Herbert Birkhofer *Editor*

The Future of Design Methodology

Springer

The Future of Design Methodology

Herbert Birkhofer
Editor

The Future of Design Methodology

Springer

Editor
Prof. Dr. h.c. Dr.-Ing. Herbert Birkhofer
Chair of Product Development and Machine Elements
TU Darmstadt
Magdalenenstraße 4
64289 Darmstadt
Germany
e-mail: birkhofer@pmd.tu-darmstadt.de

ISBN 978-0-85729-614-6 e-ISBN 978-0-85729-615-3

DOI 10.1007/978-0-85729-615-3

Springer London Dordrecht Heidelberg New York

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Cover design: eStudio Calamar S. L.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Foreword

I am very pleased to be invited to write a few words of introduction to this book of papers written for the Colloquium held in honour of Professor Herbert Birkhofer on the occasion of his retirement after a long and distinguished career. For the past two decades Professor Birkhofer has been part of a great movement in design research in a worldwide community that he has been especially instrumental in nurturing and developing. This book, which draws together leading experts in design methodology, both reflects the great progress that has been made by this community and identifies the challenges for the future development of the topic.

The book is introduced by Professor Birkhofer, highlighting the motivation and objectives and explaining the structuring of the 21 contributions into three sections. Each section comprises a number of chapters written by invited authors and with a summary by Professor Birkhofer. A conclusion addresses promising working areas for future design research. The breadth of discussion and expertise of the authors mean that the book should be essential reading for design researchers at all levels and in all disciplines!

Taken as a whole, the chapters of this book demonstrate the diversity and the achievements of research in design methodology, but also very ably illustrate the challenges that the research community faces in its future development. As such, the Colloquium is very timely, in that it has drawn out a number of very valuable suggestions on the directions the community might take, especially in working together to organise and consolidate what has been learned and to identify the research agenda for the future. In this respect I believe that the Design Society, which Professor Birkhofer so ably guided through its formative years as its first President, has a key role to play.

Chris McMahon, President, Design Society

Preface and Acknowledgements

This book developed from a reflection on the current state of Design Methodology. It aims to determine the strengths and weaknesses, finding solutions to overcome these weaknesses while maintaining the strengths. This goal can only be reached if the various viewpoints, assessments and perspectives of the international community are considered. These prerequisites are met by the fact that almost all authors are DESIGN SOCIETY members. The institution, as an international community, embraced product development and supported its further development, with many projects in the areas of research, application, education and training.

This book does not aim to determine which course is to be taken to further expand design methodology to meet the rapidly changing needs of design practice in industry and provide findings for teaching. Rather, this book is a collection of reflections, ideas, approaches and propositions for optimisation, additions or alternatives. Every author is passionate about formulating better approaches, strategies and methods to support development work. There will be the denomination of possible spheres of activity and the formulation of solution propositions, rather than *The Future of Design Methodology* being prophesied. If the book initiates discussion about the further development of design methodology within the DESIGN SOCIETY, as well as in other communities, it will have achieved its goal.

Thanks to all of the authors for their willingness to explore the future of design methodology, which they demonstrated with substantial contributions. Accepting the various obligations proves their engagement with the cause and their willingness to provide support. Special thanks go to Mogens Myrup Andreasen and Ken Wallace, who critically reviewed contributions and helped with valuable suggestions.

Special gratitude must be expressed to Shulin Zhao and Benjamin Röder at TU Darmstadt for their dedicated commitment to the editorial work and thoughtful assistance with this project. Thanks also go to Nils Lommatzsch for the English revision of this book. Additionally, Julian Sarnes performed meticulous formatting. Finally, thanks to my department, Product Development and Machine Elements (pmd) at TU Darmstadt, and employees for their willing and professional assistance on very short notice.

Springer UK provided the opportunity to publish this book. Their spontaneous acceptance and professional support is much appreciated.

Darmstadt, December 2010 Prof. Dr. h.c. Dr.-Ing. Herbert Birkhofer

Contents

1 Introduction 1
Herbert Birkhofer

Part I Specific Ways to Further Develop Design Methodology

2 Is Engineering Design Disappearing from Design Research? 21
Mogens M. Andreasen and Thomas J. Howard

3 Methodical Support for the Development of Modular Product Families 35
Dieter Krause and Sandra Eilmus

4 Risk-Driven Design Processes: Balancing Efficiency with Resilience in Product Design 47
Josef Oehmen and Warren Seering

5 Methodology and Computer-Aided Tools - A Powerful Interaction for Product Development 55
Harald Meerkamm

6 A Reuse Design Decision Support System Based on Self-Organizing Maps 67
Joerg Feldhusen, Arun Nagarajah, Sebastian Schubert and Alexander Brezing

7 Increasing Effectiveness and Efficiency of Product Development - A Challenge for Design Methodologies and Knowledge Management 79
Hansgeorg Binz, Alexander Keller, Martin Kratzer, Mathias Messerle and Daniel Roth

8 Design Theory and Methodology– Contributions to the Computer Support of Product Development/Design Processes 91
Christian Weber

9 Summary - Specific Ways to Further Develop Design Methodology 105
Herbert Birkhofer

Part II Holistic Ways to Supply, Extend or Replace Design Methodology

10 Boundary Conditions for a New Type of Design Task: Understanding Product/Service-Systems 113
Tim C. McAloone

11 Product/Service System Design and Beyond 125
Tomohiko Sakao

12 Open Product Development 135
Asko Riitahuhta, Timo Lehtonen, Antti Pulkkinen and Petri Huhtala

13 Managing Virtual Product Creation 147
Reiner Anderl

14 Systems Engineering versus Design Methodology 157
Udo Lindemann

15 The Autogenetic Design Theory-Product development as an Analogy to Biological Evolution 169
Sándor Vajna, Konstantin Kittel and Tibor Bercsey

16 Towards a Designer - Centred Methodology - Descriptive Considerations and Prescriptive Reflections 181
Petra Badke-Schaub, Jaap Daalhuizen and Norbert Roozenburg

17 A New Perspective on Product Engineering Overcoming Sequential Process Models 199
Albert Albers, Eike Sadowski and Leif Marxen

18 Summary - Holistic Ways to Supply, Extend or Replace Design Methodology 211
Herbert Birkhofer

Part III General Reflections on Design Methodology

19 What Designers Can Learn From Leonardo, an Ingenious Artist, Scientist and Engineer 221
Hans-Joachim Franke

20 "Design … but of What"? 229
Marco Cantamessa

21 Transferring Design Methods into Practice 239
Ken Wallace

22 Towards a Taxonomy of Design Research Areas 249
Amaresh Chakrabarti

23 Design Research and Education: A University Perspective 261
Dorian Marjanović

24 The Future of Design Research: Consolidation, Collaboration and Inter-Disciplinary Learning? 275
Chris McMahon

25 Summary - General Reflections on Design Methodology 285
Herbert Birkhofer

26 Conclusions 291
Herbert Birkhofer

Index 297

Chapter 1
Introduction

H. Birkhofer

1.1 Motivation

The idea for this book was inspired by reflecting decades of national and international research, working four decades in education and training, and from vast experience introducing Design Methodology in training sessions, consultations and development projects.

Looking at research today, there is an explosion of relevant work. Worldwide, an abundance of researchers is actively working in design research. Design conferences and workshops are very popular and an active design research community has developed. The amount and variety of research work makes it impossible to have an even roughly complete overview.

Design Methodology has also taken an intrinsic and important role in teaching curricula. Courses on methodical development of products have helped generations of students gain an overview of the structuring of development projects, to impart knowledge on effective methods to support particular development steps and guided them to efficiently solve development tasks, often with remarkable success. The ability to create innovative solutions within a synthesis process while using methodical and creative working methods attracts students and fills auditoriums.

In contrast, industry only reluctantly adapts design methodological models and methods (Pahl and Beitz 2007). Despite the high number of graduates with Design Methodology knowledge, researchers and practitioners conclude that methodical development is only used in part by industry and, even then, only in a rather simple, rudimentary form (e.g. morphology or simple creativity techniques). Real successes with methodology in industrial product development can only be found in a limited number of published examples (e.g. Birkhofer 1991, Schneider 2001, Birkhofer 2004). They have often resulted from cooperation between universities and industry (Lindemann 2007), where both partners bring their specific competences to a project. These collaborations achieved respectable success. However, a university's methodology is usually only partially cemented in a company.

For some time, the reluctant acceptance of Design Methodology models and methods in design practice was lamented. Some reasons are summarized in (Birkhofer et al. 2005). Nevertheless, the core problem has not changed fundamentally. The limited participation of industrial representatives at national and international design conferences is evidence of this problem.

H. Birkhofer (ed.), *The Future of Design Methodology*,
DOI: 10.1007/978-0-85729-615-3_1,

Design Methodology has achieved impressive success in research and teaching while support of it for design practice is weak and its successes there have to be judged conservatively. The questions of why Design Methodology only plays a lesser role in design practice and how the future of Design Methodology could develop in this regard are legitimate. Does the marketing of Design Methodology have to be improved? Do erroneous trends have to be compensated? Are there "burning issues" for practitioners other than those addressed by academia? Does the problem originate from insufficient knowledge transfer to product developers? Alternatively, is research in Design Methodology, due to its comprehensive requirements, so long-winded and tedious that implementation in design practice will not generate quick successes?

These questions of the value of Design Methodology to design practice are addressed in this book. The authors outline solution options and solution scenarios. Despite the domination of critical examination here, the merits of Design Methodology in education and training should not be downplayed.

1.2 Design Methodology

According to (Pahl et al. 2007) there is a distinct understanding of what Design Methodology has to be:

"Design Methodology is understood as a concrete course of action for the design of technical systems that derives its knowledge from design science and cognitive psychology, and from practical experience in different domains. It includes plans of action that link working steps and design phases according to content and organisation. These plans must be adapted in a flexible manner to the specific task at hand. It also includes strategies, rules and principles to achieve general and specific goals as well as methods to solve individual design problems or partial tasks."

To understand the strengths and weaknesses of Design Methodology in its diffusion into design practice, an overview of its development may be helpful.

1.2.1 History of Design Methodology

Design Methodology in the German-speaking world has its origins in the 19th century. The forerunners of Design Methodology were Redtenbacher (Redtenbacher 1852), Reuleaux (Reuleaux 1889), Bach (Bach 1920), Riedler (Riedler 1913) and Zwicky (Zwicky 1966). Reuleaux in particular justified the demand for an independent Design Methodology. In the middle of last century, Wögerbauer (Wögerbauer 1949) and Kesselring (Kesselring 1951, Kesselring 1954) created groundbreaking work, influenced by the pressure of scarcity caused by war. Postwar, their achievements and results were supplemented with the stronger design-

oriented works of Tschochner (Tschochner 1954), Matousek (Matousek 1957), Niemann (Niemann 1975) and Leyer (Leyer 1974). Based on their findings from scientific and pragmatic approaches, classical Design Methodology developed. It is identified with the names Rodenacker (Rodenacker 1970), Pahl and Beitz (Pahl and Beitz 2007), Roth (Roth 1982), Koller (Koller 1985) and Ehrlenspiel (Ehrlenspiel 1985). Pahl and Beitz's (Pahl and Beitz 1977) book "Konstruktionslehre", with its seven print runs, became a signpost of modern Design Methodology. Due to its translation into several languages, it influenced the development of Design Methodology worldwide. Hubka (Hubka 1974, Hubka 1976, Hubka 1984), born in the Czech Republic and migrated to Switzerland after exile in Denmark, has a special role. Together with Eder (Hubka and Eder 1992), he published his still groundbreaking work that began modern design science. Bischoff (Bischoff 1953), Bock (Bock 1955), Hansen (Hansen 1966, Hansen 1974) and Müller (Müller 1990) created independent Design Methodology in the German Democratic Republic after the separation of Germany. After German reunification, Design Methodology increasingly expanded into a methodology for product development. The representatives of this more holistic approach were, in particular, Albers (Albers 1994), Binz (Binz 1994), Birkhofer (Birkhofer 1990), Feldhusen (Feldhusen 1994), Franke (Franke 1984, Franke 1985), Höhne (Höhne 1983), Lindemann (Lindemann 2007), Meerkamm (Meerkamm and Wartzack 1998), Weber (Weber 2007) and Welp (Welp 1998).

The development of Design Methodology began later in Great Britain. In the beginning, Ashford (Ashford 1969) and Mayall (Mayall 1967) emphasised the relevance of Industrial Design. Wallace (Wallace 1952) and Jones (Jones, Thornley 1963) were the first to develop models of designing, which Feilden (Feilden 1963) put in the context of engineering education in the Committee on Engineering Design led by him. In the beginning of the 1960s British work in Design Methodology flourished with the work of Archer (Archer 1964, Archer 1971), Cross (Cross 1972, Cross 1984), French (French 1985, French 1988) and Wallace (Wallace and Hales 1987).

In Scandinavia, Design Methodology since the 1960s was shaped mainly by Jeppesen (Alger, Hayes 1964), Tjalve (Tjalve 1972, Tjalve 1979) and Andreasen(Andreasen et al. 1988, Andreasen and Olesen 1990, Andreasen and McAloone 2008). Development began by compiling methods for synthesis, which were then extended with DFX methods and mechatronic components to form the concept of a "designer's workbench". At the same time, important research on life cycle thinking and the consequent extension to "Product Service Systems", "modularization" and "product development" were published. Riitahuhta (Riitahuhta 1997) advanced the methodology of modularization in Finland.

Pighini (Pighini 1990) and Rovida (Rovida 1987), in close cooperation with Hubka, advanced Design Methodology research in Italy.

In Russia, Orlov (Orlov 1977) carried out initial research on Design Methodology. In a substantial patent analysis, Altschuller summarised the findings into an

algorithm that later became the TRIZ methodology (Altschuller 1973, Altschuller 1987).

In the USA, efforts of authors such as Gordon (Gordon 1961), Osborne (Osborne 1963), Krick (Krick 1969), Dixon (Dixon 1966) and Simon (Simon 1977) focused on finding a better understanding of design work and goal-oriented support of specific focal points, e.g. creativity and invention. Others, such as Miller (Miller and Starr 1967) and Nadler (Nadler 1967), concentrated on the management of product development. Newer workings with a strong practical relevance came from Ullman (Ullman 2002), Wood (Ullman et al. 1990) and Eppinger (Ulrich and Eppinger 1995). Suh (Suh 1989) presented a heavily formalised approach to Design Methodology.

Yoshikawa (Yoshikawa 1983) and Hongo (Hongo and Nakajima 1991) in Japan, Samuel (Samuel and Weir 1999) and Gero (Gero 1985) in Australia contributed to worldwide research.

The development of Design Methodology in other countries and contributions by authors not mentioned here are presented in detail in (Hubka and Eder 1992) and (Pahl and Beitz 1984).

Overall, Design Methodology research has a long tradition. It was regionally diverse and strong, but, since the 1970s, there has been a global understanding of the need to support design work with scientifically sound approaches.

1.2.2 Goals and Subjects of Design Methodology

Design Methodology was created to supersede the prevailing understanding of design as an art, or at least to extend it with rational models and methods based on a framework of theories from the rapidly developing natural sciences.

According to (Pahl and Beitz 2007), Design Methodology enables an appropriate, controlled and verifiable procedure to obtain resilient solutions. Independent of business type and application areas, the use of Design Methodology supports scientific findings and inventions, eases design workload and increases efficiency and effectiveness when compared to a purely experience-based, creative approach. Therefore, Design Methodology explicitly aims to support design work, especially in industrial companies.

The elements of Design Methodology should be compliant with other science disciplines and should be suitable for use in electronic data processing equipment. Yet another essential goal of Design Methodology is to create a framework of models, procedures, methods and rules that allow design to be taught in education and training, thus increasing designer qualifications. Since design work has a major impact on the welfare and prosperity of society, this social demand is indirectly accommodated too.

The revaluation of design work associated with the development of Design Methodology will attract talented, academically interested engineers, counteract-

ing the “Design as a bottleneck”, coined in VDI (1967) in the 1960s to address weaknesses in capacity of design departments.

A series of authors of design methodological research accentuated the interplay between a systematic procedure, based on scientific work, and a creative thought and action, based on experience and intuition of the individual designer. However, the likelihood of the two approaches being treated equally or one approach being accentuated evidently depends on the individual experience of the author, their geographic background and the scientific culture they grew up in (Birkhofer and Zhao 2010). While creative work is particularly encouraged in the USA, the systematic course, following a formalized and prescribed approach for design, is emphasized in Germany. This course of action peaked in the rather extreme approach of algorithmic design heuristics of the Ilmenau and Chemnitz schools (Hansen 1966), (Müller 1990).

Aside from underlining the intuition and individuality of the designer, a dominant motivation for further developing Design Methodology lies in the drive to rationalise the design process. Thus, Pahl and Beitz reason in (Pahl and Beitz 2007) that the work force is valuable and that methodical design should support division of labour.

1.2.3 Further Development of Design Methodology

There have been multiple trends in the development of Design Methodology in recent decades.

For a long time, efforts to support design were focused on the design object (Hubka and Eder 1992). An abundance of methods, rules, and guidelines regarding the design of mechanical elements, components and products exists to render engineering findings usable in design practice. Back then, engineering and design were in unison.

At the end of the 1980s, mechatronics, with its mechanical, fluid, electrical, electronic and software components, became increasingly popular with researchers. Questions regarding system integration and the embodiment of interdisciplinary and trans-disciplinary work determined research. Currently, the area of objects considered has been widened to adaptronic and even intelligent systems that recognise and evaluate their surroundings independently, and adapt their behaviour in a goal-oriented and autonomous way.

Classical Design Methodology exceeded the sole consideration of just designing objects and was strongly devoted to the consideration of the overall design process. Therefore, Design Methodology was extended with findings, models and procedures from other sciences, such as system theory, cybernetics, economic science, computer science and psychology, to become a process modeling and action-defining science (Mortensen 1997). Procedures, guidelines and development

strategies have been formulated, thus going beyond the borders of classical engineering.

As a new but equally influential and elusive dimension of development work, empirical design research (Frankenberger et al. 1998) placed the person as the protagonist from the middle of 1990s on. Parallel to this, communication and cooperation within a company and with external stakeholders was analysed and modelled. With the help of models and methods from economics and social sciences, prescriptive suggestions were derived for more efficient development and for design based on descriptive statements of a current state. Additional requirements of Design Methodology were generated by the rapid internationalisation and globalisation of development and company activities in the last two decades.

Another trend in product development is the use of extensive and extremely powerful computers (Krause et al. 2006). While classical Design Methodology was supported mainly "by hand", e.g. design catalogues (Roth 1982), applied computer science became more important in the support of design since the 1970s. Originally considered as a data processing tool, applied computer science quickly developed from providing 2D and 3D systems for graphical representation of design objects (Grabowski et al. 1991) to comprehensive and powerful tools for parallel geometry modeling and behaviour simulation of products and systems (e.g. digital mock up). New ways of visualisation (Virtual Reality and Augmented Reality) as well as powerful Product Data and Life Cycle Management Systems extended the functional range of supporting tools drastically. The aim is to map design knowledge in Knowledge Management Systems to achieve better access and greater universal utilisation of design-relevant knowledge.

During recent decades, the boundaries of design activities were increasingly extended to product development considering influences from entire life cycle (Figure 1.1).