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FACILITATING CREATIVITY AND SHARED UNDERSTANDING IN DESIGN TEAMS

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1. Introduction

Complex design tasks and reduced time to market require intensive collaboration of experts from different disciplines not necessary throughout the project but at certain critical points [Ehrlenspiel, 1995, Mascitelli, 2001]. Apart from being indispensable expertise, the diversity may also contribute to creative reframing. However, the progress of a project will depend on a shared understanding among team members about goals, requirements and criteria. Our research question was therefore how could design teams be supported both in their creativity and in their shared understanding. Using a form of protocol analysis [Cross et al, 1996] we investigated design teams in ten industrial projects with a special focus on the early stages of the innovation process. Form this; we developed a computer-based tool for team interaction, which was tested in an experiment with students.

We adopted the framework of in-depth investigation of communication among designers in the field to identify patterns of problem solving and team organisation [Stempfle & Badke-Schaub, 2001]. Our special interest was how designers use artifacts and visualizations to communicate. Mascitelli attributes a key role to prototypes in harnessing tacit knowledge for innovation: They allow for experimentation and serve as a nonverbal communication tool among designers [Mascitelli 2000]. Visualization should increase the chances that an idea survives the evaluation process. Another form of improving shared understanding could be a public protocol of comments and decisions because it helps participants to keep track of the discussion.

In the following two sections, we summarize the field observations and describe the tool for team interaction. Section 4 reports the two experiments comparing computer- versus paper-based facilitation and different creativity techniques. Section 5 discusses the findings and draws conclusions to design education.

2. Observations of design teams in industry

The observational study featured natural interaction in early stages of product development in industry. Researches gave feedback about the observation but did not manipulate the course of action. Our sample consisted of twenty-two project meetings in six different companies in mechanical engineering and in consumer goods industry. We observed a total of 79 people in ten projects. Among these were regular review meetings of two to five hours and large-scale workshops of three to five days. All groups involved more than one discipline, usually consisting of mechanical engineering, marketing, software and industrial design. The whole meeting or a sample of critical situations was transcribed and categories for problem solving activities, group process and facilitation/structure (for details, see [Lauche et al. 2001]). We rated the performance of each meeting according to a set of criteria. The observation was complemented by interviews on personal experiences and the

organisational context of the projects.
The observations showed iterative patterns of innovation with a lot of sharing of ideas and discussion. During this heuristic process, all teams used collective visualisations and prototypes to move backward and forward between requirements and solutions. Other elements of the innovation process like goal setting and requirements were less frequent and only very few decisions were made. Reflections occurred when the team got stuck or when initiated by the facilitator. The meetings rated better for their results were structured in advance and usually driven by a methodological approach. However, even in these cases the discussion did not follow idealised patterns of goal – action – evaluation. Smaller teams immersed themselves in sketching and a free flow of ideas, whereas larger or inexperienced teams were more dependent on a facilitator to structure the interaction. Another recurrent issue was internal politics such as resource allocation or conflicts with other parties in the company. Internal hierarchy influenced the discussions as members expected their superiors to take responsibility and awaited their sometimes-implicit decisions.
Asked about key factors for innovation in the interviews, the project managers mentioned intensive collaboration in small teams of experts, support and involvement of top management and a detailed analysis of the problem. They described the trade-off between efficiency and breakthrough innovation, implying that the ever-present time-pressure needs to be suspended to allow for creativity and iterations. Three companies reported difficulties from being too innovative for their traditional market. However, the project managers reflected that having undergone this experience in person provided them with a better feel for what was appropriate in terms of innovation.
For our interest in how the teams used visualisations and media to assist their discussion, we collated the observations in Table1. The most prominent forms are shown in bold, or italics if only observed in a subsample (consumer goods).

Table 1. Use of media for different functions in the observed teams

Type / **Function**	Physical prototypes	Paper	Computer-based	Distributed, asynchronous
Source of inspiration	Simple models Existing products	Notes from previous meetings, old catalogues	Internet research	
Structuring of ideas		Tables on flipchart, cards on pinboards		
Record of discussion		**Notes & sketches on flipcharts**		Meeting minutes
presentation	*Design prototypes*	Within workshops for results of subgroups	**Expert input as slides or CAD**	videoconferencing for reviews

The most common and universal form was notes on paper. For design-driven products, physical objects played a major part to stimulate ideas as well as to present them. Computer-based visualisation was not used interactively during discussions but only for presenting prepared material or for later documentation. An underlying reason for this may be that current computer equipment is designed for individual use rather than group interaction. This stimulated our brief for designing computer support for innovation teams to provide interfaces for groups that would allow modifying and annotating sketches or presentations.

3. The innoplan system for design teams

Incorporating the field observations, we developed a computer based design environment for early stages in the innovation process. It was aimed at supporting team interaction and visualisation of collective results and as well as annotations and later modification. With the main goal to start developing in a digital format, innoplan can also be seen as part of a recent development to design multi-user interfaces with direct manipulation of objects [Arias et al., 2000, Streitz et al., 2001].
We started out by mapping the so-called Metaplan or Moderation method into an electronic format

[Klebert, Schrader, Straub, 2000]. It was first developed in the late sixties by architects to involve community members in urban planning issues. People write their ideas or concerns on cards that can be assembled into clusters a pinboards. A facilitator assists by setting introductory questions and summarizing main points. The technique combines elements that research into group decision making has shown to be important, i.e. written brainstorming, visualisation and structure. From the observations we concluded that for designing the system should allow for both text and graphics. The analogies of the cards was reformulated as parallel input on simple devices that should be easy to use and still allow natural communication between members. The pinboards were interpreted as shared interaction space where the members' input would be published and modified. The primary use was seen in co-located teams though the benefits of the digital format were seen in distributed use as well as more advanced computing.

Figure 1. Team interacting with mobile version of innoplan system

Figure 1 shows a team interacting with the innoplan system: The large screen shows the ideas generated and then clustered. The existing prototype uses PDAs as personal clients, an interactive whiteboard as group viewer, and a Windows 2000 terminal server. The software was developed for this system using a Cobra middleware. The TCP/IP network allows for local communication as well as distributed work via the Internet [Kunz et al. 2001].

4. Experiments 1: Comparison of different facilitation techniques

We tested the innoplan tool against paper-based facilitation (Metaplan) and non-facilitated interaction in an experiment with student teams. Sixteen teams of students with a total of 55 participants were randomly allocated to one of four conditions.

Table 2. Four experimental conditions for teamwork

	Paper-based	**Computer-based**
no facilitation	brainstorming	chatroom
+ facilitation	Metaplan	innoplan

All teams were given a conceptual design task and instructed to do problem analysis, idea generation and a presentation of their proposal to a small committee. They were given a questionnaire before an after the task about their preferences for teamwork, their experience of working together and a recall of three main aspects of the proposal. The presentations were rated by three committee members for conformity with requirements (budget and needs consideration) and innovative solutions on a scale from 1 (poor) to five (excellent).

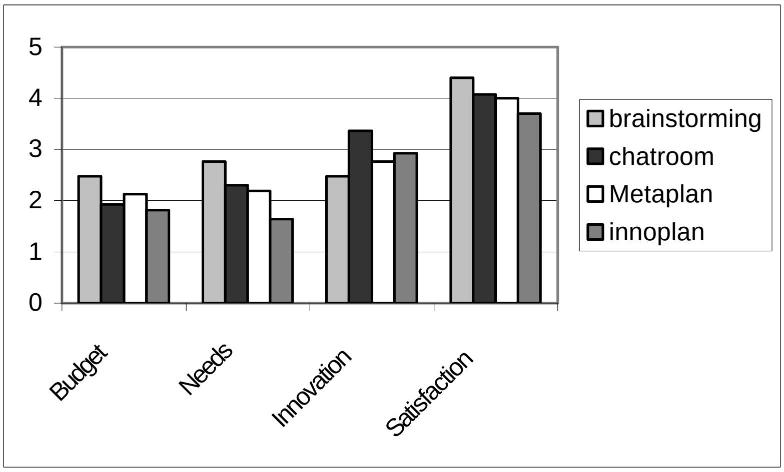

Figure 2. Differences in committee ratings and satisfaction between the four conditions

We found a main effect of the media factor in favour of paper based work for budget and needs consideration. For both criteria, the brainstorming groups outperformed all other groups. As predicted from previous literature, the computer-based condition, in particular the chatroom, generated more innovative output. The so-called illusion of effectiveness was also replicated as the brainstorming condition produced the highest subjective satisfaction. For shared understanding, we compared the similarity of initial statements and final recall cross the four conditions. Metaplan produced a significantly higher overlap in the first stage and maintained this position at a non-significant level at the end.

Generally, the facilitated groups produced weaker proposals than we expected from the field observation, which might to, due to the fact that the groups were fairly homogenous and small. We also observed usability problems with innoplan which are due to the text recognition software and our participants not being used to PDAs. The facilitation did succeed in giving members an equal opportunity to express their ideas, as the variance in the number of interaction was significantly smaller in the Metaplan and innoplan condition. The observational data also showed that the Metaplan groups produced the most detailed problem analysis whereas the chatroom generated more ideas and the brainstormimg groups commented and evaluated their ideas in more depths (Table 3). We therefore recommend combining different techniques for different stages in the innovation process depending on whether agreement or pluralism of ideas is more important.

Table 3. Frequencies of categories form the observation in Experiment 1

	Brainstorming	Metaplan	Innoplan	Chatroom
Requirements	8.5	17.25	5.75	8.00
Observations	16.5	14	11.75	20.25
Ideas	37.25	32	31.5	43.5
Comments	58.5	26.25	28.5	42.75
Evaluation	25.25	4.75	4	12.00
Decision	21.5	4.5	4	2.75
Reflection	1.75	1.75	0.25	0

5. Experiment 2: Comparison of creativity techniques

In a second experiment, we compared different creativity techniques with a sample of engineering students in their final year. As part of a course on project management, twenty-five students were asked to complete a conceptual design task in teams of five to six. They should present one solution and reflections on the technique they used. All participants knew each other from an outbound activity a months before. Their task was to design an outbound equipment for the next group.

Figure 3. Engineering students working on a conceptual design task with 6-3-5 and Metaplan techniques

Each team was instructed to use one of the following creativity techniques: brainstorming, 6-3-5, the Six Hats and the Metaplan technique. The Six Hats [de Bono, 1985] involves taking different views on a problem symbolised by different coloured hats. The students were instructed to change hats so that they would experience a variety of perspectives. A facilitator assisted the Metaplan group. The 6-3-5 technique was administered as usual: six students wrote or sketched three ideas on a form. After every five minutes, the forms are passed on to another member until all 108 slots are filled with ideas or comments. After the introduction, all groups gathered ideas for 30 min and were then given 15 min to scrutinise them and agree on one for the presentation. Table 3 give the results (the numbers in brackets are non task-relevant ideas).

Table 4. Results of experiment 2

	# ideas	Comments from students	Observations
Brainstorming	41 (11)	Individual notes not seen as very creative	Reproduced existing solution
Six hats	6	good approach but members retracted to their natural role	Recalled the abstract principles
6-3-5	87 (29)	difficulties to select one idea for presentation	Detailed solution but not exactly task relevant
Metaplan	26	Helpful technique: dynamic, democratic, visualised the discussion	only verbal output recall both concrete and abstract

The results show that brainstorming and 6-3-5 generated more but not better ideas. A jury of three rated the proposals from the Metaplan and the Six Hats groups best.

The study was replicated with 116 first year students who had to produce a crazy and a serious solution out of the ideas generated in teams of six. The solutions were rated for ergonomy, technical aspects, aesthetics, force (of the device) and creativity. Metaplan produced better crazy ideas than the other techniques whereas 6-3-5 was better at the serious ideas.

6. Discussion and implications for design education

Our observations and interviews in the field strongly support the notion of design as an iterative and social process. The mere attempt of using the same framework for industrial projects and ad hoc groups in a lab also pointed to the limits: What we learn from the controlled environment of the experiments might have little in common with the complexity of the field. In order to move forward, empirical design research will need to identify critical elements of the industrial context. Not all of this contextual information may turn out to be suitable for student class tasks and straightforward experiments.

However, there are some commonalties for both contexts: Both the field observation and the experiments showed that different techniques work equally well for small groups, well-defined tasks and short meetings as long as team members can easily communicate. The facilitated meetings were more structured and task oriented, which was seen as crucial in the industrial context and almost over-controlling in the lab situation. Computer-based communication may help to reduce cognitive and social barriers to express innovative ideas as long as it involves an intuitive or well-known interface. Using a chatroom could be one element of idea generating workshops in industry, particularly if hierarchy or internal conflicts might impact on how free people feel to contribute wild suggestions. It still seems worthwhile pursuing high-end design tools since many of the more advanced features of the innoplan were not fully utilised in this one shot experiment. However, the results show there is a lot to be gained from low-tech options.

In terms of design education, many aspects of the innovation process remain subject to personal experience that we will not be able to provide in the classroom if we do not want to simply imitate industrial reality. However, the second experiment suggests that students can develop an understanding of different creativity techniques and teamwork from being exposed to them in the classroom. Running all four conditions in parallel was helpful in educational terms as all students could see the output and listen to the reflection of the other teams. We had to modify this arrangement for larger classes but kept the element of meta-discourse about the technique in order to educate students to choose in the future.

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