/ v.d. Weth (eds): ' Yes, just make a plan....'. Symposium¹⁶
- 1993 Dissertation Fricke: Design as a flexible problem-solving process²⁰
- 1994 Pahl (ed): Psychological and pedagogical questions in methodical design. Ladenburger Diskurs¹⁷
- 1997 Dissertation Frankenberger: Product development by teams: empirical investigations and conclusions for teamwork in engineering design²¹
- 1997 Frankenberger/Badke-Schaub/Birkhofer (eds): 'Designers—the key to successful product development'. Symposium¹⁸
- 1998 Dissertation Günther: Individual influences on the design process²⁴