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PARADIGMS AND PROTOCOLS IN THE STUDY OF CREATIVE COLLABORATION: IMPLICATIONS FOR RESEARCH OF DESIGN TEAM PROCESS AND PRODUCT

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ABSTRACT:

Team design is a multifaceted process that requires the use of many skills and strategies. Understanding how these processes occur requires systematic observations of design teams while they are solving authentic design problems. Verbal protocol analysis (VPA) is a widely used method for investigating individuals and teams during problem-solving processes. This paper presents a review of research conducted using verbal protocol analysis within the areas of design and engineering design. Results are organized into a heuristic framework including categories such as constructs examined, method of data collection and analysis, theoretical framework for coding/analysis protocol, team description (type, size, etc.), and results of study. By pooling the resources of several studies we hope to contribute new understanding of the multiple paradigms

and protocols available for describing the complex processes of design teams. We conclude with considerations for use of verbal protocol analyses and recommendations for further research of social design activities.

design process, design team, protocol analysis

1. INTRODUCTION

Design is the central element of many professions such as engineering and architecture. Although the types of problems might differ based upon the field, most professions involve team structures that approach and solve design problems. Complex problems require the collaboration of people with diverse skills and expertise. Consequently, professional designers work in teams. Educational institutions are becoming more sensitive to the increasingly team-based structures in the workforce. Unfortunately, team-based problem solving processes are complex and we have limited information on ways to support learning to design when working in teams. This paper will provide recommendations in studying complex team design processes in the light of previous research on design problem solving. Before discussing the literature, it is necessary to identify the need to understand team design processes and why it is challenging to study design teams.

2. THE NEED TO UNDERSTAND TEAM DESIGN PROCESSES

While much attention has been dedicated to the study of the individual design process (Cross, Christiaans, & Dorst 1996a) comparatively little empirical evidence explores the design process of teams. Given the common practice of collaborative design work, this gap in the research represents an important opportunity for improving our understanding of how design teams work and how design and engineering education can best prepare students for this certain professional reality. Traditional curricula emphasize the individual mastery of design skills and many programs now provide students the opportunities to apply these skills in collaborative contexts. It is imperative for educators to be familiar with the multiple issues related to teamwork in order to develop thoughtful pedagogical practices regarding the facilitation of effective group design interaction. Additionally, research into the social processes of design teams is a fertile area for advancing our knowledge concerning how various activities (designing, communicating, sketching, etc.) relate to effectiveness and quality of output by groups.

3. CHALLENGES OF STUDYING DESIGN TEAMS

The challenge of investigating team design activities is due to three primary factors: task complexity, team diversity, and research design. First, design problem solving is a complex activity. Design problems are ill-defined and may result in multiple solutions based on the constraints and criteria they are built upon; therefore it is difficult to compare solutions produced by different groups. In addition, the design process is multifaceted and can be assessed according to many perspectives including creative output, product quality, member satisfaction, efficiency, etc. It is possible, for example, that a strategy which supports an efficient process might not support a creative outcome.

Second, the team context creates another challenge because the variances between teams (i.e. size, expertise, work history, composition) render it difficult to make comparisons across studies. For example, some research involves teams with three members but others report on teams of four, five, or six. There are teams composed of students and teams comprised of experienced, professional designers. Some studies utilize groups that have been assembled for the sole purpose of the study; others rely upon groups with some history of working together. The disciplinary composition of teams also presents a unique challenge when attempting, for example, to compare the work of a team of engineers with that of a multi-disciplinary product development team.

Finally, the research design utilized in the study of design teams offers a challenge (and opportunity) for comparison. There are multiple methods for documenting and describing the activities of a group. These can include retrospective descriptions of a design task, questionnaires, interviews, and protocol analyses to name a few. The variety of methods used in the study of design teams renders it difficult to compare results and to apply a range of findings within an educational setting. We have chosen to focus on Verbal Protocol Analysis (VPA) for this paper for three reasons: VPA is particularly suited to the area of inquiry because it offers a rich description of the design process as it unfolds over time and within its specific context, advances in technology allow for the capture of design activities via digital video providing *in situ* documentation, and VPA is being used with increasing frequency and diversity by the design and engineering research community.

4. VERBAL PROTOCOL ANALYSIS

VPA is often utilized in studies of design activity. The Delft Workshops (Cross, Christiaans, & Dorst 1996a) provide an example of how this approach can be used to analyze various contexts and constructs for a single design task. In the cited volume, published by the organizers of the Workshop, there is a concise description and history of verbal protocol analysis Workshops (Cross, Christiaans, & Dorst 1996b) that will be judiciously summarized here.

Verbal protocol analysis makes use of verbal accounts by participants of their cognitive processes during the completion of a task. Verbal protocols are classified as retrospective (i.e. asking one to think back to a recent event and give an account), or concurrent (i.e. also known as 'thinking aloud' during an activity). The obvious benefits of this type of analysis include the relative ease with which participants typically verbalize their thoughts and the potential for insight into cognitive processes. The potential disadvantages of this technique include the effect of verbalization which may alter the very behavior under study, and the possibility of incomplete or unrelated accounts.

VPA emerged in the 1920s as a method for exploring problem solving in psychological research. The use of tape recorders in the 1940s provided more accurate documentation of verbal reports. By the 1970s the use of video-recording technology generated additional opportunities for describing nonverbal activities. Today the protocol analysis is widely used to describe the design process in engineering and product design domains for both professional and student levels of expertise. Though techniques for capturing data (i.e. video) may be similar, there is no established paradigm for analyzing this data in order to render comparable multiple studies. The aforementioned Delft Workshop illustrated how diverse the results of inquiry could be even when each study relied upon the same data (in that case two videos) and same general method (protocol analysis).

VPA has been widely used to study individual designers. These studies have provided rich descriptions of solitary design processes. The recent use of VPA to study teams has blossomed to reveal multiple perspectives about task design, team composition, and methods of analysis. This paper does not attempt an exhaustive description of every such study. We have chosen, rather, to select a few key studies that demonstrate some similarities and differences in hopes that this discussion will generate interest in the verbal protocol method and encourage new inquiries into the social processes of design teams.

5. RESEARCH ON DESIGN TEAMS USING VPA

We have selected five studies for inclusion that utilize a protocol analysis to investigate the design processes of teams with two or more members. A descriptive summary of each study has been created using the categories of domain, task, team, coding protocol and analysis, results, and recommendations. While these studies do not represent all comparable research using VPA, they do provide a preliminary introduction to the method and offer interesting avenues for future inquiry relating to collaborative design activities.

5.1 EXAMPLES FROM THE DELFT PROTOCOLS WORKSHOP

The Delft Protocols Workshop which took place in 1994 with the aim of bringing together a group of distinguished design researchers to compare their analyses of the same data and to discuss the state of design protocol research. Three of the twenty studies resulting from this workshop have been included here.

The domain under study for the Delft protocol was industrial (product) design, hence the task chosen for the design activity. The task utilized for this study was the design of a device to enable fastening and carrying a backpack on a mountain bike. A detailed description of the design problem, its structure and its justification can be found in the book resulting from the workshop Workshops (Cross, Christiaans, & Dorst 1996a) The time allotted for the task was two hours. The Delft protocols included two different videotapes, one protocol for an individual designer and one for a team of designers. The team included three designers of comparable professional experience (approximately 5-8 years).

5.1.1 Teamwork and Social Processes in Design (Cross, N. and Clayburn Cross, 1995)

For this study the authors chose to observe the social process of the design team as they completed the task. The report describes how team interactions were identified (via transcription and video) and organized into chunks according to specific categories of interaction. The following aspects of team member interaction were included in the analysis: roles and relationships, planning and acting, information gathering and sharing, problem analysing and understanding, concept generating and sorting, and conflict coding and resolving. This qualitative approach offers

a unique opportunity to understand the individual contributions of each team member within the context of a given activity, moment, and/or context.

The results of this study offer a rich description of the design process and how the various interactions among the team members influenced the progress and finalization of the design concept. The authors also argue that many elements of the team's design activity are influenced by the social interactions that occurred. The study concludes with a recommendation that design methodology must address the design process as an integration of three processes: technical, cognitive, and social.

5.1.2 Designer as team of one (Goldschmidt, 1995)

For this study the author chose to compare the design process of the individual with that of the team. This structural analysis parsed the protocol into design *moves* which were defined as "any step, act, or operation which transforms the design situation relative to the state in which it was prior to that move." These moves were notated using a system called *linkography* which represents an instrument for comprehending the structural patterns of design reasoning. This system was used to code the activities of the team as a single entity and those of the three individuals in the team. The results of this analysis allow comparisons of individual contributions and activities within the big picture of the group. The results of this study point a preliminary finger towards the idea that the individual designer resembles a team of one more than team members resemble individual designers within a team.

5.1.3 Two paradigms for describing design activity (Dorst, K. and Dijkhuis, 1995)

This team chose to analyze the Delft team protocol through two different paradigmatic lenses to determine how closely each comes to describing the process as the designers experience it. Describing design as rational problem-solving, every 15 seconds the authors coded the process according to five different categories: 1. Acts, 2. Goals, 3. Contexts, 4. Topics, and 5. Auxiliary Topics. The score for each 15 seconds interval looked something like this: 03 04 10 35 00 with numbers referring to category-specific descriptions from a key. The second coding system was based upon Schon's description of design as reflection-in-action and included the assignment of one of three codes (MV- move, FR- frame, and BTH for underlying background theory) to the communication and design actions that occurred throughout the session. The authors conclude that while both methods offer advantages, the reflection protocol provided a clearer description of the link between process and content and more closely resembled the design-as-experienced.

The conclusive recommendation is that the theoretical base of reflection-in-action should be evolved so that it more rigorous and generalizable conclusions can be drawn from consequential studies.

5.2 REFLECTIVE PRACTICE OF DESIGN TEAMS (VALKENBURG & DORST, 1998)

This study explored the 'mechanism of reflective practice' for describing team designing. Observed teams included four undergraduate engineering students competing in a student design contest. Teams included varying proportions of students from industrial design engineering, mechanical engineering, and electrotechnical engineering. The assignment was to design and build a remote controlled robot that could transport as many balls as possible from a table to a basket 1 meter away. The initial two days of design conceptualization for each team were divided into episodes (where one activity occurs) and coded as Naming, Framing, Moving, or Reflecting. For this study, the process of a *winning* team was compared with that of a non-winning team to identify possible strategies for success. The authors describe the revelation that the most interesting moments in the design process were often characterized by frame transitions. They recommend more systematic, exploratory studies that describe design and evolve into prescriptive studies of how to improve both design practice and education.

5.3 DESIGN TEAM COMMUNICATION (STEMPFLE, J. & BADKE-SCHAUB, 2002)

This study involved three teams of four to six mechanical engineering students asked to design a mechanical sun planetarium within a one-day period. Team communication was analyzed sentence-by-sentence and organized into communicative acts. These acts were analyzed in three ways: a frequency analysis, a process analysis in macroperspective (process versus content focus, and 5 steps of the process), and a process analysis in microperspective (two-step sequences of design steps and focus). The five macroperspective steps included goal clarification, solution generation, analysis, evaluation, and decision. The authors propose a two-process-theory of thinking in design teams where different conditions result in the adoption of one of two approaches. Final recommendations include the development of a practitioner-based methodology that emphasizes the design process as a function of real-world constraints and pedagogical attention to the importance of teaching future designers to self-reflect.

	Theoretical Framework	**Constructs & Operationalized Variables**	**Method: Data collection and Analysis**	**Team Description**	**Results**
Teamwork and Social Processes in Design	Social processes and interactions among team members	roles & relationships, planning & acting, information gathering and sharing, problem analyzing & understanding, concept generating & sorting, conflict coding & resolving	Qualitative analysis of interactions evidenced through video and transcription	three designers of comparable professional experience	design process as an integration of 3 processes: technical, cognitive, and social
Designer as team of one	Linkography	Moves, links	Design 'moves '	three designers of comparable professional experience	individual designer as team of one more than team members resemble individual designers within a team
Two paradigms for describing design activity	Rational Problem Solving and Reflective Practice	RPS: Acts, Goals, Contexts, Topics, and Auxiliary Topics RP: Move, Frame, and Underlying Background Theory	Analysis using two different coding protocols for comparison	three designers of comparable professional experience	Reflective protocol description closer to designers' experience, should be evolved for generalizability
Reflective Practice of Design Teams	Reflective Practice	Naming, Framing, Moving, or Reflecting	Process of two teams organized into episodes then analysed and compared according to same protocol	four undergraduate engineering students from three disciplines	Importance of frame transitions,
Design Team Communication	Team communication	goal clarification, solution generation, analysis, evaluation, and decision	communicative acts analyzed with a frequency analysis, a macroperspective and a microperspective process analysis	four to six mechanical engineering students	Two process theory of design team communication and Importance of teaching self-reflection

6. SUMMARY AND CONCLUSIONS

The five studies chosen for this synthesis offer numerous insights regarding the verbal protocol analysis of design teams, an area of inquiry that we believe merits more attention from researchers in design and engineering education. As illustrated by these studies, the design of any research program that utilizes the VPA method must take into account multiple factors. The types of task ranged from technically simple (i.e. the fastening device) to complex (i.e. the planetarium). In some cases teams were given only two hours to complete the task and in others they worked for an entire week. Team size and composition also presents a challenge given the limited possibilities of a studio classroom as compared to a large corporation.

As evidenced by the studies cited, different methods exist for structuring the protocol (i.e. standard time-intervals or parsing process into episodes). There are also multiple theories and paradigms available for coding the activities (i.e. rational problem-solving, reflection-in-action, social interaction). Even when the same theory has been chosen, take for example the reflection-in-action approach; we have identified different ways to operationalize that theory for data coding.

Interestingly, partnerships among researchers may help overcome many challenges of studying teams. Delft workshop is an excellent example of such collaboration. Another area of opportunity is comparative studies that investigate team interactions and design problem solving processes from multiple perspectives. The cited studies compared individuals to teams, individuals within teams, different paradigms for describing design processes, and the different design processes in light of the process outcomes. Results of these studies, when coupled with the authors' recommendations, expose a number of opportunities for future research into design thinking.

7. FUTURE RECOMMENDATIONS FOR STUDY OF DESIGN TEAMS

Further study is needed to understand team processes and how they impact design solutions. This research can provide insight about the nature of design activity as well as the nurture and education of it. These studies may begin to answer critical questions such as:

How can we prepare students for the complex process of designing within a team?

How can we train teams to work effectively?

How can we promote creativity in team designs?

What type of resources do teams need when solving design problems?

How can tools for creative collaboration be taught and assessed?

The difficulties involved in following teams during their design activities and the complex nature of team interactions render VPA an appropriate method for such inquiry. In light of the variance described here it is easy to identify the challenges that one confronts when utilizing VPA to describe the complex interactions of design teams. Careful consideration of the foundational work described here paired with rigorous and collaborative future investigations offer the promise of deepening our understanding of team design processes. This deepened understanding translates into an expanded repertoire of tools that can be used to educate the designers (and teams) of the future.

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