# Are We Aware of What We Are Doing in Design Research?

## (Design Research between Science and Practice)

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## Abstract

This contribution analyzes Design Research in its past and current status with regard to a prevailing opinion, that besides great success there remain weaknesses and deficits due to its uncontrolled proliferation and fragmentation of contents, topics and goals. It describes an attempt to trace back irritating phenomena in the not explicitly articulated field of conflicts between the wish of design researchers to be acknowledged as working scientifically and the need to contribute in the same way to design practice. A first step to approach the problem might be to clarify the roles a design researcher plays or wants to play, and to focus his research activities on properly defined objectives.

**Keywords:** Design Research, Engineering Design Science, Design Methodology, design practice, science, lifecycle, customer focus

## 1 Introduction and motivation

Design Research has grown up substantially to an internationally performed and widely accepted discipline within the area of engineering research. A huge number of design researchers as well as lots of conferences and workshops demonstrate its worldwide attractiveness and the vividness of the Design Research community.

Although Design Research has matured dramatically in the past decades, its development has been uncontrolled, evolutionary and was stamped substantially also by non-rational influences from cultures, countries and schools. Being involved in designing (the process of creating technical systems and products) and Design Research for more than 40 years [1], the author wants to reflect Design Research critically in regard to its development, to its manifestation and to ongoing discussions and open questions. Many remarks from students, researchers and colleagues address true or imagined weaknesses, deficits or undesirable trends. Numerous discussions point to the right problems but mostly do not result in conclusive attempts which contribute to solutions.

This paper tries to point out some answers, of course not for all problems mentioned, and of course no holistic and final ones. This contribution should rather be seen as an attempt to demonstrate a feasible way to get a better understanding of Design Research, to contribute to the clarification of the issue and the understanding of the self-image as a design researcher. Hopefully, it may initiate a discussion within the community which gives new impulses for reflection and improvement.

## 2 Some criticism of Design Research

An overview of the past decades of Design Research shows that some characteristics are present throughout this kind of research.

First, a substantial enlargement and fragmentation of research topics is obvious over time [2]. The numbers of issues addressed in design conferences increased dramatically (**Fig. 1**).

Visiting big design conferences, the participant tends to get lost within the variety of sessions, topics and themes offered.

Second, Design Research obviously didn't attract designers. Analyzing roughly the authors of a big design conference like ICED'13 [3], even nowadays academic authors dominate (**Fig. 2**).

Surprisingly, a conference on "Engineering Design" – a topic of interest to the industries - attracts only quite a small amount of authors and also participants from industry.

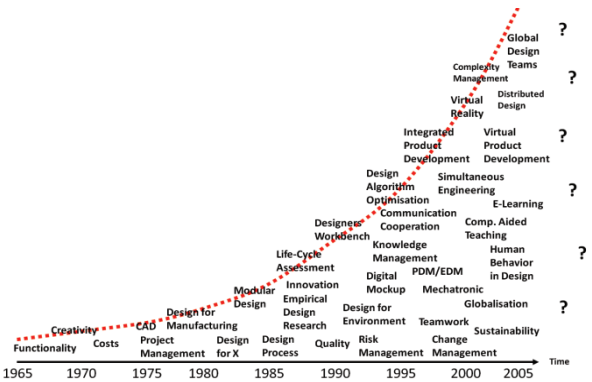


**Fig. 1 Explosion of Design Research subjects over time (1965 until 2005)**

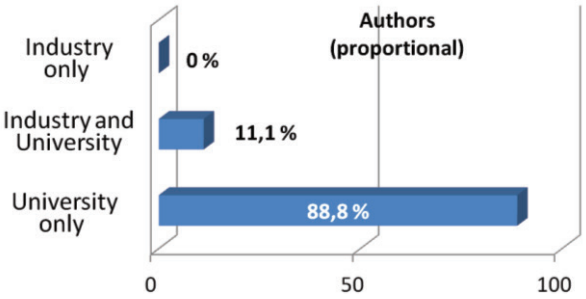


**Fig. 2 Distribution of authors (ICED'13) [3] according to their origin (academia and/or industry)**

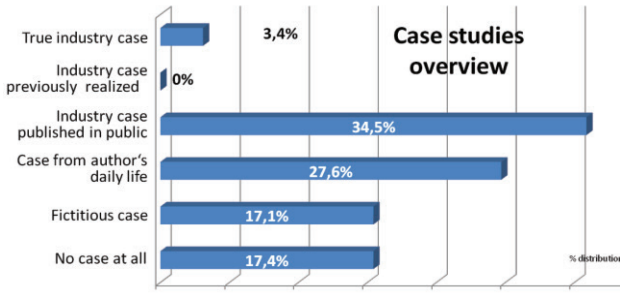


**Fig. 3 Typology of case studies in ICED'13 [3] papers**

Third, research on design and designing mutates on and on to negotiations far away from industrial context. Once again, a rough analysis of case studies within the ICED'13 [3] contributions (**Fig. 3**) demonstrates a substantial percentage of contributions without any or - if they do - fictious or limited industrial case studies.

In total, Design Research is mainly carried out by academia and hence influenced by its tradition as well as substantially seems lacking the needs and requirements of design practice.

The subsequent chapters start with a formalized review of what makes designing, Engineering Design Science and Design Methodology, to provide insights into the differences and similarities. Further some conclusions are drawn out of the findings, why designing offers such a wide area of research activities and what could be done within Design Research to balance science and practice.

## 3 The nature of designing

Presenting in snapshots a specific design project of a small 3D-adjuster for positioning fiber-optic cables (**Fig. 4**), one can see several states of design work (results, conditions) as graphs and connecting processes as arrows.

To clarify what's happening in general during such a

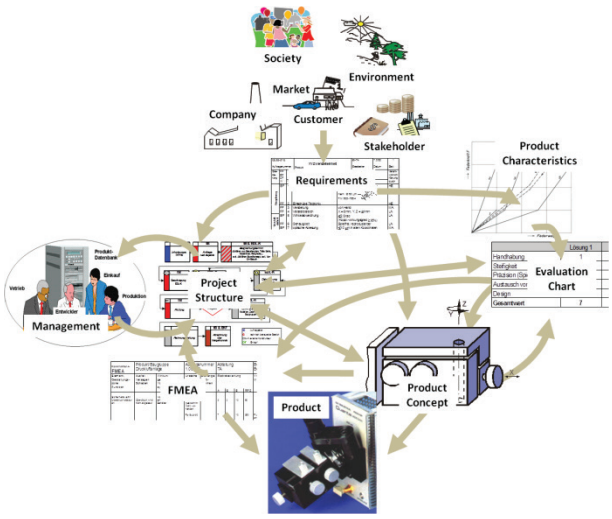


**Fig. 4 Snapshot view of processes and results for the development of a xyz-adjuster for fiber-optic cables**

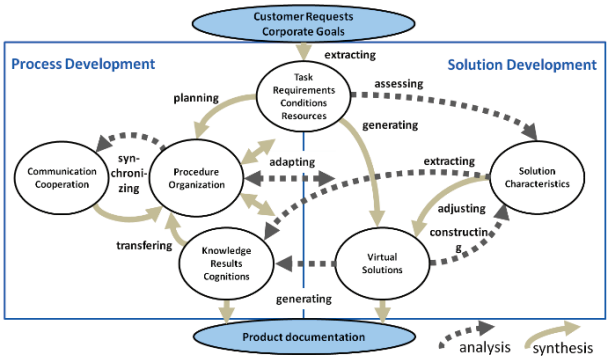


**Fig. 5 Design process with its elements and sub-processes abstracted and formalized**

design project, **Fig. 5** formalizes the content of **Fig. 4** on a commonly used process modeling approach [4]. Even if this presentation is - compared to the complexity of a real design project - highly reduced and abstracted, one may recognize various processes which result in the solution as well as processes to develop the designing itself. Steps of analysis and synthesis take turns in a complex, diverse and cross-linked manner and it's obvious, that designing is not at all a standardised procedure with fixed steps. On the contrary, it's really a complex process of applying knowledge, using experience, getting insight, recognizing new items and relations and permanently adapting the subsequent design steps on past, achieved and expected results.

Besides the product and process related activities, various influences from outside like customers, markets, suppliers or competitors affect designing as well as influences from the company itself like those from controlling, production, sales or management. Designer use a huge set of data, knowledge, models, methods and tools and the entire set of processes of acquiring, transforming and creating information has to be seen as an outstanding characteristic of design work.

It's obvious too, that human related characteristics like motivation, creativity, mental capabilities or experience are highly relevant for design work and its efficiency and effectiveness.

To sum up one may say, that designing has to be regarded as an extremely complex way of problem solving in a various and dynamic environment. That's why design work offers such a broad platform for this huge diversity of research activities illustrated in **Fig. 1**.

## 4 Supporting designing by research

Designing is substantially supported by research, but what kind of research? Is it a rather fundamental research like the one in mechanics or even mathematics? Could it be a more applied research like it is done e.g. in research on manufacturing technologies? Is there a scientific basis in design related research? Are design researchers really scientists?

Trying to get an answer, one may have a look on statements of experienced design researchers. Pahl&Beitz [5] define e.g.: "The substantial task of an

engineer (designer) is to find solutions for technical problems by the means of Natural Science and Engineering Knowledge".

Whereas "Natural Science" is fairly well defined, the term "Engineering Knowledge" seems to be vague and ambiguous. In fact, if we have a closer look on research activities supporting designing, it covers manifold engineering, natural, economic and social aspects, facets and nuances. That means too, it's no major problem for an individual researcher to detect a novel research area related somehow to design. And it's easy for him to tackle there a specific research question never been tackled before demonstrating his originality and innovativeness.

But besides the variety and diversity of Design Research activities, fundamental questions have to be asked on such a research

(a) To what and to whom this specific research activity is contributing to?
(b) Is this research linked to or based on science or is it linked to and based on something else?
(c) Does the entire set of research activities and results contribute to an item called Engineering Design Science and what makes this item similar or different to "established sciences"?

In the following the support of design work via research in general will be highlighted to get insights into the characteristics of design related research activities and to sort out a structural approach. This will be used finally to draw some conclusions for the assessment and even harmonisation of Design Research itself and for the "marketing" of Design Research outcome in publications, workshops and conferences.

### (1) Supporting designing by research on science

#### ① *Supporting designing by research on Engineering and Natural Sciences*

Engineering and Natural Science use steps of analysis and synthesis to create scientific and universally applicable theories (**Fig. 6**).

The inductive procedure observes phenomena of the real world, derives and evaluates hypothesis and formulates models and methods. These may be used to predict new or unknown phenomena in the real world, what is called a deductive procedure.

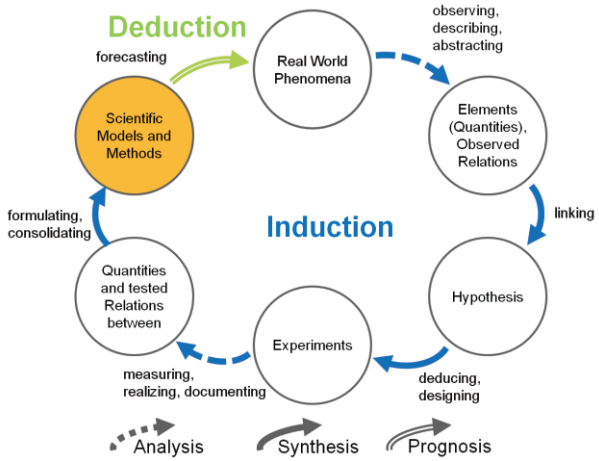


**Fig. 6 Science based research process with its sub-processes abstracted and formalized**

As a fundamental prerequisite of such a scientifically based research approach the results have to be universally valid and transferable. Everyone starting with a given set of initial conditions will consequently get the same result. The process of reasoning and getting results must be verifiable and understandable without any influences of individual factors like interpretation or estimation.

At that point, by reflecting the results of past and current Design Research and applying this rigid standard of Natural and Engineering Sciences reasonable doubts keep already raising. Do the current body of knowledge on design and the entire outcome of Design Research activities indeed fulfil these rigid criteria? And what about this construct called Engineering Design Science [6]? Does it fulfil the criteria mentioned above too?

#### ② *Supporting designing by research on Social Sciences*

Designing isn't a purely technical activity, but it is highly influenced and often dominated by characteristic features of individuals and by interactions between individuals (groups, teams, hierarchies etc.). Consequently some design researchers [7] argue that a science of design should be a holistic concept of science containing a science of artefacts as well as a science of actions. This leads directly to the assumption that Social Sciences and in particular cognitive psychology may contribute to support design work. Consequently, design researchers co-operated with psychologists and sociologists [8] since the mid-eighties of the last century to proceed in that research area what is called Empirical Design Research.

After intensive negotiation with the role of cognitive psychology [8, 10] however it must be noticed, that Social Sciences present plenty of theories and models basically useful for designing, but most need substantial adaption to the design context, part of it has to be seen as a long-termed task.

#### ③ *The need for research on a holistic Engineering Design Science*

Engineering, Natural and Social Sciences contribute amazingly to design work. The outstanding success of engineering products and the omnipresence of engineering in daily life demonstrate impressively the success not only of design work but of the related beneficial input of sciences in general. Science enriches knowledge for design dramatically and enables designers to achieve its current performance.

But looking back once again at **Fig. 5**, nevertheless, one must notice, that science supports only partly the design process in its entire complexity.

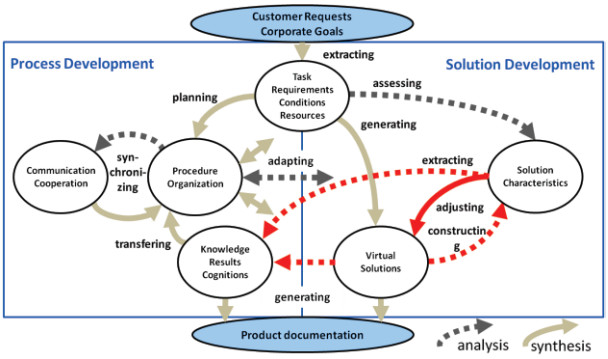


**Fig. 7 Support of Engineering and Natural Sciences to designing**

Engineering and Natural Sciences both focus on modelling and optimizing products, properties and their characteristics (**Fig. 7**). A substantial support of processes like defining design tasks, generating product ideas or deriving adequate design activities from a given embodiment design is widely missing.

The role of Social Sciences with regard to the contribution and support of design work may be demonstrated similarly. Even though the evidence cannot be provided in detail, **Fig. 8** indicates a rough idea which design processes might benefit from applying knowledge, models and methods from Social Sciences. Like the support of Natural and Engineering Sciences only a few but other design processes may benefit. It has to be stressed out this doesn't say anything neither about the effort for applying findings of Social Sciences to a specific design context nor about the actual benefit itself.

From a demand oriented point of view it's obvious that there is an urgent need for a kind of science like it was addressed by several authors [6, 11, 12, 13]. This science should relate, integrate, harmonize and develop design related theories, axioms and models of other sciences and create a coherent body of knowledge, models and methods, enabling design researchers to describe, analyse, model and support designing.

Based on the view of theories of science one should wonder that by saying there might be no evidence whether such a holistic kind of science [25] exists at all. Engineering Design Science as a rallying point and even as a unification of sciences seems to belong more

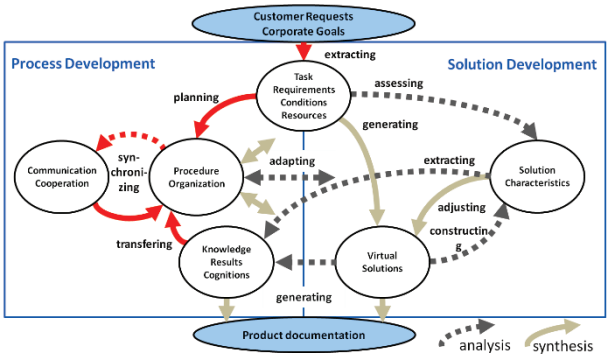


**Fig. 8 Support of Social Sciences to designing**

to the sphere of utopia than to the sphere of reality. Until now this concept of an "Engineering Design Science" isn't clarified precisely. Nevertheless, research on the way to it is one of the most challenging and at the same time fascinating activities for researchers.

### (2) Supporting designing by research on methodologies

Widely used in design work are design methodologies, methods and tools based on proposals of individual researchers [5, 7, 14, 15, 16, 24] or research schools and communities [12, 17]. Such methodologies are extremely valuable for design practice and cover the entire set of sub-processes and activities in designing (see **Fig. 9**).

Empirical design studies proved that the expertise and competence of an individual designer is highly based on the skilful use of elements of such methodologies (**Fig. 10**). The skill is strongly developed all the more as related strategies, methods and rules are internalized and used as a kind of individual thinking routine.

In the past many researchers contributed and still contribute to that body of design knowledge, producing a variety of methodical support for design work.

Jänsch [18] analysed these proposals and considered them as a kind of summarized product or process knowledge of experts in specific areas of design work.

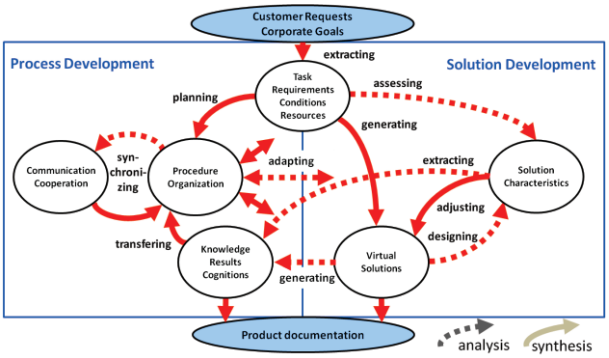


**Fig. 9 Support of Design Methodologies to designing**

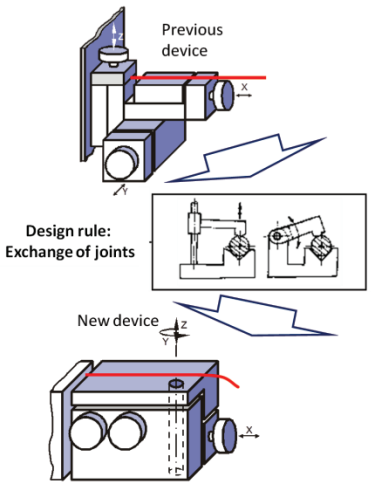


**Fig. 10 Substantial improvement of a 3D-coordinate adjuster by applying the design rule "exchange of joints"**

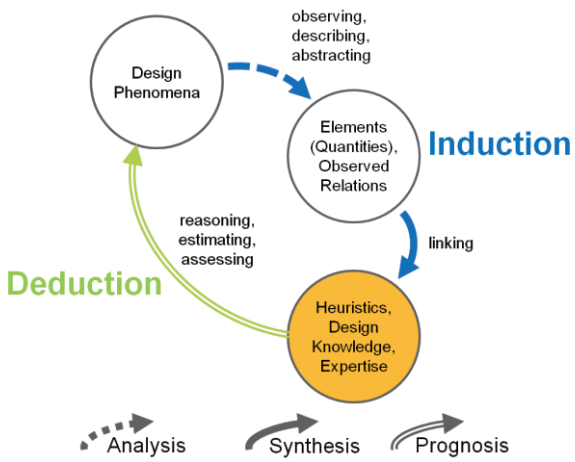


**Fig. 11 Methodically based research process with its sub-processes abstracted and formalized**

Analogously to the formalized generalisation of science in **Fig. 6**, one can describe such a process of creating methodical proposals (**Fig. 11**).

Observing phenomena while designing, an expert summarizes and condenses his observations and reasoning to an expertise which may be used individually or is published for the use in a community.

Such expertise transformed into methods and tools usually is called a heuristic. Heuristics support design work substantially and a lot of published case studies [1, 5, 7, 12, 14, 15, 20, 24] demonstrate the successful use in daily design work.

**(3) Engineering Design Science and Design Methodologies**

Comparing the processes of research in science and methodologies one can see similarities: an inductive part deriving hypothesis by observing phenomena in products and processes. But in contrast to science (see **Fig. 6**) in the process of creating methodologies (see **Fig. 11**) a formal deductive part with rigid proofs by verification and evaluation, and therefore legitimate claim for generalization is missing. It is rather a qualitative process of generalization that takes place, mostly performed in the mind of the individual researcher. Looking unemotionally on the nature of such a methodical support, one has to argue, it spares the essential criteria of science like universally validity and transferability. Methodologies have to be characterized as well-tried, virtual procedures rather than as proven truth.

In addition, compared to science elaborated axioms, paradigms or theories are missing in methodologies. Advices, case studies, hints and tips dominate, formulated by researchers to ease the use. This inherent vagueness of methods and the related uncertainties in the use are crucial for beginners exploring a design method, whereas advanced designers (better: advanced methodologists) may fall back on experience and practice by using a method for adapting it to a specific design context or even "playing" with it to test its power. Cognitive psychologists [19] label this professional dealing with design methods as "heuristic competence".

In a sarcastic interpretation one may argue, that working methodically substitutes the effort "to learn" designing by the effort "to learn" using methods properly, which in the end might be the same.

**(4) First summary and conclusions**

Research on designing is manifold in regard to themes and topics and created a huge variety of output in the past. At first glance one can differentiate research activities in fundamental, scientifically based approaches and in applied, methodological ones. Each approach is governed by specific rules, obeys specific criteria, serves specific purposes and addresses specific "customers".

Scientific based Design Research turns for the related science community, is evaluated using criteria like truth, logic or recognition and should contribute to the body of well defined, universally valid and transferable theories.

Methodical based Design Research develops "virtual procedures" to support "thought processes" for the design of artefacts as well as for the design of (design) processes. The strategies, methods, rules and tools created that way should be supportive for the use in design practice. They should increase efficiency and effectiveness of design work, be accepted eagerly, and used successfully by designers in practice or students in an educational environment. A further requirement might be the coherence to other existing methodologies.

In total, one has to realize, that Design Research until now represents mostly a mix of scientific elements with methodologies as individually gained expertise partly enriched with individual assumptions and beliefs [20]. The composition of such a mix often doesn't seem to be created consciously.

It is this pre-scientific status constituting and representing most of current Design Research, which "knits the brows" of so called "true scientists" and creates distinct reservations. Related prejudices and reproaches may affect the working conditions of design researchers to the extreme if they compete with true scientists either on budget or staff within a faculty/university or on funding of sponsors. Merely a small minority of scientists accepts to excuse scientific weaknesses on the grounds of the "youth" of current Design Research which is developing in decades only compared to the centuries or even millenniums, Natural and Engineering Sciences has had for its development.

## 5 The concept of research customers

Unlike some voices in fundamental sciences which claim that "true research" does not obey needs and purposes, Engineering Research in general and Design Research in specific has to deliver results - in a wider sense - for "customers". The mere fact that entire Design Research is paid by the society including companies, sponsors, universities or research agencies should oblige design researchers to "pay back" the investment received "to do the job". The term "design" research itself indicates (like the term "engineering" research) the appropriation of the so labeled research activities. Surprisingly, it's unlike the term "Natural" Science research, which indicates not the "customer" but the object the research is dealing with!

**(1) The 4-area model of Design Research**

Accepting the differentiation of Design Research in two ways: a scientifically and a methodologically oriented one (see chapter 4.4), the latter type of research should be regarded first.

***① The research area of methodologies and technologies***

It's obvious that this type of research producing strategies, methods, rules and tools is doing the job for design practice and partly for design education. This may be seen here as a unity and shouldn't be considered separately. If we summarize the entire design support as an area of methodologies and technologies (**Fig. 12**), this area just serves the purpose to support designing as an action.


**Fig. 12 The research area of design methodologies and technologies [22]**

In full accordance to the classification of Gramlich [21] one may differentiate:

(a) Design Technologies cover the entire set of processes using "physical" systems (hardware) to support designing like the use of computers, printers, smart boards, rapid prototype machines or even pencils.

(b) However, Design Methodologies are a label for virtual procedures in form of prescriptive advices, documented in textbooks, databases or software.

Both, technologies and methodologies are proposals for realizing processes, the former to realize (real) documentation, transformation or handling processes, the latter to realize (virtual) thinking, reasoning or communication processes.

As already mentioned, Design Methodologies and Technologies serve a purpose, and therefore have to be seen as deliveries for others. Like in product design, deliveries are accepted the more as requirements from the customers are fulfilled. That is the reason why the creation of methods and tools by Design Research may also be regarded as a specific kind of a design process with all its characteristics to support human thinking.

***② The entire 4-area model***

Consequently enlarged, one ends up with the entire Design Research model growing up to a 4-area model (**Fig. 13**) with mutual deliveries and requirements between the areas [22]. In spite of the simplified presentation in **Fig. 12,** the model stands for an enormous complexity of items and relations because of its extreme manifold and dynamic.

The "customer" of the area of Design Methodologies and Technologies is design practice, where designers work in a real design environment producing virtual

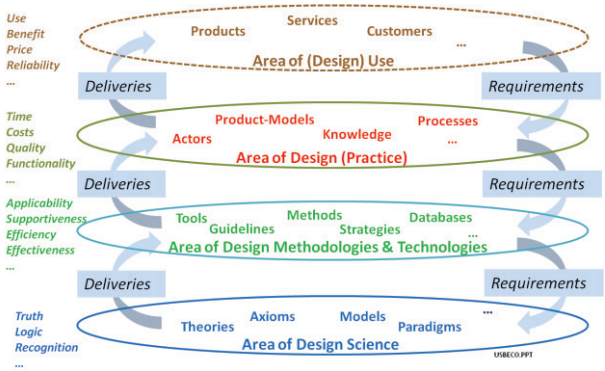


**Fig. 13 The 4-area model of design related areas with mutual deliveries and requirements [22]**

products and systems for being manufactured, sold and delivered.

Again, design practice defines originally the characteristics of products, services and combinations, which are used by (originally called) customers in the product lifecycle.

Within this model, the area of Engineering Design Science may finally be seen supportive for creating and performing methodologies and technologies for designing. This may be the case by creating the basis/fundament for them, as well as by linking, harmonizing or even consolidating findings of other sciences.

Each area has specific customers, obeys specific quality criteria and receives requirements from the area above to which it delivers virtual output or physical "goods" back.

In generalization of the 4-area model in **Fig. 12** one may say, that research on life in general may be traced back to a 4-area model of:

- Use or Usage (as a generic term for applying real or virtual items within the lifecycle)
- Practice (as a generic term for planning, designing and producing goods and/or services)
- Methodologies and Technologies (as a generic term for formalized and standardized procedures for planning, developing or producing product and process related knowhow)
- Science (as a generic term for fundamental recognitions and relations).

**(2) Design Research within the 4-area model**

Regarding the 4-area model of research activities it's now easy to depict specific Design Research activities within the model (**Fig. 14**). Each link between different areas or between different items within an area may be seen as a kind of a Design Research activity [22].

According to **Fig. 14** some examples may demonstrate the usefulness of the model to structure the variety of Design Research activities:

- "Research on Customer Needs" may collect and analyze needs and requirements in specific use areas and may propose e.g. a generic structure as a basis for storing requirements within a database.
- "Research on Transfer of Methods and Tools" may analyze current weaknesses and deficits of introduction and implementation of methodical support into design practice and may correlate the findings

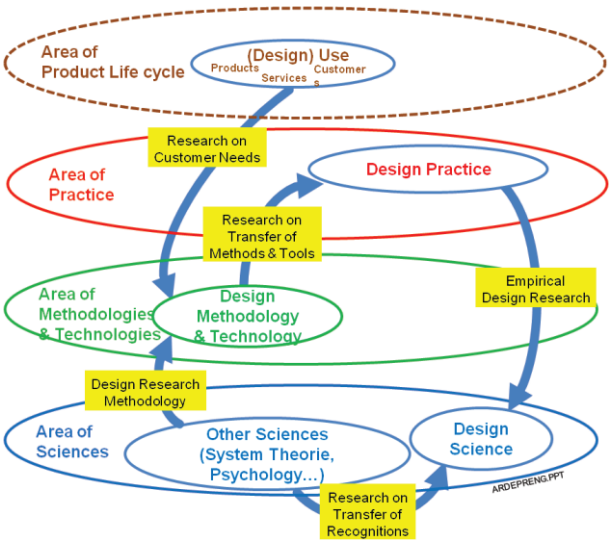


**Fig. 14 Typical Design Research items presented on the background of the 4-area model [22]**

with results from a review of literature.

- "Design Research Methodology" may analyze research approaches in different sciences, extract phenotypes of research procedures, and may transform them into prescriptive proposals for performing Design Research (see [11])
- "Empirical Design Research" [8, 10] may analyze the behavior of individuals and teams in design practice and trace back the observed phenomena on statistically proven recognitions of psychology
- "Research on Transfer of Recognitions" may select recognitions in specific areas of science (e.g. logic or systems theory) and include it in concrete terms of designing.

Obviously the model may depict the huge variety and manifold of past and current design activities with quite different objectives, procedures and purposes. These activities range

- from pure scientific research activities like development of a design language to formalize degrees of freedom of mechanical connections [9] over
- scientific based techniques of modeling of artefacts like platform systems for car-families until;
- simply pragmatic, consultancy like proposals for improved team meetings using Metaplan.

The 4-area model structures Design Research within a content based research framework. This may be seen as a value of its own. In the last chapter it will be used as a kind of surplus value to approach the questions to what extend the model may be used and whether it may contribute to dissolve the criticism raised at the beginning of this paper.

## 6 What are we doing in Design Research and is this, what we should do?

After all it has to be stated, that the obvious rank growth of current Design Research can't be traced back to the inability of design researchers to concentrate on "genuine objectives". The model rather mirrors the complexity of the research topic "designing". It is this variety and dynamic of influences on designing like technology innovation, globalisation or advance of information technology in daily life that leads inevitably to such a heterogeneous research landscape with fragments, streams, schools and islands of research.

Once again, the question arises: Is there a chance at all to succeed in developing a fairly coherent body of knowledge, models and methods for designing called Engineering Design Science? Or – a truly unsatisfactory idea – have we to accept that Engineering Design Research ends up like Sisyphus in a never ending research cycle producing a cosmos of diverging and fragmented research output?

### (1) Some remarks to the role and self-image of academic Design Research

Academic Engineering Design Research is largely carried out on universities and is inherently linked with the claim to be scientific. The 4-area model teaches us to be modest with regard to the degree of freedom, the perspectives and the chances for it.

It's no question at all that we are also able to work scientifically in Engineering Design Research creating e.g. formalized models of artefacts like it was done in the publications of the Theory of Technical Systems (TTS) [23]. But in this case our specific "customers" are not the industrialists, but above all those people, who use our theories to generate methods and tools for design practice. In other words: To work as a "hardcore" scientist in Engineering Design Research is feasible, but it means to say good bye to design practice! Without any support and adaption of scientific findings to the needs and environment of practice a transfer of these findings will hardly succeed. These crude remarks don't say anything against the value of pure scientific Design Research! But it says a lot about the disappointment of design scientists. They expect a frenetic applause for their research by designers because of its logic and clarity but nothing happens.

What else than working pure scientifically could academic design researchers do? The other extreme would be to work like a consultant and create professional support for design practice, very specifically drawn up for branches, companies or even departments. Doing this, the question arises: "What is the difference of such an academic research compared to a consultancy and what might be the "surplus value" of academic research?

A final answer to the way of academic Design Research is as often in life: "Try to create a good compromise". Such a compromise may be to agree on the development of useful methods and tools for design practice, and their successful implementation based on scientific and well evaluated models. Therefore, at least the models have to be generic, whereas the methods and tools may be specifications for the actual design context.

Of course such a strategy represents a particular challenge as it implies for a researcher to serve two lords! But doing academic research in the area of design isn't an easy task at all. It should rather be seen as a sphere of activities and a challenge for our best young people. And there is no doubt that numerous case stud-

ies like [12, 15] provided evidence of its success.

**(2) Some remarks to education and training of design researchers**

Agreeing on the requirements for a design researcher mentioned above, this has consequences for education and training too. As mentioned at the very beginning in **Figs. 2** and **3,** the industrial background of research publications in average seems to be limited. This is probably the reason for the weak industrial background of a number of design researchers.

If we ask substantial contribution from Design Research for design practice, we have to make demands too for a minimum of design experience (not necessarily expertise) on behalf of the design researchers. For example, how should a designer design a marketable product, if he doesn't reflect and understand what a customer wants to do with it? This means education and training for design researchers, curricula for students and working conditions for young researchers must take the design environment, the working procedures in design practice and the industrial context into account. To lead students and junior researchers closer to design practice in industry, convenient elements are students work in industry for one semester or even one year, industrial work within a study or intensive project work during the research time after studies.

If there isn't at least elementary design practice available, Design Research tends quickly to be done in a more hobby based, in some way naive style or it slips off in academic messing around. At this point let's come back to the famous "Early Phases", design researchers love to address in their research. This causes indeed a huge waste of time and motivation because of its inappropriate relation to the main areas and core problems of design work in industry.

**(3) Improving the marketing of design events**

There is almost no design book, no design conference highlighting its content as highly relevant or rather valuable for scientists, industrialists, students, teacher, engineers etc. The idea behind this omnipotent claim is clear: To attract an audience as big as possible. But in the view of marketing, this strategy is neither promising nor successful as mentioned at the beginning of this paper.

Remembering the 4-area model there are 4 domains with domain-specific items, requirements, needs and deliveries. To address "inhabitants" of such specific domains means to arrange specific events with specific messages, objectives and styles. A strategy "from everything something" rarely motivates participants. Consequently,

- if we want to attract designers from industry, we have to present those methods and tools supporting substantially urgent problems (not academic ones) within their daily work; we have to demonstrate them the effort in time and money needed and the benefit gained; we have to explain the process of introduction and implementation etc.
- if we want to talk e.g. about the foundation of modeling artefacts, we should organize a conference "Engineering Design Science" inviting researchers from mechanical and mechatronic engineering, from physics, chemistry, material sciences to inform each other how elements and structures of elements may be represented and presented, and which tools enable us to do this efficiently and accurately.

In fact, what we do see, at least referring to big conferences, is a mix of everything what seems to be like to fire a shotgun hoping to hit a maximum of targets with a limited number of pellets.

**(4) Harmonization, consolidation, unification of Design Research outcome?**

More and more design researchers feel uncomfortable with the rank growth of activities and outcomes in Design Research and ask for guidance. The call for harmonization, consolidation or even unification increasingly comes up. But remembering once again the 4-area model, it's obvious, that influences from quite different sciences, research approaches and views on designing have to be taken into consideration.

An often articulated proposal relates to consolidate terminology in Design Research. For example a design related dictionary or a Wikipedia should be created. At a closer look at terminology the approach of consolidation doesn't seem to be realistic. The terms "function" or "process" e.g. have quite different meanings in Mathematics, Design Methodology, Economics or Cognitive Science. The background of each term is a concept, an idea, a model, which is labelled by a term. It is the concept, the idea, the model, which constitutes that, what a term expresses – not the way around! Therefore, consolidation of terminology would mean consolidation of a label and not of the content, which seems to be quite questionable and resembles the approach to consolidate homonyms.

Instead of consolidating terminology it looks promising to consolidate the content represented by concepts, ideas or models. This approach should get started, but carefully within well defined limits, e.g. within the area of lifecycle or artefact modelling. Supposed to be successful, this approach would benefit a lot. It makes no sense at all, that e.g. in almost each PhD-thesis or dissertation a set of concepts like method, model, information or knowledge is newly defined or even worse modified, to fit better to the findings of the researcher.

Nevertheless, one should be aware that different domains like Engineering, Economics, Informatics or Psychology may have different views on a topic, each of them not being correct or wrong, but different. A consolidation of these differences in views and glances should be seen as highly questionable - even if it seems possible, or desired. Probably a mutual referencing of definitions and a careful harmonisation of concepts and models will be the maximum one can achieve.

## 7 Conclusions

This contribution starts with some weaknesses and deficits of current Design Research, analyses the nature of design work, Design Research and Engineering Design Science, derives a model of design related areas as a basis for structuring the variety of Design Research activities and ends up with some proposals for improved

Design Research activities.

The author is highly aware of the provisional nature of his reasoning, of inconsistencies and limits. The driving force behind this contribution was the expectation, to address some often mentioned but rarely in detail discussed problems and deficits of Design Research as well as of self-understanding of design researchers. Hopefully the presented models and remarks help to point out some ways, how to attack problems and how to deal with fundamental questions within our community.

Besides all niggling it should be clearly said, that in regard to its short time of development Design Research had matured to an impressive and internationally perceived level. There is no need at all to walk "in sackcloth and ashes" because of current weaknesses and deficits of our daily work in Design Research. But from time to time it should be worth to remember the saying: "The better is the enemy of the good".

## References


[1] Birkhofer, H., "From design practice to design science: the evolution of a career in design methodology research", Journal of Engineering Design, Vol. 22, No. 5, (2011), pp. 333-359.

[2] Heymann, M., "Kunst" und Wissenschaft in der Technik des 20. Jahrhunderts – Zur Geschichte der Konstruktionswissenschaft *(„Art" and Science in engineering of the 20th century – A contribution to the history of design science*), Zürich, Chronos, (2005), Chap. 8.2, pp 479-487.

[3] ICED'13, Proceedings of the 19th International Conference on Engineering Design, Seoul, Korea, 19-22nd August 2013. Design for Harmonies.

[4] Murakami, T., "Design Innovation by Engineering and Science", Proceedings of the 2nd International Conference on Design Engineering and Science, Tokyo, Japan, (2010), pp. 42 – 47.

[5] Pahl, G., Beitz, W., Feldhusen, J. and Grote, K.-H., Konstruktionslehre - Grundlagen erfolgreicher Produktentwicklung; Methoden und Anwendung (*Design Methodology – Fundamentals of successful product development; Methods and applications*), Berlin/Heidelberg, Springer-Verlag, (2007).

[6] Hubka, V. and Eder, W.E., Design Science – Introduction to the Needs, Scope and Organization of Engineering Design Knowledge, With 68 Figures, London, Springer, (1996).

[7] Lindemann, U., Methodische Entwicklung technischer Produkte - Methoden flexibel und situationsgerecht anwenden (*Methodical development of technical products – using methods flexibly and context related*), Berlin/Heidelberg, Springer-Verlag, (2009).

[8] Lindemann, U. (ed.), Human Behaviour in Design – Individuals, Teams, Tools, Berlin, Heidelberg, New York, Springer, (2003).

[9] Roth, K., Konstruieren mit Konstruktionskatalogen - Band 1 (*Design with Design catalogues – Vol. 1*), Springer, Berlin/Heidelberg, (2000).

[10] Frankenberger, E., Badke-Schaub, P. and Birkhofer, H., Designers – The Key to Successful Product Development, Berlin, Heidelberg, New York, Springer, (1998).

[11] Blessing, L.T.M. and Chakrabarti, A., DRM: A Design Research methodology, Dordrecht/New York, Springer, (2009).

[12] Hosnedl, S., Dvorak, J. and Kopecky, M., "Integrated Engineering Design Research and Interdisciplinary Education in cooperation with Industrial Partners", Proceedings of the 17th World Multi-Conference on Systemics, Cybernetics and Informatics. Vol. II. Orlando, Florida, USA: International Institute of Informatics and systemic, (2013), pp. 218 – 223, ISBN-13 978-1-936338-88-7.

[13] Cross, N.: Science and Design Methodology: A Review. Research in Engineering Design (1993), pp. 63-69.

[14] Ehrlenspiel, K., and Meerkamm, H., Integrierte Produktentwicklung (*Integrated Product Development*), München, Carl Hanser Verlag GmbH & Co. KG, (2013).

[15] Hatamura, Y., "Practice of Creative Design", Proceedings of the 2nd International Conference on Design Engineering and Science, Tokyo, Japan, (2010), pp. 1-6.

[16] Kuo, T-C., Huang, S. H., Zhang, H.-C., "Design for manufacture and design for 'X': concepts, applications, and perspectives", Computers & Industrial Engineering 41(3) Elsevier Science B.V., (2001), pp. 241-260.

[17] VDI-Gesellschaft Entwicklung Konstruktion Vertrieb (Ed.), VDI-Richtlinie 2221, Methodik zum Entwickeln und Konstruieren technischer Systeme und Produkte (*VDI-guideline 2221, Methodology for design and development of technical systems and products*), Düsseldorf, (1993).

[18] Jänsch, J., Akzeptanz und Anwendung von Konstruktionsmethoden im industriellen Einsatz – Analyse und Empfehlungen aus kognitionswissenschaftlicher Sicht (*Acceptance and application of design methods in design practice - analysis and recommendations from a design methodological perspective*), Düsseldorf, VDI Verlag GmbH (2006).

[19] Dörner, D. and Selg, H., Psychologie: Eine Einführung in ihre Grundlagen und Anwendungsfelder (*Psychology: An introduction in its fundamentals and fields of application*), 2nd edition, Stuttgart, Kohlhammer, (2005), pp. 86-112.

[20] Otto, K. and Wood, K., Product Design: Techniques in Reverse Engineering and New Product Development, Upper Saddle River, Prentice-Hall, Inc., (2001).

[21] Gramlich, S., Vom fertigungsgerechten Konstruieren zum produktionsintegrierenden Entwickeln - Durchgängige Modelle und Methoden im Produktlebenszyklus (*From design for manufacturing to a manufacturing integrating design – General models and methods in product lifecycle*), Düsseldorf, VDI Verlag GmbH, (2013).

[22] Birkhofer, H. (ed.), The Future of Design Methodology, London, Springer, (2011).

[23] Hubka, V. and Eder, W. E., Theory of technical systems: A total concept theory for engineering de-

sign (2nd revised and enlarged edition), Berlin and New York, Springer, (1988).
[24] Eder, W. E. and Hosnedl, S., Design Engineering – A Manual for Enhanced Creativity, Boca Raton, CRC Press, Taylor & Francis Group, (2008).
[25] Grabowski, H., Rude, S. and Grein, G. (ed.), Universal Design Theory, Aachen, Shaker, (1998).

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