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TRAINING FOR REFLECTIVE COMPETENCY IN DESIGN TEAMS: AN EMPIRICAL STUDY

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ABSTRACT
The need for flexibility in designers' acting and thinking processes can be seen as a core requirement for successful design practice. For designers collaborating in a team gaining cognitive flexibility is quite challenging, as cognitive processes are not directly observable for other team members and therefore hard to assess and change. The aim of this paper is to clarify how team reflection as the critical analysis and adaption of the team's acting and thinking processes can serve as an instrument to facilitate cognitive flexibility and thereby improve team performance. Based on an empirical requirements analysis a training program for reflective competency in teams has been developed. The training has been evaluated on design teams in industry. Results of the qualitative analysis of four case studies suggest that the training serves as a suitable instrument to teach effective team reflection which leads to more cognitive flexibility. Within this paper, the results of two case studies with quite different training courses are illustrated and discussed in detail. Finally, conclusions both for future research and about the practical relevance of the results are drawn.

Keywords: complexity, teamwork, knowledge management, team reflection, training

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1 INTRODUCTION

In the fields of cognitive psychology and learning theory individual and team reflection have been considered as means to learn from own experiences and thereby improve individual and team performance (e.g. Schön, 1987; West, 2000). During reflection the critical analysis and evaluation of own acting and thinking helps to adapt these processes to the current circumstances and thereby improve them.

These findings seem to be interesting especially for the design context as new developments in the conceptualization of Design Thinking have taken place: Some authors regard Design Thinking as a management tool for the realization of innovations in order to face current and future global challenges (e.g. Verganti, 2009). According to this point of view, the designer as a Design Thinker has to be able to cope with the high complexity of design problems by knowing that there is no 'one best way'. Therefore, the need for flexibility in designers' acting and thinking processes can be seen as a core requirement for successful design practice. This new Design Thinking approach can be criticized as being too abstract and drawing only a prescriptive or even idealistic picture of the designer (Badke-Schaub, Roozenburg, & Cardoso, 2010). Therefore, there arise claims for explicating ways how this overall flexibility in designers' acting and thinking can be gained.

Reflection as critical analysis of own thinking and acting processes is considered to widen the view and thus bring about cognitive flexibility. But how to reflect in an interdisciplinary team and how to gain flexibility of the team members' cognitive processes which are not directly observable for other people and therefore hard to assess and change? These problems might be the reason why there's only little evidence on the topic how team reflection can be used to enhance the flexibility of thinking and information management in a team.

The aim of this paper is to introduce a new concept of team reflection as a means to gain cognitive flexibility. An empirical study will be presented which shows evidence for the new developed training for reflective competency in teams. This training shall enable designers to analyze their own thinking processes and adapt them to the specific demands of the current situation. The training has been evaluated on design teams in industry. In the following section the challenges for design teams and the need for cognitive flexibility will be outlined and in section 3 the training rationale will be introduced. Methods and results of the empirical study will be presented in section 4.

2 COGNITIVE FLEXIBILITY AS AN EFFECT OF TEAM REFLECTION

In this section, the challenges of information management and coordination in teams resulting in the need for cognitive flexibility will be introduced. It will be explained how team reflection can be used as a means to enhance cognitive flexibility and thereby to improve team work processes.

When solving a design problem designers build mental representations of relevant aspects of the current situation. These representations allow them to describe and explain the situation but also to predict future developments. In cognitive science, these mental representations are referred to as mental models (e.g. Craik, 1943; Johnson-Laird, 1983). As members of an interdisciplinary design team often pursue conflicting goals, have different values and beliefs and possess specialized expert knowledge they normally hold quite diverse representations of the same situation. However, in order to communicate and collaborate effectively in a team designers have to share some aspects of their individual representations with other team members. These so called shared mental models can be characterized as knowledge or belief structures that are shared by members of a team, which enable them to create accurate explanations and expectations about the task, and to coordinate their actions and adapt their behaviors to the demands of the task and other team members (Cannon-Bowers, Salas, & Converse, 1993).

Researchers agree that people build at least two different types of mental models: the task model which includes knowledge about the particular task and the team model containing knowledge about the other team members, their abilities and responsibilities (Espinosa et al., 2001). Dependent on the domain of work further distinctions of types of mental models can be made. For the design context, Badke-Schaub, Neumann, Lauche, & Mohammed (2007) propose five types of mental models: the task model, the team model, the process model, the context model and the competence model. The competence model refers to the team members' shared beliefs in their collective power to produce desired outcomes (Bandura, 1998).

Shared mental models are developed by the explicit exchange of information and knowledge in team (Neumann, 2012) and, in turn, once built can decrease the need of explicit information exchange and coordination in a team as they allow the prediction of the behavior of other team members and the development of situational and task related issues (Marks, Zaccaro, & Mathieu, 2000). In general, most authors emphasize the positive effect of shared mental models on team processes and team performance (e.g. Smith-Jentsch, Mathieu, & Kraiger, 2005).

On the other hand, possible negative effects of shared mental models can be discussed: First of all, even if all members of a team would share identical knowledge, the accuracy of this knowledge is not guaranteed (Rentsch & Hall, 1994). When members of a team all agree on an inaccurate or even wrong model of the reality, this can lead to errors and negatively affect team performance. Janis (1972) described the phenomenon of groupthink as the natural tendency of highly cohesive teams to seek consensus in team. This can lead to the suppression of ideas that are not consistent with the majority's opinion. Opinions that are shared among team members but are not appropriate or even false can lead to errors and failures. Secondly, for creative tasks, such as design tasks, especially different views and diversity of thinking seem to foster innovative solutions (Badke-Schaub, Goldschmidt, & Meijer, 2007). For example, multidisciplinary project teams in design consist of experts with specialized knowledge in order to regard different aspects of a complex task and come up with creative solutions.

To sum up, although the positive effects of Shared Mental Models have been empirically proven, it has to be stated that especially in teams performing complex tasks, such as design teams, more sharedness of the individual mental models is not always better. But even creative teams need to share at least some aspects of their individual knowledge, for example, aspects of the common goal (task model) and knowledge about how to work together (process model).

It becomes evident, that for the completion of complex design tasks in teams there has to be a balanced relation between aspects of knowledge to be shared and aspects of knowledge to be distributed in the team depending on task characteristics, team composition and situational demands. Moreover, the dynamically changing requirements in design demand cognitive flexibility, which, generally spoken, is defined as the ability to restructure knowledge in multiple ways depending on the changing situational demands (i.e. difficulty or complexity of the situation) in order to understand and deal with these situations (Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987). In the context of mental models, one aspect of cognitive flexibility is the ability to question and adapt the accuracy of the mental models and the degree of consensus among the team according to the demands of the actual situation.

But how can cognitive flexibility in design teams be gained? In research, **team reflection** has been considered as an adequate means to improve team coordination and cooperation by facilitating the development of shared knowledge in a team (Blickensderfer, Cannon-Bowers, & Salas, 1997). The authors suggest that by the discussion of crucial aspects in a phase of team reflection team members increasingly develop a common understanding of the task and the process of task completion.

In addition to these findings, this contribution exposes that team reflection is also suited to gain cognitive flexibility in teams.

During team reflection, team members need to become oblivious of their thinking processes and their (common or distributed) knowledge and believes. In consequence, team reflection can serve as a means to question the accuracy of the mental models and their degree of sharedness among the team. If required, team reflection can result in a correction or confirmation of the mental models in teams or an increase or decrease of sharedness of mental models.

In order to clarify the link between team reflection and cognitive flexibility an extensive literature review as well as an interview study with 47 practitioners have been conducted and a model of team reflection has been developed (see Figure 1):

Team reflection takes place, when team members turn the acting and thinking processes of the team into objects of common discussion in order to understand, clarify and finally improve them. Team reflection includes steps of recapitulation (what have we done/thought?), analysis (Why? Where will it lead us? What did/do we assume, know, aim for? Was/is there a consensus?), evaluation (Are the mental models in team accurate? Is our degree of consensus functional?), goal setting (What do we want to change?) and solution generation (How can we change it?).

Thus, in our conceptualization, team reflection does not only refer to the process of questioning own actions but also to the reflection of team knowledge and the assessment and adaption of its accuracy and degree of sharedness. When the accuracy of shared mental models in team is considered to be low,

this can result in a correction of the wrong assumptions. When the degree of sharedness of mental models in the team is regarded as dysfunctional, sharedness can either be increased (for example by openly discussing crucial aspects of team work) or decreased (for example by obtaining a lateral thinker's opinion). In sum, the proposed model suggests an influence of team reflection on cognitive flexibility in teams.

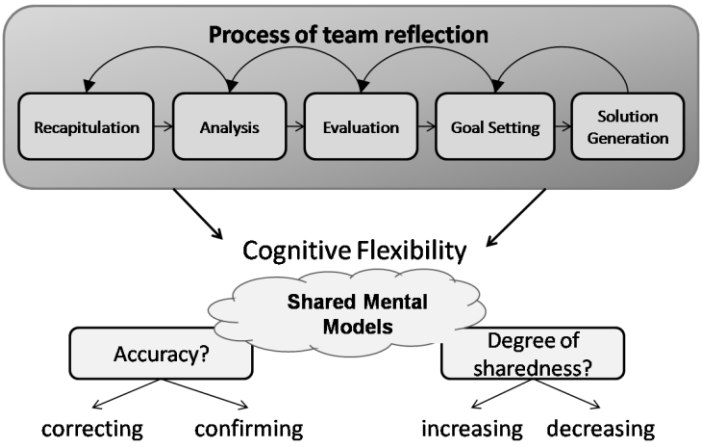

Figure 1. Model of team reflection

Despite the positive effects of team reflection, we know that reflective processes in teams do not occur spontaneously (Schippers, Den Hartog, & Koopman, 2007). That is why there have been attempts to develop trainings which support individual or team reflection. There exist approaches to train designers reflecting on critical situations during the design process (Badke-Schaub, Wallmeier, & Dörner, 1999) and a training on the adequate selection, adaption and execution of design methods (Geis, 2009). But so far there has been no training concept that explicitly aims at the practice of team reflection as a means to question and improve thinking processes and information management in design teams.

3 THE TRAINING OF REFLECTIVE COMPETENCY IN TEAMS

The model of team reflection (see Figure 1) served as an initial point for the development of the Training of Reflective Competency in Teams (TRCT). The TRCT (Bierhals, Weixelbaum, & Badke-Schaub, 2010) intends to enable the participants to gain cognitive flexibility by means of successful team reflection. The technique of team reflection should help the participants to question and assess the accuracy and the degree of sharedness of team mental models and, if necessary, adapt them to the demands of the actual situation. In some situations an adaption of team mental models may be required either by the correction of team knowledge or by the adjustment of sharedness of team mental models (e.g. by enhancing diversity by obtaining a lateral thinker's opinion). In other situations, participants can use team reflection as a means to increase the sharedness of team mental models by explication of relevant issues. The TRCT should qualify the participants for the discrimination between situations in which either stability or change in team members' mental models is required.

The training rationale is based on the experiential learning approach of Kolb & Kolb (2009): The participants themselves take responsibility for their own learning process. They make concrete experiences, reflect on them and draw abstract conclusions for future situations from what they have learned. The TRCT does not aim at the prevention of errors but at a competent error management. The training concept also includes the implementation of a gaming simulation as a training and research instrument. By representing all relevant structural characteristics of designers' real working life the gaming simulation approach provides a motivating training environment and, moreover, controlled research conditions (Romme & Georges, 2004).

The schedule of the three-day training concept can be seen in Figure 2. The first day is dedicated to impart basic skills of team reflection. During the course of the day the participants are taught how to conduct successful team reflection. Besides the presentation of theoretical knowledge on team reflection, training day 1 consists of different team exercises, workshop elements and role plays that are followed by moderated team reflection periods in which team members can practice successful team reflection. At the beginning of the training the coaches give the participants concrete assistance

how to do the team reflection sequences. The support of the coaches is gradually faded out in the course of the training while the responsibility for the team reflection devolves more and more into the hands of the participants.

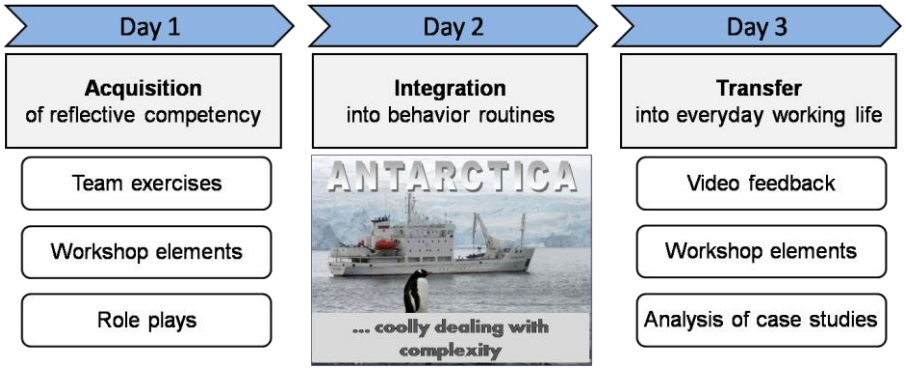

Figure 2. Schedule of the TRCT (Training of Reflective Competency in Teams)

On the second training day the gaming simulation Antarctica serves as an instrument to integrate the skills acquired on training day 1 into work routine. Although the scenario of the simulation is not design-related it reflects the structural characteristics of collaboration in design on an abstract level. The idea of the scenario is based on an idea of fresh water abstraction that has been scientifically discussed in the 1970s (Husseiny, 1978): Participants of the gaming simulation have to tow icebergs from Antarctica for the abstraction of drinking water in a joint effort and concurrently have to implement their individual interests and projects in a limited period of time with limited resources. The high complexity and dynamic of the simulation require flexible coordination and collaboration of the team members to succeed in completing the task and to adapt their acting and thinking to new situations. In order to gain this flexibility participants are asked to reflect on their collaboration during three scheduled reflection periods. These serve as occasions to question, assess and adapt the team's processes of thinking and information management and thereby increase cognitive flexibility.
The third training day was dedicated to the transfer of the acquired competencies into everyday working life. By means of an empirical investigation the effectivity of the TRCT has been evaluated (not focus of this paper) and the effects of team reflection on cognitive flexibility have been examined (section 4).

4 EMPIRICAL STUDY: CAN SUCCESSFUL TEAM REFLECTION FOSTER COGNITIVE FLEXIBILITY IN TEAMS?

4.1 Sample and research methods

One purpose of the study was to examine if the training enhances reflective competency in the team. One further objective was to analyze the effect of team reflection on cognitive flexibility in teams.
To investigate the research questions the training program was presented to three project teams working at different German companies from the sectors electrical engineering, optical engineering and mechatronics. In order to have a reference group which did not attend the training, one group of mechanical engineering students has not been trained in the basic skills of reflection (they missed training day 1) nor did they participate the transfer workshop (day 3). Instead, they only took part on the gaming simulation. The members of the project teams from industry had an average age of 35.3 years and had been with the company for on average 10.0 years. The members of the student group had an average age of 24.8 years and have been studying on average 9.6 semesters at the university.
On order to take account of the uniqueness of each participating training group and to regard the full range of complexity of the subject to be investigated a case study approach was adopted: We did not aim at matching the sample according to team composition and general conditions of teamwork but wanted to research real teams under realistic circumstances. Our study is not about comparing the teams with each other but about analyzing each training group specifically and therefore gain a maximum of understanding about the processes.

Following the approach of experiential learning (Kolb & Kolb, 2009) the gaming simulation Antarctica served as an instrument to integrate the skills acquired on training day 1 into work routine, as well as a data basis for the evaluation. Different research methods have been implemented:
In order to examine the effect of training participation on the development of reflective competency in team a qualitative analysis has been conducted. The participants' processes of team reflection have been categorized by means of a category system which has been developed on the basis of the model of team reflection (Figure 1). By categorical analysis the effectiveness of the TRCT has been evaluated. Methods and results of this analysis are not described in detail within this paper, as it focuses on the illustration of the link between team reflection and cognitive flexibility in team.
In order to measure a team's cognitive flexibility the degree of sharedness of team mental models has been surveyed by the analysis of self-ratings of the team members. The team members individually assessed the agreement in team about specific topics at eight scheduled points in time during the gaming simulation. As these topics were intended to represent the five different types of mental models proposed by Badke-Schaub et al. (2007, see section 2), the participants had to appraise their perceived sharedness of mental models in team concerning the requirements of the common task (task model), the allocation of responsibilities in team (team model), the question how to work together (process model), the estimation of the actual situation (context model) and the team's belief in its power to succeed (competence model).
For example, each individual team member has been asked at eight scheduled points in time during the gaming simulation to depict his or her own estimation of the degree of agreement among the team members concerning the process of collaboration, that is how to work together and how to structure the procedure of task completion. Figure 3 shows the scale for the topic *process* as it is presented to each single team member at eight scheduled times during the gaming situation. The eight survey marks represent a fictitious participant's rating outcome for the eight different measurement dates. In the example, the rating person assessed the sharedness of mental models about the process low at the beginning and therefore set the mark for the first measuring date near the minimum end of the scale. At each following measuring date, the person had to illustrate how his or her estimation of agreement in team (concerning the topic *process*) had changed in relation to the prior measuring points. In the example, it increased at the second measurement date but decreased again at the third measurement date, and so on.

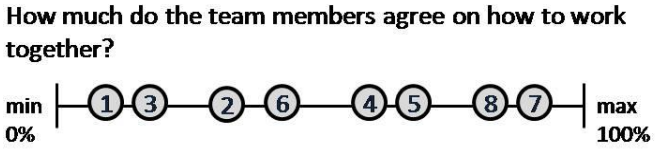

Figure 3. Example of self-ratings

The benefits of this method for capturing shared mental models are that the scales are easy and quickly to complete (at each measuring date one numbered self adhesive dot had to be placed on each of the five scales). From that we gain information on changes in the degree of sharedness of team mental models over time. It is an instrument that captures the participants' own and individual estimations of the degree of sharedness in the team. By building means over the ratings of all participants for each measurement date (either separately for each of the five topics or over a total of all five topics) one gets insights into the whole team's perception of the sharedness of mental models in team.

4.2 Results

The categorical analysis of team reflection during the gaming simulation suggests a high effectiveness of the TRCT: In most of the teams that attended the whole training program the quality of team reflection increases in the course of the training. This becomes evident for example in an increase of the depth of analysis during team reflection periods over time. In contrast, the student group that only took part in the gaming simulation showed a lower quality of team reflection.
In order to examine the link between team reflection and cognitive flexibility in teams the results of the participants' self-ratings on shared mental models in team have been interpreted: Table 1 shows the development of the mean estimated sharedness of mental models in team aggregated over all participants of one group and all five topics over time. The grey shaded columns of the table depict the

amount of increase or decrease of overall sharedness between two measuring points. In the first line the positions of the three scheduled reflection periods (refl1-3) as well as the positions of the initial project planning period (plan) and the three gaming periods (g1-3) are indicated. The last line shows the mean estimated sharedness of mental models aggregated over all four groups and its increases and decreases.

Table 1. Self-rated overall sharedness of mental models over time

	t1	t2-t1 (plan)	t2	t3-t2 (g1)	t3	t4-t3 (refl1)	t4	t5-t2 (g2)	t5	t6-t5 (refl2)	t6	t7-t6 (g3)	t7	t8-t7 (refl3)	t8
group 1	42	11	52	6	58	13	71	-6	65	14	79	6	85	7	92
group 2	34	8	42	5	47	11	58	3	60	-4	57	6	63	5	68
group 3	40	10	50	-25	25	38	63	3	66	10	76	8	84	4	88
group 4	39	-14	24	10	35	11	45	9	54	-13	41	1	42	20	63
mean	39	4	42	-1	41	18	59	2	61	2	63	5	69	9	78

The aggregated data over all groups (last line in the table) show an increase of estimated sharedness over time and especially after scheduled reflection periods: the highest increase appears during reflection period 1 and the second highest during reflection period 3. For reflection period 2 decreases in the estimated sharedness of group 2 and 4 result in a low overall increase in this period of time although increases for group 1 and group 3 are high. To explain this outcome data have to be analyzed more in depth, which is exemplarily accomplished for group 3 and 4 later in this section. The third highest increase occurs during the last gaming period (between t6 and t7), which shows that over time participants became more and more experienced with the project work and increasingly agreed on the main issues of their common work. The fourth highest overall increase of sharedness during the initial planning period (between t1 and t2) shows that strategic planning activities in the beginning of the project contributed to a common understanding in team. This increase would even be higher, if the outlier group 4 (see discussed later) would be discounted.
The interpretation of the aggregated results suggests that the participants developed shared mental models in the course of their common project work and especially as a result of the scheduled reflection periods. More detailed information can be gained by an in-depth analysis of the individual case studies which is illustrated exemplarily for group 3 and 4 within this paper:

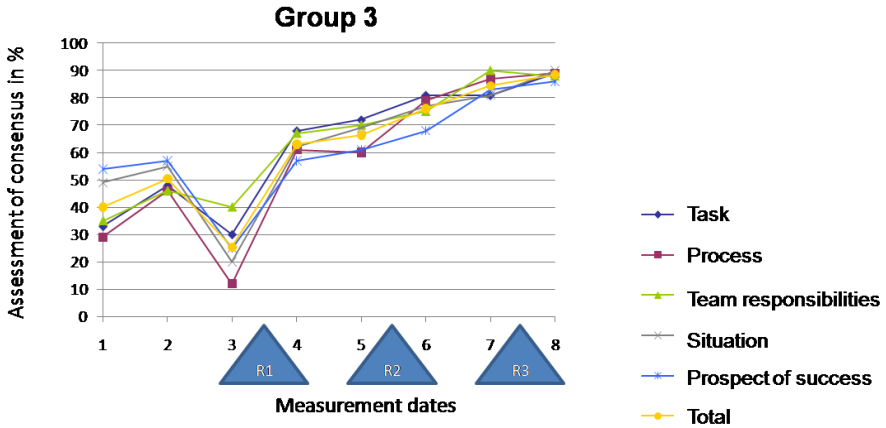

Figure 4: Detailed self-rating data for group 3

The results of the trained **group 3** reinforce the assumption that shared mental models develop over time and increase especially during the periods of team reflection: Figure 4 shows the self-rating data

of group 3 aggregated over all five participants and differentiated by topics of mental models (as described in section 2). The chart shows a consistent development for all five topics over time: The estimated sharedness in the team increased during the strategical project planning period (t1-t2) as the project task and the substantial rules of the game have been discussed. During the first gaming period (t2-t3) the participants of group 3 experienced several failures as it became apparent that they still had different views on some main issues of the game. These different views have been adapted during the reflection period 1 (t3-t4) resulting in the highest increase of estimated sharedness during the game. The other two periods of team reflection (R2: t5-t6; R3: t7-t8) also contributed to slight increases of agreement in team.

Group 4 shows that team reflection does not only lead to shared views among the team members but also enhances cognitive flexibility in teams. In the observed group, team reflection fosters cognitive flexibility by making the participants aware of low sharedness in the team members' mental models and by initiating a discussion how to deal with this problem. Figure 5 shows the detailed self-rating results for case study group 4.

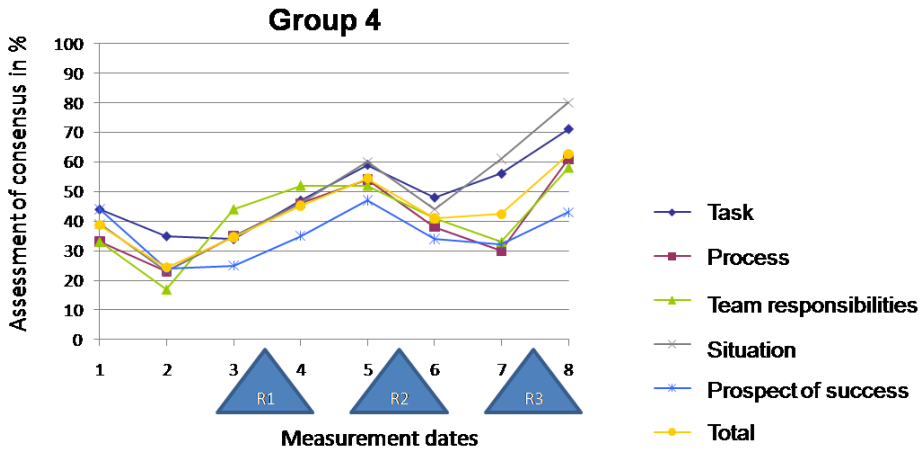

Figure 5: Detailed self-rating data for group 4

Participants of group 4 did not use the initial planning period (t1-t2) successfully: Despite gaining a common view of the main issues of the game they got confused over the numerous pieces of detailed information and therefore could not find an agreement on selecting the relevant information. During the first gaming period (t2-t3) they gained consensus about what to do (process) and who had to do what (team responsibilities); finally, during the reflection period 1 (t3-t4) and the second gaming period (t4-t5) the participants developed an increasing shared understanding of all topics of interest. During the team reflection period 2 (t5-t6) team members disagreed on how to proceed (process model): After a few initial failures they experienced in the first two gaming periods most of the participants wanted to continue to complete operative tasks rather than to reflect on their previous work during reflection period 2. One of the team members questioned this proceeding and suggested to analyze the previous failures in order to avoid future failures. The majority of team members and this single person also disagreed on their estimation of the current situation and the task, as most team members sensed an extreme time pressure and raising difficulty of task requirements. Therefore, the majority of team members recommended to continue with their operative work (process model) and to even raise the division of labor (team model) in order to deal with the multiple facets of the task. The lateral thinker held that by this unreflected and hectic proceeding further failures would occur (disagreement on the prospect of success). During reflection period 2 the participants could not gain an agreement but they became aware of the dissent in the team. In the course of the game the estimation of the lateral thinker proved to be right: By operating hectically under high division of labor and low coordination group 4 experienced further failures. During the next period of team reflection (R3: t7-t8) the team trainer instructed the participants to broach again the issue of the disagreement in team during reflection period 2. Retrospectively, the team members realized that the majority's opinion during reflection period 2 was wrong and they should have agreed to the view of the lateral thinker. The team members became sensitized to the importance of reflection in order to develop cognitive flexibility and how it can be inhibited by social forces.

Finally, a few remarks on the results of the **non-trained group 1** shall be made: The results of the self-rating data (Table 1, first line) show, that the non-trained group1 that performed poorly during the team reflection periods did not show consistently lower scores of perceived sharedness than the trained groups 2, 3, and 4. Qualitative analysis shows that the participants implemented an overall rigid and non-flexible strategy during the gaming simulation and showed no cognitive flexibility. We concluded that a low quality of team reflection does not necessarily impede the development of shared mental models, because they also develop by extensive discussions that don't need to be reflective by nature. But we learned from this case study that it is not possible to gain cognitive flexibility without periods of effective team reflection, in which the knowledge and beliefs in the team are questioned, assessed, and, if necessary, adapted. The case study of the non-trained group 1 is not analyzed in detail within this paper because the focus lies on presenting case studies that show high cognitive flexibility.
What we learned from the different case studies is that the TRCT serves as an appropriate instrument to train reflection in teams. Participants learn how team reflection can be used as a means to induce shared mental models in team. They also experience that common reflection can help to detect disagreements in the team and the necessity to deal with them.

5 CONCLUSION

The aim of this paper was to point out that for dealing with complex design tasks there has to be a well-balanced relation between aspects of knowledge to be shared among all team members and expert knowledge that team members do not have in common. The concept of cognitive flexibility has been introduced as the competence of questioning and adapting the accuracy and the degree of sharedness of team mental models according to the demands of the current situation. As successful team reflection has been regarded as a means to enhance cognitive flexibility the Training for Reflective Competency in Teams has been developed and evaluated by means of an empirical case study. Results suggest, that the training can teach the participants to perform effective team reflection that brings about cognitive flexibility in their process of dealing with complex tasks.
The results of the study are of high practical relevance: When dealing with complex problems such as design problems there is not one best way to do things. Designers have to deal with changing requirements and therefore have to repeatedly gain information and adapt their thinking and coordination to the current situational demands. Considering this, the TRCT does not provide recipes how to act and think but teaches the flexibility to deal with any kind of situation by questioning the team's own thinking and information management: The training teaches reflective competency and how to use it as a means to ensure cognitive flexibility in design teams.
In addition to the positive outcomes of the empirical evaluation the training also met with the participants' approval: Most of them considered their attendance at the training as an enjoyable and most valuable experience that gave them useful impulses for their everyday working life.
As the TRCT can be conducted within three days in house, the costs for the companies are not too high and the results can be transferred in the daily work practice. It might serve as a first step for the implementation of team reflection as a fixed agenda item in designers' everyday working life.
To gain further insights how team reflection, team cognition and team performance are related a more detailed analysis of the team process during the gaming and reflection periods as well as an assessment of the results of the gaming simulation have to be conducted in the context of this study. Furthermore, the concept of cognitive flexibility in teams and its link to team reflection need more empirical investigation in order to ensure a broader generalization of the reported results.

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