INTERNATIONAL DESIGN CONFERENCE - DESIGN 2008
Dubrovnik - Croatia, May 19 - 22, 2008.

DESIGN 2008

DESIGNING IN A GROUP – HOW CAN KNOWING EACH OTHER INFLUENCE DESIGN PROJECTS?

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Keyword: group processes, interpersonal relationships, identity

1. Introduction

This paper presents a study of engineering design groups that seeks to explain how knowing other participants can influence processes and outcomes in design projects. The paper is presented in seven sections outlining research and introducing a framework developed for analysis. First the role of individuals and groups in design projects is reviewed (section 2), identifying an increasing current interest in collaborative design work and influences in engineering design. Then literature on group processes and group development in engineering design is reviewed (section 3). Whilst this provides valuable insights, there remain important gaps that are highlighted. This review led to the formulation of a research question (RQ) to frame this study. Relevant concepts of this RQ and how they may be investigated empirically in a pilot study are presented in section 4. Analysis of the pilot study demonstrated the value of the concept of identity to consider both individual and group development. Section 5 presents further literature on interpersonal interaction, group processes and identity. This provides a basis for a number of research propositions to frame the principal empirical phase of this study. Section 6 presents rationale for case selection and case propositions drawing on aspects from sections 2 and 5. Conclusions are recorded in the final section.

2. Engineering design – context and collaboration

The environment of engineering design projects has changed over the past 20 years from typically a sequential process within one organisation to concurrent working processes that may involve several organisations. This influences how a designer is expected to work with a majority of projects requiring a group to achieve design aims. Researchers have recognised that design is a social process [e.g. Bucciarelli 1994] and that as product design activities become integrated, teamwork becomes increasingly important [Cross and Clayburn Cross 1995] creating new processes to achieve this. In teams designers need to not only provide and perform their disciplines' role but also work effectively with other professionals in a project team. To accomplish this engineers have to be aware that individual contributions are embedded in a complex technical and social process [Minneman and Harrison 1998] that takes time and effort to develop. Pressures to work in a group highlight a need for greater understanding of how individuals interact in engineering design projects.

Collaborating in a project team across disciplines and organisations is part of expected working practices in engineering design. It is being strongly promoted by governments and is frequently a central part to an organisation's strategy [Huxham and Vangen 2004: 7], however the majority of collaborations fail to be mutually successful [Tidd, et al. 2005]. This popularity and yet limited success of collaborating points to a need to learn more about existing complexities in design projects.

Bringing people together in a project group introduces a group development dynamic that records how working with other participants can change over time. This group development is important to allow

individuals to combine their abilities and work effectively together and involves defining a set of working standards that includes individual capabilities and how participants intend to achieve a common goal. Group development models focus on patterns or developments over time, but common throughout models are interdependent task and socio emotional aspects of group behaviour.
Influences on organisations have imposed changes to design working processes. Both group and individual impacts are considered in this paper looking at groups within and beyond organisation boundaries. Group processes (e.g. communication) are focused upon with particular reference to group development and influences on design projects.
Design approach and type are two significant influences on group processes. An organisation's strategy and resources are often used to help managers decide upon a suitable design approach, e.g. systematic or concurrent. Each approach has implications for how engineers design. In systematic approaches delimiting steps allow in depth knowledge to be developed, retained and used focusing on one aspect of design process at a time. In delimiting steps individuals also need to remain aware of the entire design process and relevant interdependencies to avoid problems being passed from one phase to another. In concurrent approaches reducing lead times imposes increased interaction between individuals and departments blurring delimitation of phases. This also increases the required effort in organisational and social skills (e.g. communication).
The design type is a further impact on design and group processes determining the relationship between new and old designs. Pahl and Beitz's [1996] established classification is:

- Original - generation of an original solution.
- Adaptive - solution principle remains the same changing how the task is achieved.
- Variant - solution and function principle remain the same changing only size and/or arrangement of systems.

These choices define design process but also relate to how project teams are structured and work in practice. Relevant literature on designing in a group is considered next.

3. Designing together –group processes and group development

3.1 Group processes

Groups are formed to complete what individuals alone cannot. This may seem simple but in reality it is not trivial as dysfunctional groups are common. Engineering design is achieved in groups and often crosses boundaries with inter organisational and inter disciplinary projects. This draws on benefits from synthesising different perspectives, creating a shared understanding, knowledge sharing and recognising effects on groups and individuals. Research on these topics is presented next.

3.1.1 Understanding perspectives

In looking at design in groups, ethnographic studies [e.g. Bucciarelli 1994] present design as a process of negotiation and compromise where the final product represents the consensus of participants. The social process is an intersection of object [Bucciarelli 1994] and thought [Dougherty 1992] worlds to appreciate different perspectives. When these object and thought worlds can synthesise or create a thought world, groups open paths to access participants knowledge and develop the group. Even if there is similarity or synthesis in perspectives, communication between individuals is uncertain though the impact on a project will depend on the relevance of communication.
Frankenberger and Badke-Schaub [1998b] emphasise the importance of co-operation and communication during the entire design process to permit individual perspectives on information to be heard and become less ambiguous over time. Having a common ground prior to interaction is an advantage but a luxury that is not always present. For effective communication this demands a coherent understanding of the required and received information. In a group this can be developed through creating a shared understanding.

3.1.2 Shared understanding

Shared understanding is a similarity in how key issues in design content are conceptualised and comes from industrial and organisational psychologists use of team mental models. Mental models (a group

of cognitive constructs) have been created to explain how knowledge and information are represented in the mind and are used to operationalise shared understanding. A shared mental model describes cognition between two individuals whilst a team mental models that of a group.
Group design work has been described as negotiation to be able to understand [Minneman and Harrison 1998], but understanding each other is difficult and factors that promote or create barriers to shared understanding in engineering design are empirically explored by Kleinsmann et al [2005]. Shared understanding is key to efficient group interaction and is shaped through group processes i.e. conversation, personal dynamics [Minneman and Harrison 1998] that exchange information and knowledge. Without shared understanding there are numerous iterative loops [Kleinsmann, et al. 2005] particularly in building knowledge and can cause delay, frustration and create further misunderstanding.

3.1.3 Groups and individuals

Social links are important in retaining and promoting knowledge sharing and functional expertise. These links create informal networks that can foster creative aims, diffuse information, provide contextual knowledge about individuals (e.g. logic they use), and provide support beyond project, department or organisation boundaries.
Frankenburger and Badke-Schaub [1998a, b] develop a model of group design processes for systematic design through two case studies studying individuals and group interaction. They define six linked topics (individual prerequisites, group prerequisites, external conditions, task, design process and result) that represent relations between influencing factors and process characteristics in critical situations of problem solving in design process. The study reveals that information availability for communication and analysis primarily impacts time, cost and quality of design decision making [Frankenberger and Badke-Schaub 1998a] and at critical incidents is influenced by individual experience, informal power relations, group organisation and external time pressures [Frankenberger and Badke-Schaub 1998b]. Taking time into account, group development aspects are described next.

3.2 Group development

A group has a dual purpose for participants incorporating task and socio emotional aspects that develop over time. Task aspects are orientated around accomplishing group tasks and goals (including problem solving) and socio emotional aspects concern building and maintaining relationships amongst group members to develop an effective working unit. Task aspects are recognised in design as they often define work processes; however, influences of socio emotional aspects that interlink with task aspects have had less attention. To consider the impact of affective aspects, this study looks at personal relationships. Personal relationships are acknowledged to be influenced by a group's environment, where individuals may tend towards attitudes and expectations brought from other groups or identities, and bias affective or task aspects - e.g. towards friendship or safety respectively.
In looking at group processes, researchers in engineering design record the importance of a number of topics (e.g. communication) that evolve over time. These topics are processes that all involve interaction between group participants. Subsequently this research proposes to focus on links that are created through interaction on an individual level between two individuals, noted here as interpersonal relationships (IPR). Tuckman and Jensen [1977] emphasise the importance if IPR in initial stages of group development, and others note their temporal and recurring nature throughout group development (e.g. Bales [1966]).

3.3 Critique

The choice of design process or design type influences how engineers design. In addition building a shared understanding, synchronising individuals' activity and maintaining social relations in a group are key to the social process of designing. These are often carried out simultaneously reflecting a complex interaction between engineering design and group processes. Findings from literature recognise both group and task processes with [Frankenberger and Badke-Schaub 1998a, b] producing a model illustrating individual and group prerequisites and external conditions that affect design

outcomes. Individual studies have concentrated specific group processes (e.g. negotiation [Minneman and Harrison 1998]) or looked key topics in shared understanding on key topics [Kleinsmann, et al. 2005]. In considering only certain topics there may be relevant aspects missing in understanding how individuals manage to interact with each other and work effectively together. Furthermore, few investigate how participants (and group) develop by designing together over time, or consider the influence of interpersonal relationships on designing.

4. Pilot Study

Bringing presented themes together, a research question is articulated to look at understanding designing in groups focusing on group processes, IPR and outcomes:

> **RQ: How do interpersonal relationships influence group processes and outcomes in design projects?**

To address the openness of this RQ a pilot study was carried out and relevant themes identified through data analysis. The aim of this research is to extend theory and fill theoretical categories. In order to do achieve this a longitudinal pilot study has been undertaken to refine this RQ and consider how to select cases. A temporal dimension is used to study the influence of IPR and observe if and how they change and influence engineering design projects.

Data was collected from a 14 week design project involving 6 University of Bath trainee engineers and an external engineering organisation. Interviews were carried out with all trainee engineers in both weeks 5 and 13. Participants are studied to develop a representation of IPR and consequently construct a holistic picture of a project. This involved understanding context and emotional experiences of individuals and group. Interviews were complimented with observations from group interactions and access to project documentation.

Data was analysed using themes of collaboration practice [Huxham and Vangen 2004] as a conceptual framework. An iterative process of deduction and induction of data analysis was used to recognise pertinent themes in the framework. One relevant theme in this pilot study encompassing a number of statements about group processes and IPR was identity. Focusing on identity allowed issues described by participants in interviews to be categorised on individual and group levels. This helped to explain group behaviour and appreciate their individual interpretations. In particular there were benefits to group progress when participants knew more about other group members *"I think it makes it easier it helps the group dynamic, you can tell the people that have spent more time together than others"*. This understanding was not confined to specific topics but extended to learning about how individuals performed their role (in comparison to expectations) *"particularly because J has not put in the work and the group has had to support J and do the work in the meeting"*. Appreciating their social interests was a benefit to creating a project group; it helped to improve relationships and motivation to work with certain individuals. Although participants were from different engineering disciplines, differences due to their studies were not prominent in influencing outcomes or processes. Where there are differences between disciplines involved there may be a greater impact on designing. This study recognises that a number of issues that develop and change in a design project relate to group (discipline and organisational) and individual identities. Literature on identity is presented next to consider further the RQ and produce research propositions to focus data collection and analysis.

5. Identity

The theme of identity is used to develop general propositions for the RQ. In social psychology the self is an important concept in approaches that look at how individuals maintain identity. These are split into three categories that compare the self to 1. the self, 2. other individuals and 3. other groups. An established group comparison theory is presented next to consider design project group development.

5.1 Social identity theory

Group comparison theories are centred upon to appreciate how individual and group identities interlink. Social identity theory is an established group comparison theory formulated by Tajfel and Turner [1979] and extended with self categorisation theory [Turner, et al. 1987]. The latter studied

group norms that define collective identities to understand influences between social categories and self concept. To consider both individual and group identity, social identity theory defines two types of identity:

1. Personal identity - aspects of self (e.g. idiosyncratic behaviour).
2. Social identity - groups individuals belong to (related to group norms, group behaviour).

Personal and social identity are context dependent. When interaction between individuals takes place, identity salience, i.e. prominence and clarity of an identity, can change. When an individual's social identity is salient individuals perceive themselves and others in terms of common features that define a group (its prototype). Individuals think and behave more in common with a group's norms and view each other through a narrow lens of group membership. Understanding which social identity is salient subsequently helps understand individual and group performance expectations by appreciating established norms that are relevant to each individual and group. Individuals though belong to a number of groups (e.g. project, organisation etc) and the salient social identity changes depending on group composition and participants understanding of each other.

5.2 Group processes, IPR, group development and identity

In looking at IPR and group processes during group development, identity is used as a lens to study engineering design projects. This considers identity on a number of levels contrasting personal and social identities. In doing so the aim is to look at the influence of creating an understanding of personal identity through IPR on group process and outcomes. It is important to note that an individual can have an understanding of a person's identity without interacting with them, i.e. they can know of or observe them. This point recognises that developing an understanding of a person's identity is possible directly or indirectly but when interaction is involved IPR develop.

There are five general propositions (GP) for this RQ (shown in Figure 1). GPs 1, 2 and 3 look at the link between IPR and group processes by considering personal interaction and identity. GP4 considers how group processes and outcomes influence each other with the relevance of group identity. GP5 focuses on IPR and outcomes considering personal interaction and uncertainty reduction.

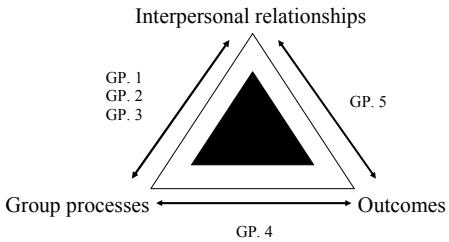

Figure 1. Where the general propositions (GP) focus on links in the RQ

The role of personal interaction and identity is considered first:

GP1. An increase in personal interaction increases group members' understanding of each other's personal identity.

GP2. An increase in personal interaction increases the development of a project group identity.

Group development models record the importance of developing interpersonal relationships (IPR) and understanding participants to help groups work effectively. Tuckman and Jensen [1977]) emphasis their importance during initial phases and others (e.g. Bales [1966]) note their temporal and recurring nature throughout group development. Self is an integral part to personal identity that is developed and maintained through comparisons of one's self, with other individuals and groups. GP1 emphasises that with more interaction, there are more opportunities for understanding identity through comparison. GP2 recognises that personal interaction aids developing a group identity through establishing accepted standards of behaviour and recognises Fay et al's [2006] empirical findings that a shared vision and higher frequency of interaction led to better team processes.

Considering the link between personal and social identities:

GP3. As participants understand more about each others personal identities and project roles then a design project's group identity becomes clearer.

In social identity theory as a group develops it establishes a group identity through harmonising personal and social standards and behaviour (implicitly or explicitly). Looking at personal identities in design projects aims to understand how influential they are on establishing group identity and group processes to design together. Furthermore Worchel and Coutant [2001] suggest that group dynamics have interpersonal and intergroup components that should be included when studying the links between individual and group relationships. Clarifying aims aids individuals to achieve what is appropriate for a project group identity.

Next it is important to recognise the relevance of considering project group identity:

GP4. Establishing a project group identity (group norms etc) is more important for group development when multiple, disparate identities (e.g. participants' disciplinary backgrounds) are involved.

Worchel and Coutant [2001] posit an identity development model illustrating how individual roles and identity are influenced by changes in group identity. This model shows individuals' membership of a group is temporal and it is important to maintain a group identity for a productive group where salient components of individual identity change during group development. In addition to creating a project group identity there will exist a number of group identities reflecting participants association with other groups (e.g. discipline, organisation). These differences are important to recognise to create a group identity that participants are motivated to be part of and exhibit as their salient social identity.

Having considered personal interaction and its influence on group development and personal and group identity, the final proposition relates to how interpersonal relationships link to uncertainty:

GP5. When interpersonal relationships develop there is a greater ability to adapt to uncertainty and risk.

An individuals' motivation plays a significant role in addition to the process of social categorisation to achieve social identity salience. Individuals can make sense of and reduce uncertainty about themselves and others to feel relatively positive about themselves where uncertainty reduction is a fundamental motive to alter current status [Abrams and Hogg 2001]. This suggests that developing IPR and knowing the people that one works with may help designers to adapt as events occur.

In studying identity the importance of understanding project participants for who they are and how this impacts on design outcomes is considered. These five propositions bring together aspects from relevant literature to inform studying identity and group development in engineering design. These are generic propositions will be investigated with a case study strategy. Selection of appropriate cases is discussed in the next section appreciating concepts of project complexity, risk and uncertainty.

6. Case selection and propositions

Cases are categorised according to design type and design setting. This recognises that identity and designing are both contextually dependent: individuals show different aspects of their identity in different contexts, and designing is influenced by type (see section 2) and setting.

1. **Design type**. Recognising that different approaches may be used in designing products, this research classifies cases using Pahl and Beitz's [1996] distinction between original and adaptive design noting that familiarity of a design process may influence group processes.
2. **Design setting**. Increasingly individuals are designing beyond organisation boundaries. This aspect is used to acknowledge that there is an added layer of complexity in designing between organisations (inter) than within an organisation (intra).

The purpose of these two aspects is to classify potential projects and establish how a case set can be analysed. Multiple cases are used to add confidence to findings through similar and contrasting cases. Similarity is considered through a consistent methodology and by selecting at least one case in each design setting and design type. Contrast is achieved first through comparing cases across the two aspects (i.e. intra vs. inter and adaptive vs. original) and secondly by noting that each case has different design aims.

These two aspects illustrate differences in complexity, risk and uncertainty of design projects. Typically a project (both task and management) will increase in complexity risk and uncertainty moving from adaptive to original design and from intra to inter design projects (shown in Figure 2).

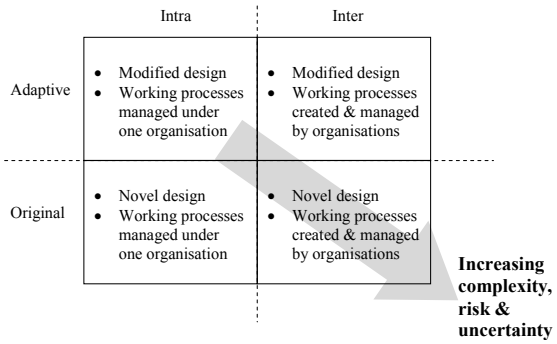

Figure 2. Considering complexity of engineering design projects

Increasing project complexity increases dependence on project participants, and can illustrate how integral individuals are to achieve project aims. In projects of higher complexity participants are increasingly required to work as an effective group that can be achieved by creating group identity and group development. Both group identity and group development are reliant on developing effective group processes and IPR. The importance of understanding personal identity (skills, experience etc) is proposed to be related to how integral an individual is to a group (both task and socio emotional aspects).

In considering design type and setting, it is proposed that understanding personal identity and building IPR will be more critical for group processes as complexity of a project increases i.e. in inter or original design projects. It is acknowledged that the quality of interaction may influence designing in a group and this will be explored when data reveals further avenues to refine existing propositions.

Following this case selection method acknowledges that design is carried out in different contexts. This will further existing research by illustrating how design type and setting influences IPR, group processes and outcomes in design projects. This appreciates that individuals are brought together to solve different types of problems that may, or may not, involve interdependent tasks, group solutions (e.g. to synthesis their expertise), or creating new design processes.

Research output will include guidance to help improve practice focusing on how group processes impact upon project outcomes; this has implications for managing collaborative projects, improving participants understanding and developing tools for collaborating.

7. Conclusions

Research in this paper contributes a framework to approach understanding how interpersonal relationships influence group processes and outcomes. This acknowledges that engineering design is achieved through individuals working in groups. Intrinsic to working in a group are the participants and group processes (e.g. communication) that facilitate interaction, exchange of information and creation of appropriate design solutions. First a temporal perspective is introduced to understand how individuals (through interpersonal relationships), group processes and outcomes influence each other; secondly identity is presented as a theme to focus on how knowing other participants identity influences group processes and outcomes. Both individuals and groups are considered under this theoretical theme where influences in group interaction and development can be captured. Within this framework it is recognised that engineering design has different levels of complexity of which two aspects are considered: design type and design setting. These aspects place different demands on a project group and its members and this structure provides an opportunity for cross case analysis to

generalise findings. The aim of this research is to bring a greater understanding to how designers interact and cope with differences in working methods and personal character whilst recognising that participants look beyond an individuals' role to understand each other and design together.

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