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Guidance for design method validation: Operationalisation of efficacy

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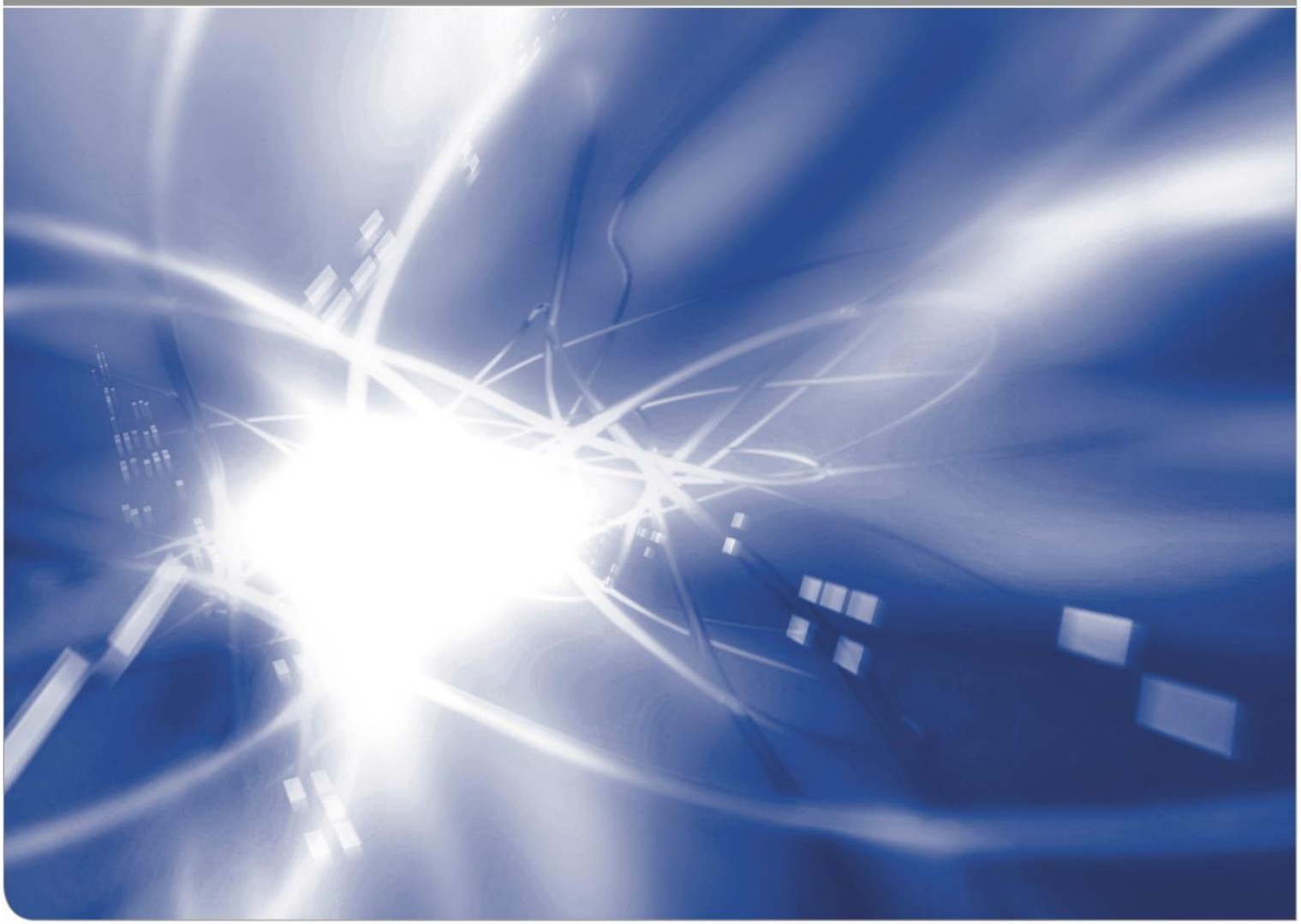
KIT SCIENTIFIC WORKING PAPERS 205



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(2) Information on parallel publications in anthologies, conferences

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Abstract
This contribution gives guidance for design method validation. Through consolidation of research approaches three core steps of design method validation are identified: structure, effect and performance validation. Within validation, three success criteria need to be considered: applicability, usefulness – comprised of efficacy and effectiveness – and acceptance. Through analysis of best practices for operationalisation of efficacy, two ways towards standardisation are identified: (I) use of established knowledge through benchmarking design methods and research methods, and (II) utilising knowledge from design research and other disciplines for operationalisation. For missing knowledge, 'reflective research practice' is introduced as a pragmatic approach to develop design methods together with research methods for assessment. The guidance given can support researchers in the standardisation of design method validation.

Keywords: *design methods, operationalisation, research methods, reflective practice, design method validation*

For several decades, design methods have been developed using different approaches and with incorporation of various scientific disciplines (Cross, 2007). This complicates identification of similarities between methods and in turn hinders the development of standards for research on design methods. A review of studies on *design fixation* (Vasconcelos & Crilly, 2016) gives an example on how difficult it has become to compare studies even in specialised sub-areas of design research: The authors identified 14 different variables to assess *design fixation* and various research methods within a sample of 25 studies. This lack of comparability particularly affects research on design methods.

A common overarching goal of design methods can be defined as influencing the thinking and actions of designers to positively impact the design process and its outcomes. To reach this goal, *"a method guides and challenges designers to consider things outside of their intuition and preconceptions"* (Lloyd, 2019, p. 170). To identify influences of the design method, the changes in the thinking and actions of designers through application to be made accessible for assessment through operationalisation, which is a demanding research task (Matthiesen, Nelius, & Eisenmann, 2022).

In design method validation, the effects of the design method on the design process and outcomes are evaluated through theoretical investigations and empirical studies. Insights gained through this evaluation are crucial to advance existing methods and foster development of new design methods. Additionally, studies within design method validation enable analysis of underlying core mechanisms for theory building and testing. Thus, design method validation plays an important role for theory-driven as well as practice-driven design research.

For validation, the design method goals need to be operationalised through variables describing observable changes in designers' behaviour, thinking and design outcome. Those variables are linked with corresponding research methods for assessment. From a research

quality perspective, research methods for assessment as well as variables should contain as many standard elements as possible to enable meta-analysis (compare Cash, 2018). The development of standards for operationalisation, following the examples of medicine as suggested by Frey and Dym (2006) or social sciences as suggested by Bender et al. (2002) and Blessing and Chakrabarti (2009), has the potential of highly beneficial effects on research quality in design method validation.

However, an analysis of the current research practice shows that *"most design method developers set goals for their own methods and therefore develop a separate operationalisation*" (Eisenmann et al., 2021, p. 633). This results in a multitude of observable variables and corresponding research methods for assessment.

Summing up, there is a particularly strong need for consolidation and standardisation in design method validation. Thus, this paper aims to contribute to the *study of design methods* (Cash, Daalhuizen, & Hay, 2022) through guidance for design method validation. The paper focusses on the operationalisation of *design method efficacy*. *Efficacy* describes the direct effects of a design method to be considered in early stages of design method validation (see Section 1) making it a plausible starting point for standardisation. Additionally, operationalisation of *efficacy* enables comparison between design methods and thus plays an important role in the development of standards for research methodology and corresponding variables (see Section 2).

The s*hort-term objectives* of this contribution are*:*

- Consolidate existing approaches for design method validation to provide a description of core steps and success criteria to be considered.
- Illustrate best-practices on how to operationalise design method goals comparably for the use in design method validation.
- Provide guidelines to support researchers in building studies on design method efficacy.

The l*onger-term objectives* of this contribution are*:*

To foster discussion on

- …comparability of design methods through common goals.
- …operationalisation of said method goals through standardised variables as well as corresponding research methods to assess design method efficacy and in turn design method usefulness.

1 How should design methods be validated?

Following the above objectives, this contribution first discusses how design methods should be validated by consolidation of approaches and provision of guidelines for the process of design method validation.

1.1 Consolidation of existing approaches

Design method validation describes all research activities investigating if and how a design method can fulfil its purpose. To comprehensively validate a design method, multiple studies, each posing specific requirements on research methodology, are necessary (Blessing & Chakrabarti, 2009; Marxen & Albers, 2012; Tromp & Hekkert, 2016). Possible investigations range from theoretical and logical reasoning over empirical studies in controlled academic environments to field studies in the designated context of application.

Multiple approaches to design method validation have been developed within design research. Some approaches formulate criteria for design methods to be fulfilled within validation (e.g. Olewnik & Lewis, 2005) or use analogies to illustrate the benefits of adapting research methodologies from other scientific disciplines (e.g. Frey & Dym, 2006). Also, there are comprehensive approaches for research such as the *design research methodology (DRM)* (Blessing & Chakrabarti, 2009). Within design research, three approaches explicitly discuss necessary steps for comprehensive design method validation: The *evaluation types* within *DRM* (Blessing & Chakrabarti, 2009), the *Model for design support development and validation* (Marxen & Albers, 2012) building on the types of design research by Cantamessa (2003) and the *Validation Square* (Pedersen et al., 2000). Thus, these approaches are used in the following as a starting point to consolidate typical steps in an overall process for design method validation. A summary of the steps within the three approaches and the suggested consolidation in the three steps *structural validation*, *effect validation* and *performance validation* is shown in Table 1. The approaches have in common, that validation takes place in a successively wider context.

The first step in design method validation deals with the structural soundness of the design method. In *DRM* and the *Validation Square* the first validation step deals with the design method composition. In *support evaluation* within *DRM,* the focus lies on internal consistency and logic of the design method. The *Validation Square* additionally suggests investigating the *theoretical structural validity* through analysis of each element the design method is composed of. The first step in design method validation is therefore consolidated as s*tructure validation (theoretical)* (see Table 1).

Table 1: Consolidation of existing approaches to design method validation into three overall steps of design method validation – structure (theoretical), effect (empirical) and performance (empirical).

approach	**validation steps**			
DRM (Blessing & Chakrabarti, 2009)	support evaluation	application evaluation	success evaluation	–
Model for design support development and validation (Marxen & Albers, 2012)	*(implicit during development)*	experimental research	implementation studies	education studies
Validation Square (Pedersen et al., 2000)	theoretical structural validity	empirical: structural validity / performance validity	theoretical performance validity	–
consolidation	**structure validation (theoretical)**	**effect validation (empirical)**	**performance validation (empirical)**	

In a second step, the validation of design methods moves from theoretical and logical considerations to empirical studies of design method effects. In *DRM* the focus of these studies within *application evaluation* lies on applicability of the design method and verification of immediate effects such as the number of generated ideas through the use of ideation methods. The *Model of Marxen* additionally prescribes *experimental research* for study designs to be used in this step. The *Validation Square* contains two elements dealing with the application of the design method in empirical studies: *Empirical structural validity* aims at qualitatively checking the chosen example problems to be used as design tasks in empirical studies. Within e*mpirical performance validity* quantitative studies should be conducted to investigate the immediate effects of design method application in a controlled environment. This also involves checking whether those effects are truly caused by the design method. Thus, the second step in design method validation is consolidated as *effect validation (empirical)* (see Table 1).

The third step in design method validation deals with the impact of the design method on performance in practice. This involves studies investigating indirect and possibly long-term effects of design method application on the outcome of design activities. Within *DRM* this involves multiple studies investigating the chain of impact from immediate effect to impact in practice. The *Model of Marxen* assumes sufficient credibility after the preceding experiments and prescribes *implementation studies* in the field which include application of the design method in practice. Within this step the *Validation Square* disagrees with the other approaches as it describes a theoretical validation activity. Pedersen et al. (2000) argue that design methods cannot be comprehensively validated through empirical studies and should be founded on established concepts. This view allows a claim of generality of design method performance based on the preceding steps. Here, it becomes visible that there are different stances towards design methods within design research: the *theoretical* and the *pragmatic stance* (Reich, 2010). Because the *Validation Square* assumes design methods can be

developed and validated using theoretical concepts, it uses criteria for validation differing from the other approaches. Both the *DRM* and the *Model of Marxen* take a *pragmatic stance*. This stance allows design methods to be developed based on best-practices and experience resulting in validation criteria based on empirical findings indicating performance. In the view of the authors of this contribution, the body of scientific knowledge and corresponding theory on design method effects is in many areas not yet sufficient for solely theoretical reasoning to claim generality. Instead, hypotheses on possible effects of design methods should be formulated and tested in empirical studies to build up a body of scientific knowledge (Cash, 2018). Summing up, the third step in design method validation is consolidated as *performance validation (empirical)* (see Table 1).

1.2 Focussing success criteria one at a time – first applicability then usefulness then acceptance

The above consolidation of steps for design method validation provides guidance which kind of investigation might be appropriate in which stage of validation. Additionally, it is necessary to define criteria for design methods to enable investigations on whether they can fulfil their purpose. Also, criteria are helpful to define the focus of studies as validation activities should be as focussed as possible (Isaksson et al., 2020). Success criteria for design method validation are *applicability, usefulness* – comprised of *efficacy* and *effectiveness* – and *acceptance.*

How well a design method can be applied by users is described through the criterion *applicability* (Blessing & Chakrabarti, 2009; Eisenmann, Grauberger, & Matthiesen, 2021; Kroll & Weisbrod, 2020; Motte & Eriksson, 2016). In order for a design method to achieve its intended effect, it must be applied correctly. If it is not applied correctly, an effect cannot be unambiguously explained by following the core idea of the method represented by a described method procedure. This unambiguous connection of cause and effect is necessary for the internal validity of a study. *Applicability* is therefore to be seen as a necessity for the purposeful investigation of *usefulness*, as it allows to explain how effects are caused by method application. Hence, *applicability* should be in the focus of early investigations in the validation of design methods before focussing on *usefulness* (see Figure 1).

The central criterion for design methods to fulfil their purpose is *usefulness*. *Usefulness* describes to what extent a design method reaches its predefined goals (Blessing & Chakrabarti, 2009) what equals design method performance. Daalhuizen and Cash (2021) specify *usefulness* further by defining *efficacy* and *effectiveness* as influences on design method performance. *Efficacy* relates to immediate, direct effects of the design method on designer behaviour and is usually investigated in a controlled environment (Daalhuizen & Cash, 2021). Hence, *efficacy* is in the focus of e*ffect validation* (see Section 1.1). *Effectiveness* relates to indirect effects of design method application on performance and is therefore usually

investigated in the designated context. Hence, *effectiveness* is in the focus of *performance validation* (see Section 1.1).

The third criterion to be considered in validation is *acceptance* which describes how users perceive the design method after application (Reiß, Albers, & Bursac, 2017; Wallisch, Nicklas, & Paetzold, 2021). Acceptance is influenced by the *applicability* and *usefulness* of the design method, as Jänsch (2007) illustrates. It is necessary to assess *acceptance* with users in a real-life context after the investigation of *applicability* and *usefulness*. This puts *acceptance* in the focus of late validation studies during *performance validation* (see Figure 1).

All three success criteria need to be considered through the whole process of design method validation. However, it is advisable to focus on one of the criteria at a time, starting with *applicability* followed by *efficacy* in studies during *effect validation*.

In the following, this contribution focusses on *effect validation*. This is due to the objective of supporting operationalisation of design method goals. *Effect validation* is the first step which demands for operational definitions of design method goals to be used in empirical studies. Therefore, *effect validation* is to be seen as a plausible starting point for standardisation.

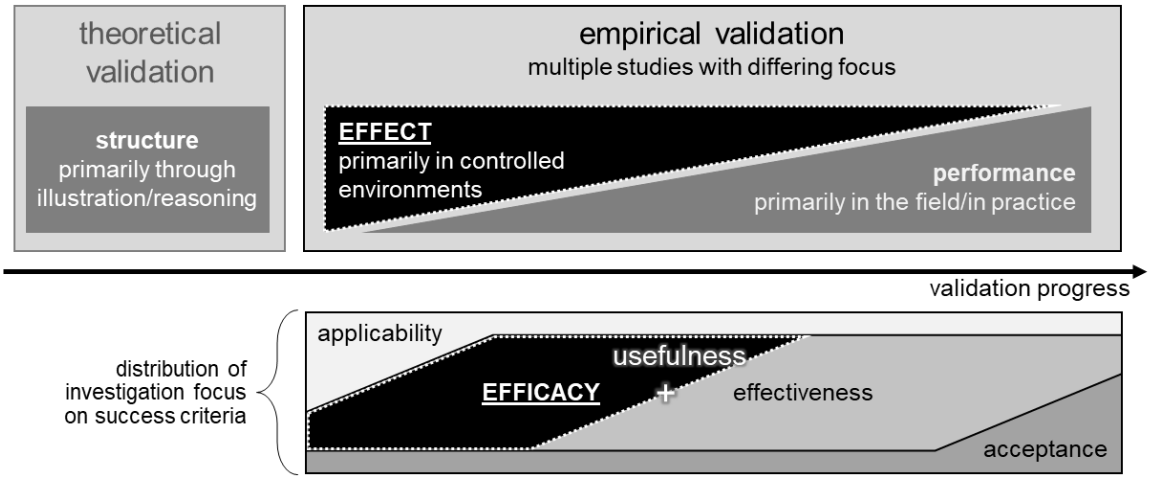

Figure 1: Consolidated steps in the process of design method validation and success criteria to be addressed in empirical validation. The focus of this contribution on efficacy within "effect validation" is highlighted.

1.3 Understanding precedes measurement – first qualitative then quantitative

To investigate the effect of a design method, a qualitative understanding of the application of the design method by a user is necessary in method validation. Design methods aim to change the thinking and actions of the users. Therefore, it must be understood precisely how the design method influences thinking and acting in detail. This understanding is also the basis for a valid operationalisation of efficacy in the form of observable variables. Wacker (2004) also stresses the need for a detailed understanding of abstract concepts before moving on to metrics and operational definitions. Concerning design research this view is supported for example by Eckert, Clarkson, & Stacey (2004).

Qualitative studies are particularly necessary to uncover influences on the thinking of the method users. Through in-depth observation of the method users with subsequent questioning and reflection on the implementation, insights can be gained in this regard. In addition, if validation is not successful in a quantitative study, the causes remain unclear if a qualitative understanding of the effects of design method application has not been built up beforehand. Hence, qualitative studies provide the foundation on which quantitative studies are built. Validation in relation to the effects of a design method should therefore take place both qualitatively and quantitatively.

Applicability should be investigated empirically in addition to a theoretical consideration. By observing the actual application of the design method, an understanding of how the design method is understood and how its *efficacy* arises from the application can be built up within empirical investigations. A qualitative investigation focussing on the *applicability* therefore seems to be purposeful in order to ensure the application of the design method. In addition, such investigations help to generate an initial understanding of how the design method achieves its effect. An example how to conduct such qualitative studies focussing on *applicability* is given in Eisenmann, Grauberger, & Matthiesen (2021).

Effect validation focusses on *efficacy* as part of *usefulness*. For the investigation of *efficacy*, in addition to qualitative investigations, studies are necessary that allow quantification of the effects of a design method. Consequently, at least two studies within the empirical validation of the effect are considered necessary: A qualitative study focussing on the investigation of *applicability* and a quantitative study focussing on the *efficacy* of the design method (see Figure 2). The actual application of the design method still has to be tested for internal validity in the quantitative study.

In the process of method validation, there is a chance in every step that the design method does not fulfil the requirements set. In this case, the design method should be further developed according to the validation results. As in the development of technical products, this leads to iterations in the actual process. Through empirical validation of the effect of design methods, further development through iterations can already take place within a controlled environment. By splitting the validation into two separate studies, the design method can be specifically developed further in terms of applicability – after the qualitative study – and in terms of efficacy – after the quantitative study (see Figure 2). Depending on the extent of modification, it has to be decided how far back in the process to go. If far-reaching modifications of the design method are necessary after the quantitative study, a new qualitative study with a focus on applicability or even a renewed structure validation might be necessary.

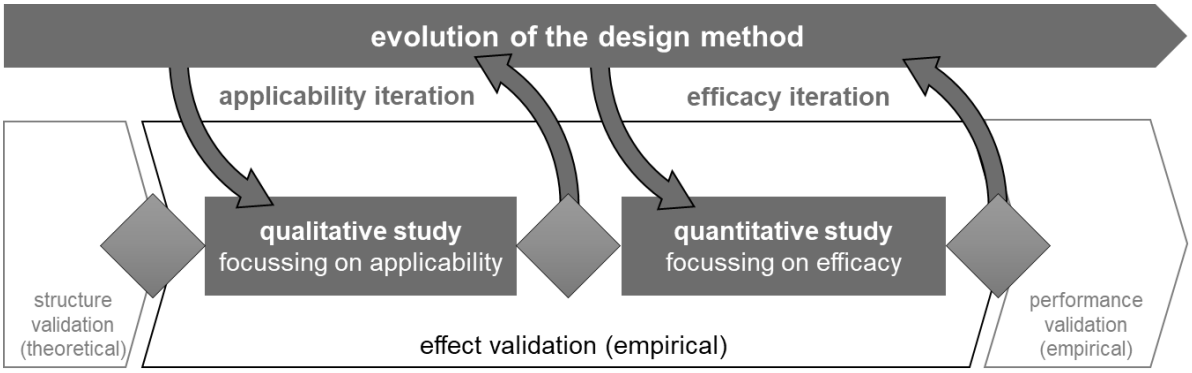

Figure 2: Stage gate process for validation of design method effects embedded in the overall process of design method validation. Iterations can occur after each of the studies shown.

In the following, this contribution focusses on the operationalisation of *efficacy.* The objective of this contribution is to foster discussion on standardisation of operationalisation. Standardisation needs a body of knowledge containing comparable elements to enable selection of standard elements. *Applicability* is characterised by method-specific and mostly qualitative attributes such as *ease of understanding* or *ease of use* (Eisenmann, Grauberger, & Matthiesen, 2021; Kroll & Weisbrod, 2020). Those attributes help to optimise a single method but allow only limited comparability between design methods. Whereas e*fficacy* relates to operationalisation of design method goals which should reflect potentials to positively influence design practice. Various design methods can address the same goals. *Efficacy* is therefore likely to be comparable between different methods. Additionally, quantification of *efficacy* further improves comparability.

2 How can we foster standardisation in operationalisation of efficacy?

This section analyses current research practice while focussing on design method efficacy. The objective is to derive possible ways towards standardisation depending on different starting points concerning the degree of knowledge available for operationalisation: *established knowledge* on operationalisation of method goals for validation (see Section 2.1), existing but *scattered* or *related knowledge* (see Section 2.2) and *missing knowledge* (see Section 2.3).

2.1 Transparent use of established knowledge

A systematic literature review of the current practice of design method validation (Eisenmann et al., 2021) shows a lack of standards for research methodology in many sub-areas of design research. A best-practice example identified in the review is research on design creativity as studies validating design methods for ideation show a high level of comparability. This is particularly visible in the use of established variables for the assessment of ideation outcomes. Shah, Smith, & Vargas-Hernandez (2003) are to be seen as the central contribution consolidating research on creativity assessment. They analyse contributions dating back to

the early 1960's to bring together different views and terms. By relating existing research to *expansion* and *exploration of the design space,* they arrive at four central variables for ideation outcomes: *quantity, quality, novelty* and *variety* of ideas generated. Those established variables allow researchers to make use of strategies beneficial for research quality and further standardisation:

Benchmarking design methods. With common design method goals and variables to assess them, comparison of efficacy is possible. Researchers in the field of design creativity can make use of 'standard' methods such as *brainstorming* as a benchmark for their own design methods (e.g. Cardin et al., 2013; Hatcher et al., 2018). Additionally, benchmarking allows to study differences in efficacy between multiple design methods (e.g. Chulvi et al., 2012; Chulvi et al., 2013) to gain insights for the understanding of underlying mechanisms. These insights can then be used to develop new design methods.

Benchmarking research methods. Research on design creativity mostly agrees on the four above-mentioned variables to assess ideation efficacy. However, there are still various possibilities to operationalise those variables for assessment in detail. Therefore, investigating design methods using different research methods for assessment (e.g. in Chulvi et al., 2012) can yield insights on the suitability of those research methods.

Replication of studies. While standardising operationalisation of efficacy, the replication of studies should be considered as well. Otherwise, failed replication later on can put the obtained results into question, comparable to the replication crisis in psychology (Shrout & Rodgers, 2018). Thus, variables and corresponding research methods for assessment should only be standardised if they are able to produce reliable results. As a first step towards replication, own studies can be repeated (as e.g. Chulvi et al., 2012; Chulvi et al., 2013) to test reliability of results. Then, other researchers then can try to replicate the study.

All of the above strategies benefit from research being as transparent as possible. Therefore, researchers should make descriptions of procedures for data collection and analysis as comprehensible and applicable as possible during reporting. Provision of supplementary data to this end can help to sustain readability of published research papers.

2.2 Identification and consolidation of existing knowledge

While knowledge on established variables for design method efficacy is promptly available in research on design creativity, other areas are confronted with scattered knowledge or a lack of knowledge for operationalisation. In this case, scattered knowledge needs to be consolidated and a lack of knowledge might be compensated through search for related knowledge within design research or for experiences from other disciplines.

Consolidation of knowledge within design research. To consolidate knowledge, systematic literature reviews identifying concepts relevant for operationalisation can be used. In the sub-

field of research on modularisation of technical products Salvador (2007) shows an example on how to find scattered research and consolidate results in concise concepts. Another possibility is illustrated by Eisenmann et al. (2021). They discuss how models central to design methods – such as the design structure matrix – might be used to define method outcomes and therefore possible variables for efficacy assessment.

Utilisation of knowledge from other disciplines. As design research is influenced by various disciplines some researchers suggest to utilise research methodology from those disciplines for the investigation of design methods (Bender et al., 2002; Frey & Dym, 2006). In addition to implementing research methods for assessment, it is also possible to identify operationalisations from those disciplines (e.g. from psychology or neuroscience as in Surma-aho & Hölttä-Otto, 2022) with impact on design. For example, Nelius et al. (2020) use a combination of think aloud protocols and eye tracking to make influences of the *confirmation bias* on the search and interpretation of information in design visible. The operationalisation of influences is founded on insights from psychology.

Making consolidation and relations visible. To make consolidation of existing knowledge as comprehensible as possible, visualisation of effects through design methods can be helpful – especially when using knowledge from other disciplines. For this cause, variables and their interrelations should be combined in some kind of depiction. Established ways of visualisation include *impact models* within *DRM* (Blessing & Chakrabarti, 2009) or *path diagrams* (Baron & Kenny, 1986). Also, newly developed illustrations as in Hackl and Krause (2017) can help to bring structure in segregated islands of knowledge.

Identification and consolidation of knowledge originating from design research as well as from other disciplines to operationalise design method goals needs rigorous and systematic literature work. This includes the search for established concepts and variables as well as drawing conclusions on their interactions. In order to make the resulting insights comprehensible for researchers, appropriate tools for visualisation should be used.

2.3 Building knowledge through reflective research practice

In the above discussed examples of research on design creativity and modularisation, researchers can build upon decades of research on the topic. However, other areas of design research lack such a rich body of knowledge which can be consolidated. Researchers trying to validate their design methods face the problem that neither variables for design method efficacy nor research methods for assessment are present. Suitable operationalisations and corresponding research methods for assessment thus first have to be developed from scratch. In this regard not the procedures or tools – such as the data collection through an interview or a questionnaire – need to be developed. There rather is a lack of established design method goals represented by non-observable variables and operationalisations into observable

variables. However, newly developed operationalisations have not yet been validated, just like the design method under investigation. Therefore, results of validation studies on efficacy are unintentionally influenced or newly defined variables are not correctly assessed. This uncertain situation in design method validation shows similarities to design in practice: Design problems are usually ill-structured and designers initially neither can fully grasp the problem nor directly define elements of the solution. This is why practitioners iteratively work towards a solution through experiments to test their assumptions and reflect on the outcomes (compare Schön, 1983).

Since research methods for assessment aim to capture the effects of design methods, they relate directly to how the design method influences the designers. Especially in detail, research methods and design method are therefore closely linked: The achievement of the goals of a design method is tested with the help of research methods for assessment and suitable observable variables. If new findings on the effect of the design method emerge during validation, the observable variable and therefore also the research method for assessment may have to be further developed. Conversely, the assessment may reveal previously unknown aspects of the situation under investigation. If these aspects directly relate to the design method under investigation and its designated context, this can result in a further development of the design method.

Without available standards or any prior knowledge for operationalisation, it might be beneficial to apply Schön's reflective practice to research as 'reflective *research* practice':

Applying reflective research practice. Setting up a study for effect validation is based on multiple assumptions concerning variables for efficacy and research methods to assess them. This means that the study results must be interpreted not only with regard to influences from the application of the design method, but also with regard to influences from the applied research methods for assessment. There is also a possibility here for the research methods not to meet the requirements. For newly developed variables and associated research methods for assessment, iterative further development may therefore be necessary during effect validation. This view impacts both qualitative and quantitative studies in effect validation (compare Figure 2). This is why the validation process needs to be adapted to reflective research practice (see Figure 3).

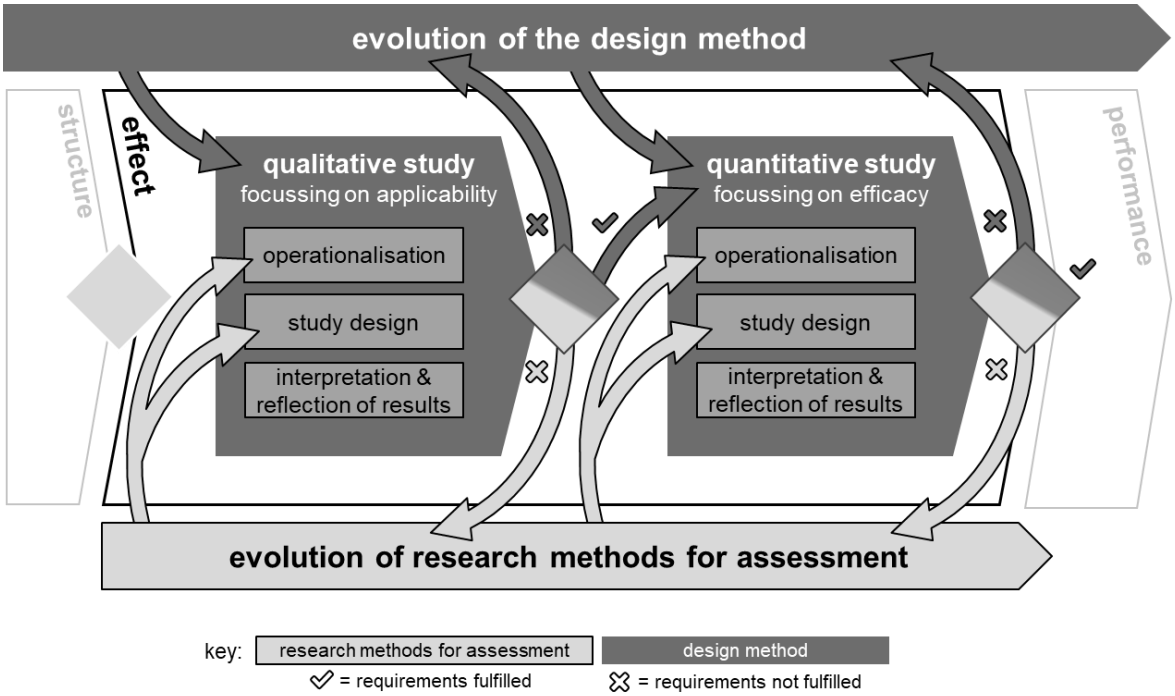

Figure 3: Process for the validation of design method efficacy including the pragmatic approach of 'reflective research practice' enabling co-evolution of research methods and design method.

Strictly speaking, applying *reflective research practice* violates the basic rules of scholarship as both research methods for assessment and the design method under investigation are not validated in advance to the investigation. However, valuable insights can be gained through allowing reflective research practice. A similar conclusion is reached by (Cash et al., 2012, p. 210) that such *"small-scale scoping studies, although not always ideal, play an important role in design research for pragmatic as well as methodological reasons."* The kind of insights gained through such scoping studies is often crucial for the development of study designs for larger studies. However, without publication these insights remain hidden for the research community. It is to be noted that intense discussion of limitations is a must-have for papers reporting this kind of study. Building on gained insights, the design method as well as the operationalisation used for effect validation should be investigated using separate follow-up studies.

3 Conclusion and outlook

The main objective of this contribution was to bring research on design methods closer together by providing a consolidation of existing approaches and strategies to comparably investigate effects of design methods. The general conclusion to be drawn in this regard is that we have a long way to go, because there is a lack of established knowledge and theory in many areas. All the more should we cherish the knowledge on operationalisation that has been built up in sub-areas.

Researchers investigating design methods and their effects with such knowledge available therefore should

- …use established knowledge where possible to benchmark design methods as well as research methodology and replicate studies.
- …identify and consolidate knowledge from related design research or from other disciplines and make newly drawn connections transparent through visualisation.
- …move from a mindset ‘my method is better’ towards building a shared understanding of underlying mechanisms.

Design method goals, variables and research methodology for validation are closely linked with each other through operationalisation and have to be developed mutually. When knowledge on how to investigate the effects of design methods is not available, researchers should

- …conduct and publish qualitative and quantitative small scale scoping studies to put possible operationalisations to discussion with the community.

Those small-scale studies, conducted in ‘theory building mode’ can contribute to the definition of variables (Cash et al., 2022) for a theory of design methods. A common language in the description of design methods (Gray, 2022) can additionally help to raise comparability between methods and therefore promote this process of theory-building.

We as a community should therefore value the contribution and foster research focussing on the development of operationalisations as well as research trying to build bridges between islands of understanding in the field. Comparability is the first step for the development of standards. Standards in turn support meta-analysis to yield new insights on design methods.

Acknowledgements and Funding

Part of the research presented in this contribution originates from the research project “MProvE” on design method validation and is supported by the German Research Foundation (DFG, Deutsche Forschungsgemeinschaft) [447357425].

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