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IMPROVING THE PRODUCT INNOVATION PROCESS IN TEAMS BY SUPPORTING REFLECTION

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1. Introduction

A company's innovation ability is a factor of increasing importance. In order to meet the rapid changes of market demands, business enterprises are more than ever reliant on innovations. Innovative product design is a key competence of growing importance in today's increasingly competitive markets.

A sustainable support of innovativeness needs a deeper understanding of the psychological processes behind innovation. In engineering sciences, the main focus is shifting more and more to human skills, for example to aspects of knowledge [Horváth & Vergeest, 2000]. From a psychological point of view, innovative product development processes occur under conditions that can be characterised by complexity, time pressure, high demands and unclear goals. Thus, especially the continuous and repeated goal orientation is one of the key factors for the successful development of new, innovative products [Hacker, 2002]. However, studies in thought psychology [e.g. Doerner, 1998] identify problem areas that hinder goal orientation like limitation of short-term memory, deficient ability to extrapolate and to predict long-term effects etc. Furthermore the product innovation process itself is settled in a social setting, both on an organizational and group level, that supports (e.g. by extension of available knowledge) as well as hampers (e.g. through coordination problems, social loafing, etc.) innovation.

Facing this research – how can we support the product innovation process? Recent findings [Hacker & Wetzstein, 2004] show that verbalized reflection can enhance solution quality in design tasks employing laypersons. Reflection in terms of "thinking-aloud" was also found to increase task accomplishment under specific conditions with non-verbal tasks [Bartl & Doerner, 1998]. Reflection also shows positive effects on knowledge handling and avoidance of mistakes in specific work situations [Herbig & Buessing, 2004]. The findings mentioned above dealt predominantly with individuals and did not consider the social context that is usually present in product development situations. West [2004] reported promoting effects of team-reflection in terms of a continuous adjustment of team-activities to process-goals. However there is a clear lack of systematically methodical support of team-reflection and of the examination of its effects under controlled settings. To fill this gap, we developed a method for enhancing team-reflexivity and tested the method's supporting effects on team-innovativeness in a controlled experiment with mechanical engineering students. We argue that supporting reflection of experienced persons, who work in groups, can also enhance the quality of product innovation process outcomes.

2. Method

This study investigates the contribution of reflection support to the successful development of an innovative product. In the presented work we used an adapted version of Kelly's Repertory Grid method [Kelly, 1963] to foster reflection about a group task.

2.1 Sample and experimental design

Sixty students of mechanical engineering were asked to create an innovative solution for an engineering design task. The students were assigned to teams of three, resulting in a total of 20 teams. Most of the participants where male (female = 5), average age was 23.6 years. Instructions where given as a written task description, in which the product requirements were listed. The task duration was 90 minutes. The objective of the task was to develop a principle draft.

Experimental conditions were: Reflection vs. no reflection, individual reflection vs. collective reflection; in an additional control condition ("dummy"), the effect of task irrelevant reflection itself was controlled for. Two experienced product development engineers independently assessed the innovativeness of the resulting product concept, based on an innovation assessment methodology developed at the Institute of Product Development, TU Muenchen [Baumberger, 2002]. Innovation itself is defined as "the development *and application* of ideas in practice", whereas creativity is seen as a part of the innovation process [West, Hirst, Richter & Shipton, 2004]. Innovativeness and requirement fulfilment are two main components of the implemented innovation assessment method, constituting rating aspects are based on a five-point rating scale, and the total result is a weighted sum. The expert ratings showed a good inter-rater reliability ($r = .56 - r = .83$). To control for effects of experience and knowledge in the area of product design, all participants took a test in the area of task relevant knowledge and filled in a biographical questionnaire concerning former product design experience in particular, and practical technical experience in general.

2.2 Reflection method

As mentioned above, the administered reflection method was based on the Repertory Grid Technique by Kelly [1963]. This technique is based on the assumption, that every person construes a subjective orientation system. This subjective system leads one's interpretation of the world and one's activities. By verbalizing the leading aspects of a particular situation, the underlying cognitive structure is revealed. This revelation is the precondition for a modification of situational adverse knowledge structures. Comparative effects can be expected on the team-level.

Based on this technique, the Institute of Psychology at the TU Muenchen developed a computer program for the administration of repertory grids, which was successfully applied in former research [e.g. Herbig & Buessing, 2004]. In our study, we asked 50 per cent of the participants to interrupt their task after exactly half of task duration, and reflect on salient content points of the current situation of the engineering process.

The specific procedure was as follows: after the task interruption the participants where asked to write down six important action guiding elements of the actual situation. In the individual reflection condition every participant wrote down aspects he personally believed to be important. In the collective reflection condition the aspects were brought together by all of the team-members.

After these action-guiding aspects were fed into the computer program, six pairs of the aspects were presented successively with the following questions: "Are the two presented aspects similar or dissimilar?" If the aspects were rated as similar, the program asks: "What is the similarity between the two aspects and what is the opposite of this common feature?" If the elements were rated as dissimilar, the question was: "What feature describes aspect one as opposing to aspect two?" With this procedure, the participants generated a pair of bipolar attributes that is able to describe both of the presented aspects, or to discriminate between them. In a third step, the participants were requested to evaluate all of the six important aspects on the basis of the generated bipolar attributes on a five-point scale (1=aspect is completely first pole of attribute up to 5=aspect is completely second pole of attribute). Altogether the participants generated six pairs of bipolar attributes.

In the individual condition, the described procedure was completed by every participant on his own, and supported, if necessary, by the experimenter. In the collective reflection condition, the participants executed the procedure in form of a group discussion.

Table 1 shows an example of the repertory grid data matrix (collective reflection) from the study. The generated aspects are listed in the second row, the elicited bipolar attributes in the first and in the last column. Ratings towards the first description pole are represented by the number one, ratings towards the second pole by the number five. The cells show the ratings, based on the description poles, for each aspect. Subsequently, every aspect was rated on every dimension, which is defined by the description poles. For example, the aspect "adjustability solution" was rated as "completely problematic" (scored 1) on the "problematic-clear" dimension and as "completely free" (scored 5) on the "structured-free" dimension. For reasons of clarity, the mentioned scores are displayed in bold numbers in Table 1.

Table 1. Repertory grid data matrix

	Aspects						
First description pole, scored 1	Structured proceeding	Problem definition	Communication	Method application	Adjustability solution	Completely new concept	**Second description pole, scored 5**
problematic	2	3	5	2	**1**	2	clear
creative	2	4	3	2	2	2	narrow minded
successful	5	4	2	5	5	2	bad
accomplishable	5	4	2	5	3	3	not accomplishable
necessary	2	1	2	2	1	2	irrelevant
structured	1	3	3	3	**5**	5	free

After the grid data matrix was completed, a correspondence analysis was carried out and the results were plotted. The correspondence analysis is a statistical procedure that compares objects with each other, using ratings on specified dimensions for structuring the objects according to similarities in object ratings. Objects are arranged in a multi-dimensional space (two-dimensional in our case), so that objects (or aspects in our case) rated similarly are close to each other. The resulting plot was presented to the participants and the results were discussed (see also Figure 1). This visualization of results allows for a further understanding of the important aspects of the situation, and therefore may help to gain new insights as well as new starting points for problem solving. In this particular example, the rating of "method application" and "structured proceeding" as being problematic reflects the notion that the use of methods under conditions of time-pressure, posed a serious restriction of the process in this particular group. Furthermore, the communication of the group was rated as clear and structured, which indicates that this process aspect was perceived as positive.

3. Results

The experimental groups did not differ regarding experience and knowledge. Regarding our experimental manipulation (application of the reflection method), the results are as follows. Table 2 shows that by supporting team reflexivity, the outcome quality increases. Collective or individual reflection did not differ significantly. The results indicate that even if innovativeness did not increase in the experimental group, the experimental group produced significantly less errors and fulfilled the task requirements better than the control group. Thus, an overall better solution quality was achieved.

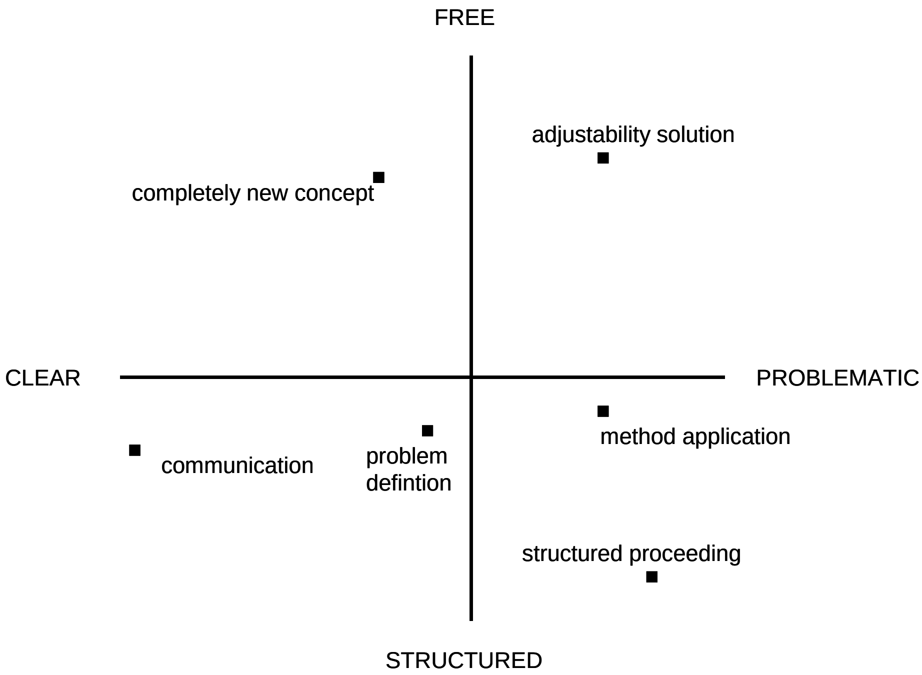

Figure 1. Example plot

Table 2. Experimental results

Dependent variable	Conditions						
	Experimental Group *N*=8		Control Group *N*=8		Dummy *N*=4		
	*M***	*SD*	*M*	*SD*	*M*	*SD*	Exact *p**
Innovativeness	3.1[a]	.50	2.83[a]	.61	3.2[a]	.78	.61
Errors	**5.38[a]**	2.07	**8.13[b]**	3.0	6.5[a,b]	1.73	.13
Construction flaws	3.13[a]	1.25	3.63[a]	1.92	3.5[a]	1.73	.74
Not fulfilled requirements	**2.25[a]**	1.67	**4.5[b]**	1.77	3.0[b]	.00	**.014**
Overall solution quality	**1.16[a]**	2.33	**-1.8[b]**	4.15	-.30[a,b]	3.17	.28

*Kruskal-Wallis-Test (Monte Carlo simulation with 100.000 iterations)

**Same character-indices in a row show no significant differences, different indices show significant differences between cells (Mann-Whitney-test, exact p≤.05).

Average innovativeness did not differ between groups with task irrelevant reflection ("dummy") and the experimental group. The former ("dummy") produced a poorer overall solution quality than groups with task relevant reflection. However, the differences are not statistically significant. This may indicate that reflection on task relevant issues affects the quality of the task outcome in a more positive way than task irrelevant reflection.

4. Discussion

Lindemann (1999) recommends an alternative problem scope within a product development process, the "principle of modality-change". This implies the systematic fostering of perspective change through reflection. For instance, following perspective-categories are proposed:

- Abstract and specific
- Synthesis and analysis
- Planned and opportunistic

In this context, our method can be viewed in different ways:

Firstly: It can bee seen as a reflection-based deconstruction of the problem space with the aim of process outcome improvement. Our results indicate that the overall outcome quality in complex product innovation processes can be improved by systematic reflection, although the innovativeness of the solutions was not enhanced. Possibly this is a hint that our reflection method supports convergent, but not divergent thinking. In order to test this assumption, further experimental investigations are needed.

Secondly: It can be seen as a methodological assistance to analyse the interrelationship between technical, methodological and social influences in critical situations of the product innovation process (see Figure 1). Such analyses help to define possible deleterious effects of these factors in such situations, and to initiate process improvements.

Thirdly: Especially in opportunistic stages in the early phases of the product innovation process, our method can enhance the adjustment of team activities to super ordinate process goals. In these terms the method fosters the iterative development of goals "on the way" [Hacker, 2002].

To refine the reflection method, the next step in our research is the systematic implementation of our method in the practical context of product innovation. Particularly the assumed positive effects on the planning of the product innovation process have to be proven in "real" long-term design projects. Moreover, the following requirements have to be met for practical purposes: The method has to be economical in use and must allow for a flexible adjustment to various design tasks as well as to different stages of the product innovation process. As the method already proved its potential to enhance reflection, and concurrently solution quality, we are quite optimistic that it will also become a helpful tool in the applied product innovation process.

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