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Development of a Sustainable Training Program to Enhance Methodological Competence of Designers

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Abstract
In this paper we claim that methodical competence is the most important prerequisite of a designer to be able to successfully choose and apply design methods in his or her daily work. Following this assumption it is crucial to define methodical competence and – even more important – to know how it can be improved. To address this question, a model of methodological design competence is presented from which recommendations are derived for successfully teaching methodological competence in appropriate forms of training.

Keywords: methods, knowledge, expertise, methodical competence, training, design.

1 Introduction
”Practice makes perfect“ is a well-known proverb which can be interpreted in two ways: a) practice in terms of exercises and rehearsals leads to perfect performance or b) practice in terms of doing and applying is necessary for a successful result.
Both interpretations appear reasonable and hence it can be said that a designer’s competence needs to be trained *and* applied in practical daily job routine to achieve mastery of the design process. Therefore, teaching and using methods should be an integral part of corresponding trainings to reach successful and sustainable transfer of methodical competence into application.
But what exactly is methodical competence and how can we teach it?

2 Definition of "methodical competence" of designers
First of all, it is important to define the terms competence, specifically *methodical competence of designers*.
According to the dictionary competence means "responsibility", "authority" or "power" (Kaiser, [12]). From an educational and psychological point, competence describes skills that allow to flexibly choose appropriate behavior, while developing own procedures and actions. Thus, successful and adaptable behavior is always newly generated and combined.

A difference has to be made between competence and performance. For example, what a person says (=performance) might be less than she is capable of saying in terms of for instance background information (potential = competence). Kaiser [12] states that, according to pedagogical findings, competence can be gained by learning and training. According to Kaiser methodical competence means to have a flexible repertoire of heuristics to solve problems. Expert knowledge (knowledge of specific domains in science and general ability for problem solving) is an important base for methodical competence.
Klippert [14] splits methodical competence into two areas: macro-methods and micro-methods. Knowing macro-methods means to be familiar with methods themselves, while micro-methods contain elementary learning- and working-skills as well as elementary conversation and cooperation-techniques. So according to him, methodical competence includes a certain problem solving base (expert knowledge or expertise) plus the knowledge of procedure while using certain macro-methods.
Empirical studies showed that not only in design but also in other complex environments heuristic competence is one of the most important capabilities of designers [4, 5, 9, 20]. To gain heuristic competence, it is important not only to gain factual knowledge, but also to consider feedback resulting from usage of methods or experiments. Pahl [16, 17] described sound and structured knowledge, appropriate balance between concreteness and abstraction (based on the situation), dealing with uncertainty and fuzzy data and continuous focus on the goals (while adopting flexible decision making behavior) as characteristics of *heuristic competence*.
Kauffeld et al. [13] define "professional competence of actions" as all knowledge and skills that support the mastering of familiar or new tasks in a successful, self-organized, targeted, flexible and responsible manner. They state that competence is usually divided into four sections of competence: expertise, methodical competence, social competence and self-competence, which includes reflection and adaptation. All four parts of competencies are dependent on each other and need to act together. Kauffeld et al. define *expertise* as the complex of organizational, process- and task- specific skills and knowledge and the ability to sort and assess organizational knowledge whereas methodical competence is the ability to describe problems in a structured, flexible and situational overlapping manner to reach a point, where decision making is possible. Following this definition Kauffeld et al. assign different skills to expertise that are named elsewhere as ingredients of methodical competence. So they see “naming and describing of problems” or “generation of solutions” as expertise, while more procedural aspects like “delegating tasks” or “time management” are named as methodical competence. This differentiation however does not held for a disjunctive combination as for example, process-specific skills are claimed being part of expertise, whereas “suggesting further procedures” is part of methodical competence.
Team-competencies are defined by Cannon-Bowers et al. [3] as a mix of *knowledge* required to perform the task effectively, *skills* and actions required to perform the task effectively and the appropriate *attitude* to perform the task effectively. They distinguish four basic team competencies: context-driven (competency specific to team and task), team-contingent (specific to team, generic with respect to the task), task-contingent (specific to task, generic with respect to the team) and transportable (not specific to any particular task or team) competencies. Focusing on the nature of task competencies, task-specific competencies describe knowledge of specific role responsibilities for a particular task, while task-generic competencies like planning skills may be of use across different tasks. Cannon-Bowers et al. state that depending on the situation and the task a team needs different types or mixes of competencies. For example facing a task that requires a high amount of interaction, high flexibility, and the collaboration between different disciplines, context-driven competencies are needed (specific competencies regarding the tasks AND the team). On the other hand, new

composed teams coping with different non-specific tasks need team-specific competencies (e.g. interpersonal relations, intra-team feedback, etc.) and task-generic competencies, too. Cannon-Bowers et al. propose that competencies are a mix of knowledge, skills and attitudes that need to be situation-, task- and team-specific. Depending on the task, other task-competencies may be needed. Competencies regarding tasks involve either the execution of teamwork behaviors in a specific task (task-specific behaviors) or task-generic competencies with more general nature.
Martin [15] distinguishes four fields of competence: characteristics of expert competence, characteristics of social competence, of self-management and methodical competence. While he allocates expert knowledge and practical experience to his concept of expert competence, he defines methodical competence as a generic term for actions like project management, problem-solving-, planning-, and creativity- or moderation-techniques.
Analyzing strategies and qualifications of experts, Jänsch [11] states that experts (assuming the existence of methodical competence) possess an extensive stock of problem-solving procedures, which they can immediately link to the sub-problem or the complete problem retrieving knowledge in a very structured and efficient way. In addition, problem-solving procedures of experts are partly routine behavior and thus stable. In her doctoral thesis, Jänsch [10] showed that design methods – as externalized expert knowledge – successfully support the problem solving process. Expertise is defined as the ability for outstanding performance in a certain domain. Experts do not only achieve high performance in standard situations but also in exceptional circumstances. Experts have a lot of knowledge and are able to gather knowledge effectively. Experts do not only plan their proceeding better than novices, but they adapt their plans to their cognitive resources, reflect processes and actions, control procedures and they can easily adjust their thinking and actions to actual situations or events. Domain-specific expertise is thus seen as a combination of domain-specific expert knowledge with knowledge and skills needed for flexible and targeted proceedings regarding problem solving. This definition of expertise is equivalent to a combination of expertise and methodical competence – or the term "heuristic competence" (as defined by Dörner [4, 5], see also [16, 17].

Table 1 lists and compares the differing views on methodical competence. While Cannon-Bowers et al. [3] define competence in relation to team and situation and thus do not deliver a definition of methodical competence in general, the other authors [10, 11, 12, 13, 14, 15, 16, 17] suggest different definitions of methodical competence.

Table 1. Comparison of different concepts of methodical competence

	Kaiser	Klippert	Ladenburger Diskurs / Pahl	Kauffeld	Cannon-Bowers	Martin	Jänsch
problem solving skills (analysis, dealing with uncertainties, generation or assessment of solutions, etc.)	x		x		o	x	x
elementary working skills (time management, prioritization, planning, cooperation, visualization of tasks,…)		x		x	o	x	
includes knowledge & expertise (about processes, products, tasks…)		x	x		o		x
needs knowledge & expertise (about processes, products, tasks…)	x			x	o	x	

Summarizing these findings it becomes obvious that methodical competence is hard to define and that it partially includes – or at least is dependent on – other competencies, especially expertise. Expertise and reflection are named as essential for design performance by almost all sources in literature.

3 Model of Methodical Competence of designers

As shown in the previous chapter methodical competence cannot be seen as a pool of certain skills without considering other supplementary aspects. On the contrary, adding other important attributes to this concept is seen as necessary. To speak only of "methodical competence" in a design context falls to short, as construction tasks cannot be carried out without suitable knowledge or expertise [16, 17]. Therefore, the supplementation "…of designers" is attached to create a more appropriate and design-specific label. This concept of methodical competence of designers (MCD) is somehow similar to and complements the concept of "heuristic competence" as described before.
Analyzing all the different concepts of methodical competence, the following are found as an extended concept of heuristic competence of designers:

- Methodical competence of designers includes expert knowledge
- Methodical competence of designers includes skills needed for prioritization, planning and organization within the process of problem-solving
- Methodical competence of designers includes a reservoir of problem-solving actions like abstraction, generation of solutions, dealing with uncertainty or decision making
- Methodical competence of designers contains the ability to analyze, adapt and control the problem-solving process
- Methodical competence of designers necessarily contains the ability to reflect and adapt one's own actions.

According to these aspects "methodical competence of designers" is an intersection of expert knowledge and methodical competence in general as shown in Figure 1.

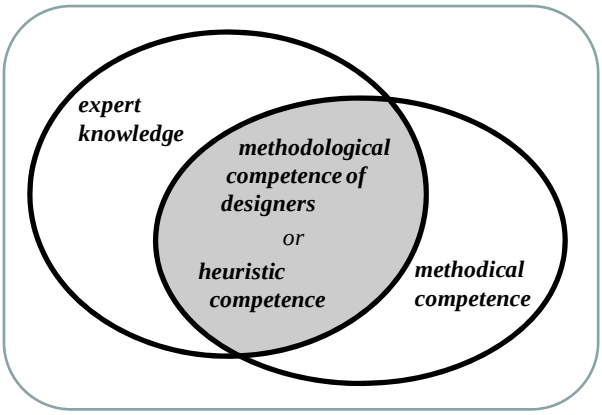

Figure 1. Definition of methodical competence of designers

Based on the before illustrated theoretical assumptions and empirical data, we assume that methodological competence of designers (MCD) is a confluence of five elements (see Figure 2), consisting of:

1. expert knowledge

Expert knowledge (also called expertise) includes theoretical knowledge about machine elements and design processes as well as knowledge of a certain set of methods and their scope. Additionally, it includes experience in problem-solving actions.

2. choice of methods

Before a method can be applied, task(s) and situational characteristic(s) ("situation" includes boundary conditions and their connections; also embedded in the process) need to be thoroughly analyzed. Then after an assessment of available and feasible methods, an appropriate method or a set of methods is chosen and a strategy is built for mastering the design task. Experts can gain and recall this knowledge quickly and effectively [10, 11].

3. adaptation of methods

After having discovered and analyzed the boundary conditions and the interrelations between the constraints, the methods have to be analyzed, as to whether they fit and/or correspond to the actual needs (see [2]). Eventually in this phase design methods have to be changed (e.g. QFD: 'house of quality' without the 'roof' or brainstorming with less people than initially required) and possibly the whole proceeding is adapted to the combination of situation ↔ task ↔ method.

4. execution of methods

Methods must be carried out, to move along in the process. The ability to implement, eventually adapt and execute design methods as well as controlling one's own actions is necessary to perform successful problem-solving. In this context, actions like dealing with uncertainty and fuzzy data, appropriate balancing between concreteness and abstraction and continuous focus on the goals, which were already mentioned as qualifications of good problem solvers [17], are executed.

5. reflection on actions

As last element of methodical competence, reflection on the process and the outcome of the execution of methods guarantees better quality in both problem-solving and future processes. The results of the reflection improve experience and knowledge about methods (maybe there is an increase of additional procedural or task-specific knowledge as well…) and thus can be seen as an increase and improvement of methodical competence of designers.

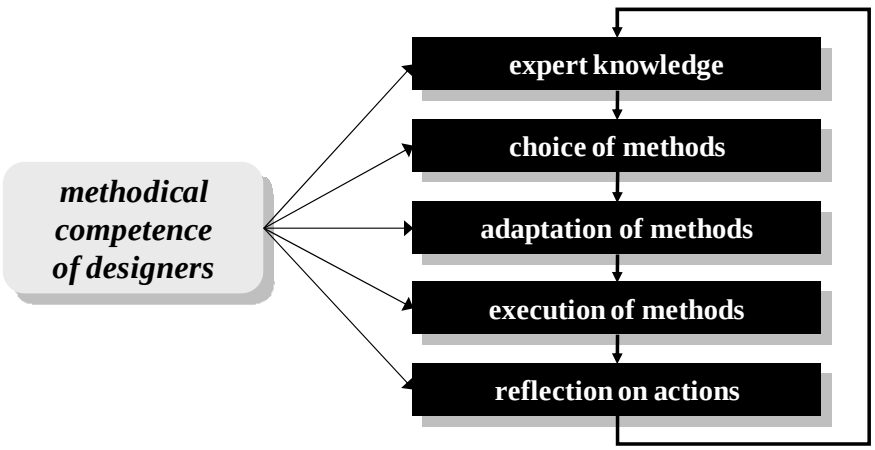

Figure 2. Model of methodical competence of designers (MCD)

Designers as well as human beings in general are usually not motivated to reflect on their own actions and procedures [14], and potentials of reflection in the industry are not used to a satisfactory extent [21]. Thus, a training of MCD must create the necessary space and motivation to reach a sustainable acceptance of this aspect of methodical competence.

4 Training of methodical competence

As described by Geis et al. [8], methods must be taught and practiced at appropriate events while alternating between different learning styles and techniques (as proposed by Edelmann [6] or Quosdorf [18]). It is important to get a mix of behavioral, cognitive and constructive training elements, to gain and hold motivation among the participants and to promote all different types of learning, namely receptive, exploratory, mechanical and sensible learning [1]. Lectures, workshops, exercises and reflection phases (including cross checking, feedback, etc.) should therefore be combined to achieve all the elements of expert learning, like self-assessment, strategic learning, etc. (see also [11]). Flexible and changing parameters within the training force the participants to continously analyze, reflect and adapt to the situation. This is important to execute sustainable training so that the participants can transfer their trained knowledge and skills to their daily job routine.

The participants of the Ladenburger Diskurs [16] (a discourse of a group of professors from eastern and western Germany aiming at finding shared terminologies and a shared base for improved education of design engineers; May 1992 to October 1993) also compiled the following requirements for development and training of competence:

- motivation needs to be created by presenting events, problems, fascinating pictures, etc.
- the goal of a training measure should be declared and explained
- descriptions of professional or methodical details should be given
- demonstration of examples is necessary to deepen the content
- reflection (the abstracting view on process and product) is always necessary to see the extent and the consequence of actions
- although complexity needs to be reduced, it must still be present so that no false reality is feigned
- transfer of skills to other domains is important to improve knowledge and skills and to train transfer skills.

All these findings about training of methodical competence, like motivating, informing, stimulating, leading the participants of the training through the process while they work on a challenging task and giving feedback are also taken into account by Robert Gagné's [7] assumption, which claims that combinations of different instructional conditions are most effective for sustainable training. Gagné's model "Instructional Design" [7] supports different learning types and fulfills (at least partially) the requirements of an optimal training architecture, formulated e.g. by the Ladenburger Diskurs [16], Ausubel [1] or Edelmann [6]. Instructional Design requests, that participants get advice and feedback, are controlled in a structured approach and simultaneously develop strategies and organize their procedure on their own in a discovery approach.

The "Nine Events of Instruction" developed by Gagné, give advice on the architecture of training sessions:

1. Gain the attention of the participants (e.g. by giving visual stimuli)
2. Inform the learner about objectives (e.g. by writing training objectives on a board)
3. Stimulate recall of prior learning (e.g. by asking questions about prior experiences)
4. Present (new) content/material (e.g. by using a presentation or movie)
5. Provide learning guidance (e.g. by giving examples or case-studies)
6. Elicit performance (practice of new skill or behavior, e.g. in a design-task)
7. Provide feedback (e.g. by giving additional answers and guidance)
8. Assess performance (possibility of a post-test for participants)
9. Enhance retention transfer (e.g. by handouts, online-aids or follow-up-sheets)

Regarding all these requirements, training sessions can be developed that reflect and support all aspects of methodical competence as defined before. In a training session, new knowledge (e.g. WHICH methods exist for WHAT kind of tasks and HOW do they differ?) must be presented in fixed lessons and participants also need to be given the opportunity to choose, adapt and execute design methods in practical exercises. Different reflection phases, where participants reflect on their performance and raise measures for further procedure, including assessment of proceeding, advice and feedback by a monitoring expert, ensure sustainable retention (what is equivalent to an improvement of method competence).

In our model of MCD, reflection is seen as an essential and important factor for successful transfer of methodical competence. A lot of designers like the participants of the Ladenburger Diskurs [16], Pahl [17], Wallmeier [21] or Jänsch [10, 11], support this point of view, as design processes are often of iterative character with continuing assessment and adaptation of product and procedure [16]. It is also stated by Pahl [17] that one of several properties of a good designer is permanent reflection on his own approach and actions and the adaptation of his proceeding to the actual state of the problem and/or situation. However, reflection is usually not considered to be an essential part of training sessions, and therefore the following section will be used to analyze what reflection in a design process is and how it can work.

Schön [19] introduced the term “reflective practice” and stated that all professional practice is design-like (dealing with problems like uncertainty is seen by Schön as the 'artistry' of a professional) and needs reflection-in-action, which guides the engineer through the design process. As each situation is unique, uncertain and full of value conflicts, designers have to determine their position in the situation. With their decisions, designers convert indeterminate situations into determinate ones and create new situations themselves. Schön’s point of view can be compared to the Greek philosopher Heraklit, to whom the philosophy "panta rhei" (everything is in a state of flux) is commonly followed back to. Heraklit created the river simile, saying that one cannot step twice in the same river, as the river flows with new water and oneself got older or has changed, so that both sides changed and a new situation has originated. These new situations (acc. to Schön [19] again) can be of two different types: familiar and unfamiliar ones. Reflection-in-action is seen as a tool to gain a constructivist view of the reality and the situation that the designer deals with.
Although (acc. to Valkenburg [23]) Schön's work provoked a lot of criticism, for example inadequate empirical evidence, incomprehensibility, or a lack of precise terminology, his work has inspired a lot of researchers. Valkenburg and Dorst [22], for example, set up a descriptive model for reflection-in-action using four design activities (described by Schön, [19]): naming, framing, moving and reflecting. These design activities of reflective practice can be combined and visualized to support the process as shown in Figure 3.

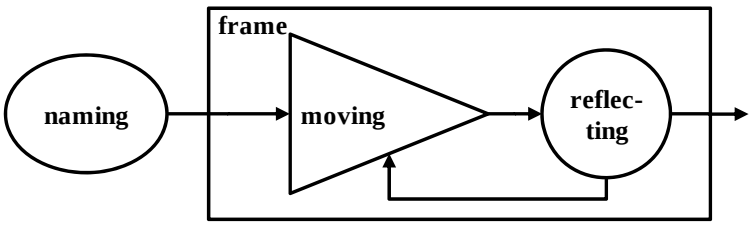

Figure 3. Reflection-in-action acc. to Valkenburg and Dorst [22]

According to Schön the design process may be described by four activities: the designer names an issue (*naming*) and establishes/defines the parameters of the problem (*framing*) [19, 23].

Then – moving along in the frame of the problem – the engineer solves problems and makes decisions. All the actions taken therein, including generating solutions, looking at the consequences of decisions, etc. are labeled as moves (*moving*). At last the designer may evaluate his moves in terms of desirability of consequences, conformity to implications set up by earlier moves and in terms of appreciation of the newly created problems or potentials (*reflecting*).
Although reflection itself has no universally accepted formal structure or procedure, regarding the findings of Schön [19], Wallmeier [21], Valkenburg [23] and others, an exemplary model for reflection in design processes can be given.

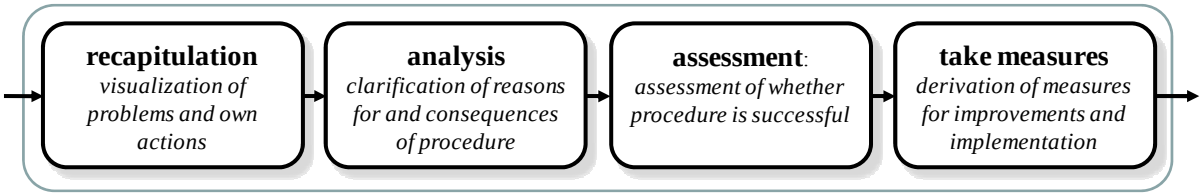

Figure 4. Process of reflecting

As depicted in Figure 4, at first the actual situation needs to be recapitulated and further analyzed, to remember which actions were executed and what consequences these actions had. After assessing whether the procedure was successful or not, measures for the further proceedings must be raised to successfully adapt one's own moves. These measures must be documented and implemented afterwards and while moving further (which is equivalent to the creation of a new situation), reflection-in-action has to be conducted every now and then.

In summary, reflection can be seen as an essential factor in gaining and developing competence and thus aids to successful developing and designing processes. In one sentence: the problem-solving process must be analyzed through reflection, and reconstructed, in order to derive what problems occurred and what measures can be taken to solve these problems.
Reflection must therefore be part of the training of methodical competence to get used to the structured procedure needed, while still successfully reflecting on one's own procedures and actions.

Modules for the training of methodical competence have already been developed and implemented in student teams at the Technische Universität Darmstadt. Regarding the findings of structures of trainings and teaching concepts, the training was developed with the structure as shown in Figure 5.

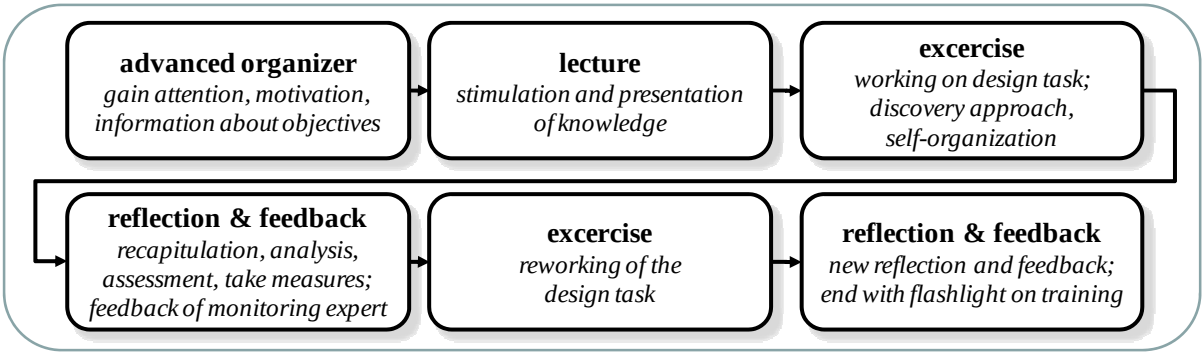

Figure 5. Setup for trainings of methodical competence

After an advanced organizer, used to motivate and inform the participants about the objectives of training, existing knowledge is stimulated in a lecture and new material is presented. The

teams then receives a challenge and practical tips regarding the use of methods and problem-solving and then carry out this practical exercise (approx. 45 minutes), which they will do in self-organization in a discovery approach while being observed by an expert. Subsequently, a reflection- and feedback-phase (RFP) takes place in which the group has to assess their performance in a led discussion. They must find causes of possible problems, interrelation and must generate measures for further action. In addition, the team receives feedback and tips from the monitoring expert. To ensure sustainable success of the training, the group works on the task again, respectively is continuing it (approx. 30 min.). While doing so, the team members try to take into account and to apply the measures and the feedback of the RFP. Finally, in another RFP, the team analyzes whether the procedure was successful and has led to the desired result. The training ends with tips and an assessment of the second exercise phase, followed up by a 'flashlight' (which is some kind of "flash-feedback", where each participant has the chance to state their opinion in one or two sentences) on the complete training and its success.

The teams carry out a design game before AND after the training and comparisons are drawn of trained and non-trained groups (inter-team comparison). Analysis of the teams results of the design game before and after the training (intra-team comparison) are carried out, to determine whether the training proved to be successful. Supplementary modules and follow-up-instruments are currently in development.

5 Summary

Methodical competence of designers is a complex pattern of capabilities including general methodical competence (like organizing- or problem-solving skills and knowledge about method usage) AND expert knowledge (e.g. about process, tasks, products, methods, etc.). Based on the recommendation of literature, a *design-specific model of* "*methodical competence*" was conceptualized including five elements: a) expert knowledge about methods, tasks and process, b) choice of methods, which includes the analysis of situation and interrelations, c) adaption of methods, which includes analysis, organization and adaptation of methods and proceeding, d) execution of methods, refers to problem-solving behavior and control of actions and e) reflection on actions as measure to improve own actions and proceeding and thus improve the own methodical competence. These elements must be reflected in an appropriate form of training that has to be developed using findings on optimal training architecture and learning concepts (such as Instructional Design) and reflection has to be trained repeatedly to achieve good acceptance and retention. A first training session has been realized at the Technische Universität Darmstadt and proved to be successful.
Results warrant further work and lead to the confidence that future improvements and implementations will help to further improve the training of methodical competence of designers.

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