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Opening up Design Methodology

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Abstract. Contemporary product development has transformed from being mono-disciplinary to increasingly trans-disciplinary. Design problems often do not match the boundaries of a single discipline. The integrated use of tools, techniques, and methods, which are intended to support designers in their work, is a subject of design methodology. This paper presents a critique of the current state of design methodologies from a transdisciplinary perspective, and their industrial uptake. A case for an open community based approach for design methodology is made that considers contexts and mind-sets and provides a platform for consolidating design methodology in a dynamic perspective. The paper particularly addresses the following research questions: What needs should be addressed in the further development of design methodology? What developments are required to meet these needs?

Keywords: design methodology, systematic design approach, transdisciplinary, product development

1 Introduction

Design problems often do not match the boundaries of a single discipline. Subsequently, design practice requires collaboration of designers from different disciplines. This collaboration from different disciplines can happen in different ways described as multi-, inter, or transdisciplinary. Currently these terms are used interchangeably with a degree of overlap. Transdisciplinarity, as opposed to multi-disciplinarity and inter-disciplinarity, concerns that which is simultaneously between disciplines, across different disciplines, and beyond all disciplines [1]. Ertas et al. [2] define trans-disciplinary design as the integrated use of the tools, techniques, and methods from various disciplines.

The integrated use of tools, techniques, and methods, which are intended to support designers in their work, is a subject of design methodology. Here, the term design methodology is used in order to refer to a specific approach to design, for example described in Pahl et al. [3]. A design methodology is “a concrete plan of action for the design of technical systems (...). It includes plans of action that link working steps

and design phases according to content and organisation.” [3] The action plans are supported by methods.

Current design methodologies and methods are essentially mono-disciplinary [4]. Exceptions are a methodology for the design of mechatronic systems [5] and some initial support for the development of Product-Service-Systems (PSS) [6, 7] in which the design of services [8, 9] and products are to be integrated. The integration of different design disciplines in the notion of transdisciplinary design is not sufficiently considered in current design methodologies [4], which is a limitation but might also guide the further development thereof.

Design methodologies aim to structure the design process, to support planning of product development projects, and to provide support for related design activities, thereby to avoid project failure. The use of a design methodology as a way of thinking is said to enhance the probability of a successful product development project [10]. “[...] even though it has seldom been established ‘scientifically’ that design methods work, it is certainly sensible to use these tools sensibly, especially in situations in which the firm’s own experience falls short, and the design process threatens to come to a standstill.” [11]

The discrepancy of current design practice and current state of design methodologies motivated the following research questions:

- What needs should be addressed in the further development of design methodology?
- What developments are required to meet these needs?

In this paper we provide an overview about critiques of current design methodologies, discuss on-going developments and outline directions for the further development towards a transdisciplinary design methodology.

2 Current state and critiques of design methodology

Consolidation is required.

“... classic Design Methodology has deficits in supporting current or even future development work that necessitate a substantial reformation.” [12]

As reformation does not mean to start from scratch, it can build upon existing work. As much of the existing work is fragmented or related to a (discipline-) specific context, consolidation is required [13, 14].

A challenge for consolidation and also for overcoming the boundaries of current rather mono-disciplinary approaches is the lack of understanding of the different design processes and of the differences and communalities of the various methodologies and methods to support these processes.

Analyses of design methodologies from different disciplines such as: Mechanical Engineering, Electrical Engineering, Software Design, Industrial Design, Service Design, Mechatronics, Product-Service-Systems, Building Design, and Systems Engineering show that the reviewed approaches show major commonalities across the

domains [4, 15, 16]. Most approaches propose a stage-based procedural process model. The activities composing the different stages are quite similar across the disciplines, even though the naming of the stages might differ [15].

However, the disciplines also show important differences regarding: the prioritization of specific activities, the modelling approaches proposed to represent the different design states, additional discipline specific design states and design activities, terminology, design methods and tools [4, 15–18]. A design state is the incorporation of all the information about a design as it evolves [19].

Critique of current design methodologies.

A review [4] of comparisons and analyses of design methodologies and process models indicates that systematic approaches are seen as suitable means in order to offer support for designers in different disciplines; even though current design methodologies need further development as different aspects of designing are not sufficiently considered. Consensus exists that further development of design methodologies, related process models, and further research are required. But no consensus exists on how detailed such a support should be and how detailed it can be. The review provides several critiques of current design methodologies and process models:

- Current approaches focus on original design, despite the majority of design tasks are based on existing designs [20, 21].
- Current approaches focus on development projects initiated by market pull. Technology push as an alternative impulse for product development is not appropriately considered [22].
- Current approaches focus usually either on design or on management. Both aspects have to be considered in order to provide an improved support [23].
- Current approaches do not explain how to perform design activities (only what to do [24, 25].
- Current approaches do not explain the rationale of the proposed processes [23].
- The creative process is not sufficiently represented in current approaches [20].
- Transdisciplinary team-work is not sufficiently supported by current approaches [26].
- Goal iteration is not sufficiently considered in current approaches [27].
- A pattern found in different disciplines is that knowledge about problem and solution emerges together (Co-Evolution) [24, 25, 28, 29]. So far this is not appropriately represented in current approaches [27].

3 Transferring design methodology into practice

The missing link.

A major critique concerning design methodology is its sparse application in practice [30–34]. Design methodologies are mainly used for teaching, at least in the US and Northern Europe, but the industrial uptake of the methodologies has been limited and many remain unknown. Wallace [35] states that much of the support that has

been developed by design researchers over the past 40 years has not been transferred into practice. However, some of the underlying concepts of the developed methods did find their way into practice and had a profound impact on design processes in industry [17].

Wallace [35] summarises reasons identified by other researchers such as: methods tend to be too complex, abstract and theoretical, too much effort is needed to implement them, the immediate benefit of applying them is not perceived. Wallace then highlights another reason for the slow or absent transfer of knowledge from academia (developing new methods) to design practice (applying methods). He argues that much of the methods – irrespective of their efficacy and efficiency - are not applied in practice because no one is responsible for their transfer into practice, thus a real evaluation of their efficacy and efficiency will not happen. Wallace refers to this as the missing link between academia and design practice (see **Fig. 1**).

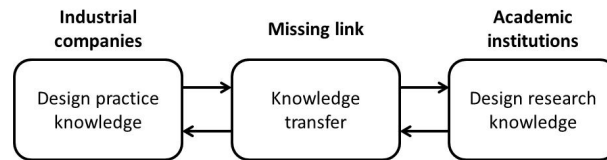


Fig. 1. Knowledge transfer – the missing link [35]

Approaches to the transfer of design methodology.

Until the day design methodology is largely transferred via textbooks and it seems that for many designers their academic training is the main source for knowledge about design methodology and design methods. There are some past and present attempts to transfer textbook based design methodologies into web-based method databases [36–41]. Some of these databases provide interesting additional features which are not provided by textbooks:

- visual overview of entire methodologies
- searchability
- linking of methods to highlight similar or subsequent methods
- templates for the execution of methods
- presentations for training purposes
- initial guidance for selection of methods

Despite the large efforts taken, each database shows some or all of the following major limitations/potential for improvement:

- discipline specific: the content does only address a small portion of the disciplines involved in design processes
- limited input from design practice: the database is created mainly by academics
- effort for setup: the content is provided by a (small) team, which limits the coverage and depth of the provided support

- not updated/static: many databases are not maintained after the original team left the project; new methods and tools and user feedback are not considered
- pure repository: methods are not linked to a methodology
- generic: the database does not support the transfer to a specific context

4 Developments in design methodology

The need for consolidation, overcoming the identified shortcomings of current design methodologies and consideration of multi- and transdisciplinary design practice stimulated different developments. Most of these developments are currently in a conceptual stage, thus still under discussion and require further research.

Some recent propositions for the development of design methodology (e.g. [42]) further develop ideas from systems engineering. Much emphasis in on-going discussions and developments is put on the design process, as the process is seen as “the glue that hold the activities within product development and design together.” [43]

Two lines of research relevant for the further development of design methodology are highlighted in the following. Both aim to enable a better transfer of design methodologies to design practice though being based on different paradigms. The first is the on-going research on the context dependent adaptation of design methodologies and the second is summarized as mindset approach.

The issues addressed in both lines of research will become even more relevant for a design methodology aiming to support transdisciplinary design practice.

Context dependent adaptation of design methodology.

In this line of research design methodologies are interpreted as prescriptions for design work. The underlying assumption is that prescriptive process models as proposed in design methodologies require a context dependent adaptation in order to serve as a basis for planning and design management and should be followed as they represent best practice.

Miriam-Websters [44] defines context as “the interrelated conditions in which something exists or occurs”. What is usually meant by the term context factor are influencing factors, i.e. “‘people or things having power’, with power as ‘the ability to affect outcomes’” [33, p.29] referring to [45]. Thus, both terms context factor and influencing factor describe a factor having an influence on the course of a design project.

The claim of design methodologies to provide a support which is applicable to a wide range of different contexts resulted in a dilemma. In order to cover a wide range of different contexts the process models proposed in the methodologies, thus the whole design approach, became rather abstract. The high level of abstraction resulted in the perception of being of limited use [17, 27].

An approach suggested by different authors [21, 46] is to start with an abstract, context-independent approach and adapt it to a specific context. Lawson [24] points

out that the ability to manage this adaptation is one of the most important skills of designers.

Even though, a context dependent adaptation is seen as a suitable means to make a substantial improvement of current design methodologies, only few contributions were made over the last years, and it often remains somewhat fuzzy what context actually means. A challenge for empirical research on influencing factors is the vast amount of factors and their interdependencies which have to be considered when analysing the effects on product development [47]. The complex relationships between the influencing factors hamper an empirical deduction of recommendations for a context dependent adaptation of systematic approaches. As a consequence the outcome of adaptation is currently dependent on interpretation and understanding of a design methodology by a particular designer.

Mindset approach.

In another line of research design methodology is interpreted slightly differently. Prescriptive models as proposed in design methodologies are usually not (and do not aim to be) an accurate representation of how a product development process will proceed [48]. Eckert and Stacey [48] argue that process models do “not need to be totally correct in order to be useful” because correctness does not guarantee usefulness. Thus, design methodologies and the provided prescriptive process models should be seen as guidelines – as heuristic methods which need interpretation. Designers should not treat design methodologies in a dogmatic way, rather opportunistic and use them at least as guidance for their work [49]. This can be seen as a mindset approach.

Mindsets [50, 51] represent mental states of a person, leading to a preference of specific sets of mental processes depending on the particular mode of action “that produce a disposition or readiness to respond in a particular manner ...” [52]

"A mindset is the proper understanding of a method's use in accordance with the designer's reality: interpretation of task, situation, execution, validation etc. and in accordance with the method's background and proper use." [Andreasen M.M., personal communication, 2013]

That what is called here in a simplifying way a mindset approach requires much more than just an explanation that a design methodology is not a recipe. A challenge for the further development of design methodologies is to understand what enables the successful individual application of a design methodology in a specific context. This understanding is required in order to improve the training of design methodology and its transfer into practice and might also ease the development of a support for a context dependent adaptation of design methodologies.

5 Opening up design methodology

Current design methodologies suffer from a couple of limitations. In order to overcome these and to continue on-going developments, the underlying concepts for the development and transfer of design methodology established in the past have to be changed. Aspects that have to be addressed in this change are for example:

- **Disjoint research communities** focussing on their own engineering discipline, creating methodology islands, not sufficiently supporting transdisciplinary design practice
- Transfer of the provided support via **static media** such as books and simple web-repositories
- Waiting for **empirical proof of value** from applying design methodology
- Lacking support for **adaptation**

A concept for the further development of design methodologies addressing these challenges is to open up design methodology. The process of opening up design methodology is a multidimensional one; it means design methodology should be:

- Open for all disciplines (mechanical engineering, software engineering, product design, ...), enabling the creation of a transdisciplinary design methodology
- Open for practitioners and researchers, enabling a consolidation of existing support, best practices and new methods, tools and research results
- Open for active participation and feedback, enabling a dynamic evolution and continuous improvement

From disjoint research communities vs. design practice to an open design community.

A large variety of design methodologies and process models exists [15]. Each is more or less specific to a certain discipline. This situation is not so much a result of the needs of design practice but rather a consequence of the historical development of design methodology. Until today design methodology is at large an output from academics in fairly closed discipline-specific research communities. Transfer of knowledge from design practice to academia is currently done via empirical studies of design practice and practitioners entering design research.

New ways of extended bilateral information exchange are required in order to reduce the distance between design research and design practice. Bilateral exchange means direct involvement of practitioners in the development of design methodology.

An open design methodology should build on the knowledge of a community of design researchers and design practitioners. Everyone interested has to be enabled to contribute through active participation in evaluation of the resources, their modification and addition of information.

As most design practitioners have very limited resources for extensive contributions to design methodology, additional mechanisms for low effort incorporation of user-feedback have to be created for design methodology, allowing the users to participate, change and sculpt the open design methodology in a closed feedback loop. Such mechanism will not only provide practitioners opportunity for participation in the building of design methodology but offer to design researchers an invaluable test-bed for new methods and research results.

Development, improvement and maintenance of design methodology can be achieved by an active and open community in which everyone will be able to consult as well as to add information.

Opening up design methodologies to academics as well as practitioners from a variety of design disciplines is one step onwards the creation of a transdisciplinary design methodology. Consideration of the contributor's context is hereby important as transdisciplinarity does not mean to strive for harmonisation, but to identify, share and apply those practices, methods and tools that are shared across the disciplines while those which are specific to a certain discipline become apparent as such.

From static to dynamic.

Design methodologies tend to be very resilient, once they are created. The design methodology of Pahl and Beitz for example originates from the 1970s and rather small changes were made to the basic concept. To the contrary the situation in design practice changed dramatically during these decades and will not stop to do so in the future. Hence a future design methodology has to be built with the capability to evolve equally.

As continues evolution of a methodology takes immense effort, the common approach (create, evaluate, adapt) is not manageable by a small community of researchers. The integration of design practitioners into an open design community should be employed to dynamically adapt design methodology over time as well. Co-evolution with continuous integration of user feedback will help to maintain and raise usability of design methodology.

As the aforementioned dimensions of opening up design methodology on the one hand and the analysis of today's web activities in design methodology on the other hand demonstrate, design methodology needs to embrace the vast opportunities of the internet both for transfer of scientific knowledge into design practice and for feedback from design practice into design research. An open design methodology should be created in an open web based community enabling the required dynamics and a convenient stakeholder involvement.

From empirical proof of value to community shared benefits.

The lacking acceptance and uptake of existing design methodologies can easily be related to the inability of the research community to demonstrate the (economic) value of the methodology they propose. The number and extent of empirical studies to be undertaken in order to demonstrate in a generalising way the (quantitative) benefits of design methodology are not manageable. Besides the unbearable effort of comprehensive empirical studies this inability is closely intertwined with the lacking uptake. If there is no uptake there is no proof of value and if there is no proof of value there is no uptake. This is well known in design research but consequential change of strategy lacks.

Exploring alternative ways for demonstrating the value of proposed support might resolve this dilemma. In an open design community benefits as well as problems could be communicated between practitioners. Trust in recommendations of peers working in a similar context supported by empirical studies of academics might be more convincing than empirical studies alone.

From generic to context dependent.

Context dependent adaptation of generic design methodology is required in order to meet the needs of design practice. The discussion of the current approach to adaptation on the other hand showed clearly its limitations. Most intriguingly, relevant factors and interdependencies are not known and empirical deduction is practically impossible.

Hence the required guidance for context-dependent adaptation has to be developed by different means. Combining the strengths of the mindset approach and context dependent adaptation design practitioners have to be enabled - supported by design research - to adapt suitable elements of design methodology themselves.

A combined approach could benefit from building the aforementioned open design community. In such a community, the information on the adaptation of support elements will be built and shared as to minimize the effort for the individual and enrich the quantity and quality of specific adaptations. An open, web-based application with filtering and improvement of available support based on context-data and feedback could provide the additionally required guidance for the selection of suitable support.

6 Conclusion

Design methodology itself and its transfer from design research into design practice have to be improved significantly in order to meet the needs of the 21st century. Isolated, disjoint methodologies as evolved over the last decades are often not sufficient in order to support transdisciplinary design practice thus rejected by practitioners.

The challenges for the further development of design methodology which arise from the evolvement of design practice are manifold.

A consolidation of existing support and the further development of design methodology should be accompanied by an opening of design methodology. The opening should concern: the involvement of multiple relevant disciplines resulting in a transdisciplinary design methodology; and the involvement of researchers and practitioners, leading to a dynamic exchange of knowledge about systematic approaches to support design as well as knowledge about the application thereof in practice. The creation of an open community that develops such a design methodology, the ascertainment of feedback from practitioners, and the dynamic evolvement of the provided support require intensive research along different axes of research. Joint efforts are required in order to avoid going in circles and waste the opportunity to improve the transfer of knowledge from academia to practice as well as from practice back to academia.

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