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# Cognitive Problem Solving Behaviors of Design Teams In Different Tasks

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**Abstract**

In this research, the design processes employed in three different design tasks that are undertaken by a design team are analysed. Cognitive behaviors of the design team have been observed in an experimental environment to fix individual and environmental factors. The team problem solving behaviour is also put under scrutiny in the context of the decision making cognitive acts that are displayed during the design processes. TCTA (Team Cognitive Task Analysis) approach has been utilized in order to ensure the applicability to practice and validity of the results of the study. The design processes employed in the Routine, Innovative and Original design tasks by design team are observed to be able to describe the effects of the various design tasks over the problem solving behavior and cognitive decision making processes.

Decision making is accepted as the most critical step in the problem solving process. In this research the analyses cognitive processes have been done by defining cognitive decision components and the actions appeared under these components. Design team developed different numbers of design decisions during the three tasks although they have spent similar amount of time for each of the task. Every verbal utterance produced by design team members in three design processes has been transcribed and coded by pre-defined decision component categories and cognitive actions. The results posit that there is not any regular relation between design tasks and decision components. Designers in the team were more satisfied from design process and the decisions they made with decrease of their familiarity to the tasks. If the team design processes in all design tasks are considered, it is obviously could be seen that design team tend to be more 'solution oriented' when the design problems' solution space gets wider. In other words design team focuses to the solutions more when solving problems with wider solution spaces.

**Keywords: Design teams, problem solving, cognitive decision making, design process**

## Introduction

Nowadays companies recognize the importance of design on the success of the product in the market. Over time the design tasks faced by companies becoming complex design problems to be solved within short periods of time. Today, many design tasks requires working as a team collaborate with other professions rather than a single designer. On the other hand, design decisions being taken during the product development process are the directly effects the cost of product. It is required for improving the efficiency of decision making processes

that the design teams design processes need to be support for the discarding the losses. In order to support decision-making processes of design teams it is important to understand and explain how design team members make the decisions. When the design research studies have started in the 1960s the question of "how a designer designs?" was the main idea. Today this question transforming into “how a team of designers design”

## Teamwork as a Design Activity

In design literature, the design team researches are mostly done in different fields such as architecture (Gross et al., 1998), engineering (Reid and Reed, 2005), product design (Redelinghuys and Bahill, 2006), aviation (Baird et al., 2000) and software design (Lloyd P. Scott, P., 1994).

After the nineties, the research done by Tang and Leifer (1988) considered to be the one of the first article among the other design team researches by drawing attention to design team. In this study a research model was investigated depending to the actions and the behaviors in the working environment. In 1993, the first systematic study on the design teams has taken place in the International Conference on Engineering Design (ICED’93) under the sub-theme "team work”. The papers presented at the conference observed were related with many different subjects. Most of the design researchers approached to this new area, yet not complicated in that time, from the points which were important for themselves. After ICED 93, in 1994 a workshop with the name Delft Protocols Workshop (1996) has been organized by the participation of the researchers who have been mostly participated in ICED. In the workshop, design teams and individual designers have been observed in the laboratory environment and different from the minutes of verbal and visual protocols of the designers acquired from this sessions have been analyzed by more than 20 design theorists. This workshop has an important place in the design cognition literature due to it was covering research papers on analysis and comparison of individual and team cognitive processes. In cognitive researches of designers the decision-making process has gained more importance in understanding teams as being the basic units in the high complex and stress environments.

Especially after the 2000’s, the subject of shared understanding started to gain importance. It is important to investigate the collaboration aspects to understand the motivation of the designers and design project stakeholders on the design process. Brereton (1996) suggests that teamwork would be seen as successful only if the design team members have balanced team roles and with well-controlled processes of negotiations.

## Design Cognition

Cognitive capabilities of design teams should be developed to support designers during solving complex design problems. 'Design Cognition' which has become an important concept defined as by Eastman (2001, s.147) ‘to examine the human information processing behavior within the context of various theoretical and empirical design paradigms'. Due to the fact that many approaches (Newell and Simon, 1972), (Pahl and Beitz, 1996), (Rowe, 1987) accept the design process as a problem-solving action, cognitive theories come close to the design activity. Problem solving has been always one of the main subjects of cognitive science.

An increasing number design, research and process models are turning to cognitive analysis, and this area is called design cognition (Cross, 2001), (Eastman, 2001). In the context of design teams, design cognition researches covers issues such as design methodology, cooperation, teamwork, knowledge management and design representation (Langa et al., 2002). Investigating design teams’ actions, unlike the individual design activities, it should be

considered that the design teams host organizational behaviors. Kunz et al. (1998) proposes that *design teams* which a kind of organization, are information processing and communication systems that solve given design problems.

Simon (1992) states that all parts of life is foundation of problem-solving and decision- making activities. In this context all the work done is actually consists of identification of needs, identifying goals, designing actions, evaluation and choosing among alternative actions (Figure 1). Simon (1992) adds that the first three phases of indicates problem solving activities and the last two stands for decision-making behavior.

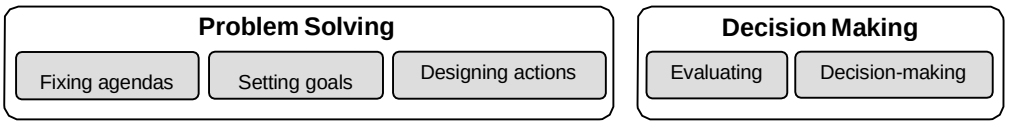


**Figure1.** Problem solving and decision making as Stages of Choosing according to Simon (1992)

## Research Methodology

In this research the empirical study based on the conceptual design phase. Research methodology have been developed to identify and compare the cognitive decision making processes of three different design processes carried out by the design teams. Three different design problems were given as tasks to the design team. Design tasks are defined according to the classification of Beitz and Pahl (1996):

- *Routine design* - rearrangement of dimensions, materials, or existing solutions while function and solution principle remains the same.
- *Innovative design* – is to develop new and creative solutions for new or old design task. The principles of the solution vary.
- *The original design* - to adapt a known solution to new or modified task. The solution principle is usually remains the same.

Design teams mostly work under the influence of many organizational and social conditions along with design task differences. The mental processes of the designers have been observed in a controlled laboratory environment. One of the main aims of the experimental research was to make the designers to design under situation close to the practical design activity as in industry. Therefore experiment set-up has been designed involving stages respectively individual phase, conceptual design, executive meeting, detail design, reviewing and presentation.

During experiment a table provided and A3 papers, sketch pens and colored pencils are given to team. The design process was recorded by two video cameras. While one of the cameras is used for general shooting the other one used to capture close-up view of the table. Each experimental study has spread over approximately two hours. One hour is given to be devoted to the design process.

Protocol Analysis method has beeen used to analyse cognitive activities of design team. Protocol analysis method consists of recording in a controlled environment, transcribing the protocols, segmenting and coding segments. Verbal expressions are accepted as the externalizations of the mental process. Therefore in this study verbal expressions obtained are the fundamental data for analyzing cognitive processes. Every meaningful part of the expressions produced by the design team members constitutes significant cognitive acts of the design process. During analyzing cognitive acts also visual expressions produced by the designer team and the notes of the researcher were utilized to determine the cognitive act more precisely.

In the analysis of cognitive decision-making behaviors in designing, developing the coding system to define verbal expressions constitutes the critical stage. Design decisions occur in various complexity levels. Design teams make decisions within a social process. Primarily, decision components defined by the coding system. Cognitive components of the design decisions are defined depending to the model proposed by Simon.

*Table 1. Design Decision Components*

| Problem Solving Phases (Simon,1977) | Problem Solving Phases | Decision Components |
|---|---|---|
| Intelligence | Analysis | Goal |
| Design | Generating | Knowledge |
| | | Problem |
| | Synthesis | Constraint |
| | | Reguirement |
| | | Concept |
| Choose | Decision | Alternative |
| | | Solution |

Simon's model (1977) defined the design process as the stages of intelligence, design and selection (Table 1). New model has been developed to identify the decision components by detailing the Simon's model. While **intelligence** phase corresponds to mental activities on defining *goal*, the **design** stage detailed to the *knowledge*, *problem*, *constraint*, *requirement* and the *concept*. The **choice** phase further elaborated as *alternative* and *solution* components. Decision components describe the theoretical framework of cognitive decision making behaviors exhibit by design teams when problem solving (Table 2) rather than a complete model of design process.

*Table 2. Design Decision Components Coding Systems First Level*

| S | **Category** | | **Definition** |
|---|---|---|---|
| | Goal | $Go^c$ | Goals, Aims |
| | Knowledge | $Kn^c$ | Knowledge sharing |
| | Problem | $Pr^c$ | Defininig Problem Areas |
| | Constraints | $Cc^c$ | Firm, User and Legal issues, standarts |
| | Requirements | $Sp^c$ | Defining product needs and specifications |
| | Idea/Concept | $Or^c$ | New idea, conceptual solutions |
| | Alternative | $Al^c$ | Alternative idea proposals |
| | Solution | $So^c$ | Proposed solution after defining problem |

Coding system used for the analysis of design decisions consist of two-level categorization. Decision components when creating the first level categories (Table 2), second level categories defines the actions ensure the use of decision components (Table 3). Components of design decisions while pointing to the epistemological pieces, acts represent the mental actions that are deal with those components. Decision components are processed / applied by using cognitive acts as being cognitive parts of design decisions. Designer may search, define, generate, elaborate, evaluate or decide with one of the design decision components. Those cognitive acts constitute *Design Decision Cognitive Acts* (Table 3).

Eight *decision components* and six *cognitive acts* that can be connected with each of the decision component consist of a coding matrix with 48-category. This matrix developed in order to cover all the possible cognitive behaviors could be occur in making design decisions

by design teams. Such cognitive process model for design teams would help to analyze the group behavior in problem-solving and also will allow comparing design teams' cognitive processes.

*Table 3. Second Level of Decision Components Cognitive Acts*

| **Category** | | **Definition** |
|---|---|---|
| Searching | Se[a] | Search, |
| Defining | Id[a] | Modelling, Atıfta Bulunma, Saptama, Yayma, Ayrıştırma Açıklama, |
| Generating | Ge[a] | Proposing, Claiming, Answering |
| Elaborating | El[a] | Detailing, Structuring, Reviewing, Formulizing, Forming |
| Evaluating | Ev[a] | Reasoning, Judging, Comparing, Priotrizing |
| Deciding | De[a] | Selecting, Interfering |

## Results

Cognitive behaviors introduced by the design team during *Routine*, *Innovative* and *Original* design tasks were analyzed. Problem-solution space, prior experience level of designers in solution principles of the related design problem, level of the information about the problem and whether there is any similar product on the market have been considered in determining criteria for the experimental design tasks. From routine design task to innovative and original design tasks, the information that designers have about the product being designed decreases. On the other hand, possible solution spaces of the design problems become larger from Routine design task to Innovative and Original design tasks. In other words, design tasks determined according to the problems that team members have less experienced to more experienced.

### Team Design Problem Solving Behaviors

The team made different numbers of design decisions even though they have worked on three tasks in the same amount of time. Depending on the characteristics of the design tasks, a correlation between number of decisions and design tasks could be predicted. For example, it can be said that to solve the design problem with narrow solution space less *alternatives* or more *problem* decision components would be produced. However, as a result of this research any correlation between *design tasks* and *design decision components* and *acts* has not been identified.

Among the design tasks, most design decisions were taken in the *routine design* task. 16 out of 48 decisions occurred as *alternative* and 15 were taken with the *solution* components. During *original* design task most decisions were belong to the *solution* component. Innovative design task has significantly less number of decisions, with total of 23, only two of them occurred with *solution* component, 12 of the decisions belong to the *concept* component. The design team in three different design processes has produced an average of 550 verbal expressions. Each expression has been coded with one of the categories of design decision and cognitive acts. Figure 4 represents frequencies of cognitive decision components.

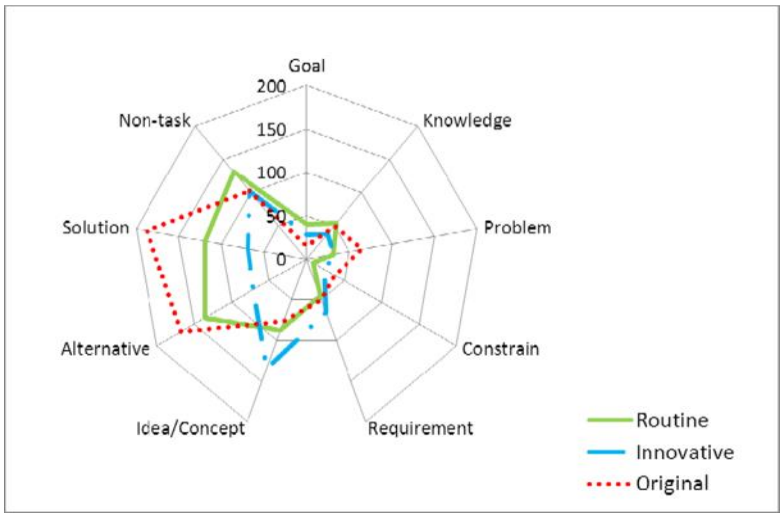


*Figure 2. Number of cognitive acts according to design decision components*

During the *original* design task, although, team produced most *alternative* and *solution* components alternatives did not often transformed into a decision. While solution space of the *original* design problem is larger than *routine* design problem, less concept components were used in *original* design. *Concept* components cognitive acts produced during the *original* design task with the ratio of 11% is the least among the all tasks. On the other hand this ratio is 24% in *innovative* design task. This ratio is very much higher than other tasks.

Comparing the use of concept it is obvious that when designers deal with the design problem having less knowledge and experience they produce fewer concepts and they adopted concepts quickly as design decisions. Throughout the design process every decision may occur in the context of any component. Sometimes an alternative detail decision could be taken; sometimes the decision about a constraint can be taken. Design decisions according to the decision components in three design tasks are presented in Figure 3

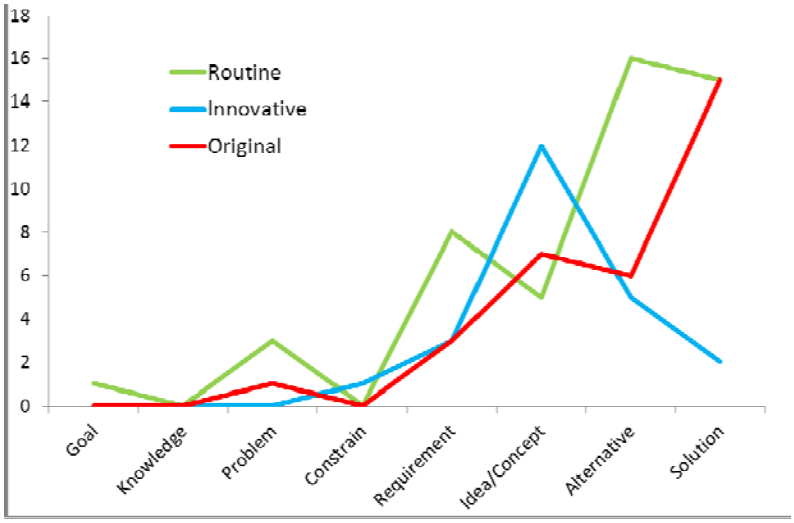


*Figure 3. Number of Decisions in Design Tasks*

Although the most *concept* decision is made during the *innovative* design task by design team, in the same task their decisions about *alternative* and *solution* have the minimum number. The number of the decisions taken by design team is directly proportional to the

number of decision components have been produced in the design process. This result indicates that design teams needs or uses components in proportion to the design decisions.

One of the reasons for the fewer number of decisions in the *innovative* design task is using most of the time for the development and evaluation of new ideas. In *innovative* task team produced fewer *alternative*s compared to other tasks. Design team didn't develop their concepts proposed by detailing solutions. In this regard, it can be said that they did not make sure the concepts.

In *original* design task as an opposite situation to the innovative design task; design team made decisions on the more *alternative*s and *solution*s than *concept*s

In *routine* design task the least decision was taken with the concept component. The primary reason for that is the design team could not reach satisfactory product concepts that they believe as innovative enough. The design team members although have worked many times on design of the the similar products before, they focused more on the *requirements* than other design problems. Most of the design decisions occured in this context. Decisions on *requirement* component are much higher in routine design problem than other design problems. Despite the fewness of number of *concepts* produced in *routine* design task by the design team, decisions on *alternatives* and *solutions* have been the highest number. At the point innovativeness and product differentiation design team passed to the design detailing by reaching quickly to a consensus.

The design team members less interested in constraints when they have less experience in the related design problem. So, lack of experience in design teamwork was reducing the intensity of the *constraint* and decreases the number of design decisions evaluated attentively. In case of lack of experience, in teamwork, the evaluation of the constraints decreases in progress of design decisions, and the number of solutions generation increases.

## Conclusion

Considering all design processes that team executed, wider problem-solution space team tend more 'solution-oriented' design. Namely designers tried to reach a result product by focusing to the *solutions* in wider solution space problems. In case of *solutions* could be selected from broad space team spent more time on solutions and they less preferred to narrow the solution space by structuring the design problem. In these conditions they tended to accept the first satisfactory solution idea and accept it as design decision.

In future studies, different teams' design processes in different design task situations need to be compared. In this study a research model developed for research of cognitive processes of design teams. Also other research studies are necessary such as the comparison of individual design process and team design process. Exploring design teams working with the relationship between learning processes and decision making processes would be helpful. Learning is today's one of the topics increasingly gaining importance, describing the collaborative of problem solving behaviors of design teams.

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