Poster

TITLE

An Exploration of Knowledge Integration Problems in Interdisciplinary Research Teams

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ABSTRACT

The integration of function-specific expertise into a shared knowledge base is a crucial, but complex process for success in interdisciplinary teams. This paper presents an empirically derived typology of knowledge integration problems and links their occurrence to degree of heterogeneity and present stage of a team's life.

PRESS PARAGRAPH

The cooperation of multiple disciplines is a common phenomenon in many areas. The success of interdisciplinary collaboration stands and falls with the ability to integrate the disparate approaches and expertise of individual disciplines towards a common goal. Reality shows, however, that this is not an easy task especially for highly heterogeneous teams. This paper investigated work processes and interactions in existing interdisciplinary research teams to identify areas and behaviors that hinder knowledge integration. First results indicate that not only degree of heterogeneity, but also a team's maturity influence how many and what type of problems occur.

According to Matta and Ashkenas (2003) in the Harvard Business Review, well over half of big team projects fail. Often, failures do not occur because of individual member's incapability, but are due to miscommunication, inter-personal conflicts, and the inability of teams to adequately coordinate and align individual contributions (Hackman, 1987; Zaccaro, Rittman, & Marks, 2001). These challenges become even more pronounced when the team is interdisciplinary in nature. Interdisciplinarity manifests itself in educational or expertise diversity characterized by differences in knowledge, skills, and experiences of team members educated in different academic traditions (Dahlin, Weingart, & Hinds, 2005; van der Vegt & Bunderson, 2005). Academic disciplines can be seen as distinct "thought worlds" (Dougherty, 1992) in which the same information is processed, weighted, and used in different ways. Education diversity is thus related as much to the plurality of information available to a team as to the different styles of information use and processing (e.g., Cohen & Levinthal, 1990; Kilduff, Angelmar, & Mehra, 2000).

The promise of educational diversity lays in the availability of a broader range and wider variety of information which is generally connected with the expectation of more efficient and creative solutions to complex problems (e.g., Pinto, 1989; Simons, Pelled, & Smith, 1999; Smart & Barnum, 2000). The general argument is that interdisciplinary teams provide an apparently manageable way to bring diverse cognitive resources to bear on a project (Northcraft, Polzer, Neale, & Kramer, 1996) and that the pooling of such diverse resources in terms of knowledge, skills, and abilities increases the potential for team performance (Pelled, 1996; Miller, 2001). Interdisciplinary teams are therefore often employed where homogenous or mono-disciplinary teams might provide too narrow an approach. The reality of interdisciplinary team work shows,

however, that expertise diversity can lead to tensions, conflicts, and actual losses in efficiency (e.g., Bunderson & Sutcliffe, 2002; Keller, 2001; Pelled, Eisenhardt, & Xin, 1999).

Academic research is one area in which interdisciplinary cooperation is highly common. Academic research as knowledge work has its primary goal in the development of new content or more generally the ‘production’ of new knowledge (Harvey, Pettigrew, & Ferlie, 2002). Knowledge can thus be considered its “key intangible asset” (Harvey et al., 2002, p. 747) and the combination of diverse areas of expertise seems a promising way to increase the complexity and innovativeness of scientific work. The success of ‘knowledge production’ in interdisciplinary research teams stands and falls with the ability to share distributed knowledge and to integrate it towards a common goal (Janssen & Goldworthy, 1996). This process of knowledge integration is related to team learning and the development of common ground (Clark, 1997). More precisely, *knowledge integration* is the process of constructing a common, integrated knowledge base of isolated areas of knowledge and experience shared by all team members.

Knowledge Integration in Interdisciplinary Teams

While homogeneous teams can rely on a certain degree of pre-existing common ground acquired through comparable experiences and education, heterogeneous teams in general do not possess this initial advantage. At early stages of a team’s existence, the overlap between knowledge areas and frames of reference is usually relatively small and often determined by general images or assumptions of what the other discipline knows and does (*communal common ground*, Clark, 1997; cf. Ellis, Hollenbeck, Ilgen et al., 2003). In the course of their cooperation, however, team members have the opportunity to acquire first-hand experiences of each other and move from *communal* to *personal common ground* (Clark, 1997). This shift is achieved through

the process of grounding which Clark and Brennan (1991) define as the collective process by which listeners strive to reach mutual understanding with the speaker.

Developing an understanding of the respective knowledge areas, skills, and approaches represented in a team and the knowledge on 'who knows what' (*transactive memory systems*, Wegner, 1987), is a first step towards creating common ground. It has been shown that transactive memory systems are related to team performance and viability especially in knowledge-intensive team work (Lewis, 2004). But beyond the 'knowledge of who knows what' the (at least partial) integration of knowledge of other disciplines into the knowledge base of individuals as well as the development of a shared understanding of problems, tasks, goals, and methods is necessary to allow team performance in the long-term. For this learning at two different levels has to occur at the same time: individual learning and team learning. On the individual level learning can be defined as a "relatively permanent change in knowledge or skill produced by experience" (Weiss, 1990, p. 172), while team learning constitutes "a relatively permanent change in the team's collective level of knowledge and skill produced by the shared experience of the team members" (Ellis et al., 2003, p. 822). On the individual level, team members have to adapt and integrate information into their individual existing knowledge and world views, while on the collective level team members need to share information and create a common frame of reference. The success of interdisciplinary team work thus is closely related to the ability of team members to integrate disparate knowledge repositories into *shared mental models* and create a common understanding on areas like technology, task, team interaction, and the team itself (Cannon-Bowers, Salas, & Converse, 1993; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Effects of team learning and team mental models on team performance are well established (Edmondson, 1999; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas,

2005; Yeh & Chou, 2005). Especially similarity and accuracy of team mental models have shown a positive relation to team performance (e.g., Edwards, Day, & Bell, 2006; Lim & Klein, 2006). Van der Vegt and Bunderson (2005) argue that performance of a team relies on the degree of intra-team learning behaviors providing team members with knowledge of dispersed areas of expertise in their team. The more team members learn from each other the easier and the more effective communication and cooperation will be. The authors showed that team learning behaviors partially mediated the relationship between functional diversity and team performance and concluded that the potential of multidisciplinary teams can only be realized through the dispersion of expertise through team learning behaviors.

Research Questions

While a number of studies investigated the effect of functional or educational diversity on team learning and team performance (e.g., Dahlin et al., 2005; Gibson & Vermeulen, 2003; van der Vegt & Bunderson, 2005), much less is known about what type of knowledge teams need to share and integrate. The literature of team mental models often differentiates between four different areas that are considered to be important for team functioning, namely technology, task, team interaction, and team (Cannon-Bowers et al., 1993; Mathieu et al., 2000). Both task-work (technology and task) and team-work (team interaction and team) mental models have been found to directly or indirectly influence team performance (e.g., Lim & Klein, 2006; Mathieu et al., 2000). Problematic is that most research in the areas of team mental models and team learning is based on laboratory studies (Ellis, 2006; Ellis et al., 2003; Mathieu et al., 2005) and/or use self-report data (e.g., Gibson & Vermeulen, 2003; Lim & Klein, 2006; Offenbeek, 2001; Yeh & Chou, 2005). Generalizability of results to the more complex tasks of real project groups and specifically academic research is thus questionable. Additionally, even though most

authors agree that knowledge and knowledge production are central to research collaborations, in general, they do not provide a clear identification of the content areas interdisciplinary research teams need to share or conceptualize (e.g., Kraut, Galegher, & Egidio, 1988; Sargent & Waters, 2004). So far it is not clear what type of knowledge interdisciplinary teams need to integrate and at what stages in the research process. The study presented in this paper aimed to obtain a better understanding of underlying areas relevant in knowledge integration. It was conceptualized as an exploratory, qualitative field-study in existing interdisciplinary research teams. The following research questions guided the investigation:

- What are the underlying causes of knowledge integration problems in knowledge work?
- How is the occurrence of knowledge integration problems by factors like degree of expertise diversity over the duration of a research project?

METHODS

Sample and Procedures

Our sample consisted of seven interdisciplinary academic research teams ($n_{\text{total}} = 47$) tasked to develop new technologies and engineering approaches. The teams consisted of four to 15 members ($m = 6.7$, $sd = 3.7$) of which 87.5% were male. The number of disciplines in the teams ranged between two and five ($m = 3.57$, $sd = 1.13$). Degree of heterogeneity was calculated using the Teachman diversity index H_T (1980) leading to a range of 0.56 to 1.32 ($m = 0.97$). To our knowledge, no clear rule exists what constitutes high or low heterogeneity. Therefore, a rule of thumb was used with $H_T < 1.0$ indicating low or moderate (three teams) and $H_T \geq 1.0$ high heterogeneity (four teams). The teams spanned a spectrum from newly formed (observations starting with the very first team meeting) to longstanding (up to five years).

Considering both tenure and heterogeneity, the teams can be grouped into the following categories:

- Low heterogeneity:
 - Newly formed: team 1, team 7
 - Longstanding: team 2 (approx. four years)
- High heterogeneity:
 - Newly formed: team 4, team 6
 - Longstanding: team 3 (approx. three years) , team 5 (approx. five years, with change of one member in the first observed session)

Our focus in studying interdisciplinary research teams was on investigating problematic collaboration processes with respect to knowledge integration in direct face-to-face communication among disciplines. We therefore observed two subsequent team meetings in each team, which gave us a direct, unfiltered view upon individuals' interactions and behaviors and a 'snapshot' of the present state of team processes and relations between members. The meetings lasted between one and three hours and were spaced approximately three to four weeks apart. As the teams did not work together outside these meetings, they represent a genuine sample of knowledge sharing processes in interdisciplinary collaborations. In total, 32.5 hours of observations were gathered for analysis. All team meetings were videotaped for later analysis.

Data Preparation and Analysis

Prior to analysis, we orthographically transcribed the videotapes of all team meetings marking speakers, addressees, and accompanying behaviors. To familiarize us with the content and the dynamics of the meetings, we repeatedly read the transcripts until we felt we had a good understanding of how the discussions developed. We also repeatedly viewed the videotapes to

get a feeling for the atmosphere of the team meetings. Being familiar with the content of the transcripts, we started to analyze the transcripts with respect to problem occurrence. First, we identified problematic interactions within the meetings. Interactions were rated as problematic if either team members themselves identified a problem or if later interactions showed that a specific incident had impaired the further work in the team. The subsequent categorization into problem causes followed a scheme of originally eight categories based on a study by Steinheider and Burger (2000), which used retrospective reports of members of interdisciplinary research teams to identify main causes of knowledge integration problems. During the analysis of the observations, one further category was added to the scheme (see Table 2 for an overview of the categories). Two raters achieved an agreement of $\kappa = .92$ in their classification of problems. Disagreements were solved by discussion.

RESULTS

Over the fourteen observed meetings, we identified a total of 321 problematic interactions, the large majority of which took place between members of different disciplines: 305 (95.0%) compared to just 16 (5.0%) between members of the same academic discipline. More than 2/3 of the problems were found in only two teams (Team 5: 153 problems and Team 3: 88 problems), while in the remaining teams problem frequency ranged from five to 34 over both meetings (see Table 1).

-- insert Table 1 about here --

In total, we identified nine separate causes for problematic interactions in our sample: discipline-specific technical language, use of unfamiliar or different methods, use of unfamiliar or different theories, choice of different approaches, incompatible objectives, avoidance behaviors, work in subgroups, lack of acceptance, and unclear argumentation (see Table 2 for

descriptions of the individual categories). The first five of these categories seem directly related to the disparate sets of expertise and discipline-specific approaches of team members and indicate content areas that seem to be problematic in reaching a common understanding between team members. The last four, in contrast, rather indicate problematic behaviors and processes that hindered knowledge integration in the teams. We therefore grouped these nine categories into two higher-order categories to indicate two primary problem domains for grounding in interdisciplinary teams: structure-based and procedural problems. *Structure-based problems* in this context refer to challenges due to the structural characteristics, i.e., interdisciplinary composition of teams primarily in terms of deep-level diversity attributes like diverse knowledge bases, terminologies, experiences, etc. *Procedural problems*, in contrast, point to dysfunctional processes or problematic team behaviors that hinder the development of common ground (cf. Table 2).

-- insert Table 2 about here --

Over all teams, structure-based problems accounted for 76.95% of all problems, compared to only 23.05% of procedural problems. For better comparability and to eliminate possible effects due to the different length of observations, we divided the number of problems by the total length of observations. As Figure 1 (top) shows, highly heterogeneous teams tend to have generally more structure-based as well as procedural problems. Interestingly, older teams in both groups – moderate as well as highly heterogeneous teams – experienced more problems than the newly founded teams. Team 5 was particularly interesting in this respect. The team had been working together for about five years, but exchanged one member at the first observed session. This change in membership seemed to result in a considerably higher number of problematic interactions compared to similarly heterogeneous teams. Comparing the relative

percentages of structure-based versus procedural problems, new teams experienced prevalently structure-based problems, whereas procedural problems were found to a higher degree in longer-standing teams (Figure 1, bottom).

-- insert Figure 1 about here --

To get a better impression of the differences in problem causes in newly formed and longer-standing teams, we compared relative frequency of individual categories (cf. Figure 2). Technical language, particularly unfamiliar terminology, as well as different or unfamiliar methodologies accounted for about 2/3 of the problems in new teams. This result is in line with observations by Younglove-Webb, Gray, Abdalla, and Thurow (1999) on one interdisciplinary research team whose problems were associated predominantly with differences in disciplinary knowledge and methodological preferences. The proportion of such problems is considerably smaller in longer-standing teams, however. Longer-standing teams also experienced a wider spectrum of problem types than newly founded teams.

-- insert Figure 2 about here --

DISCUSSION

The aim of this exploratory study was to examine the occurrence of knowledge integration problems and their causes during normal work processes in existing interdisciplinary research teams. Based on the qualitative analysis of work interactions in teams with different degrees of heterogeneity (moderate vs. high) and at different stages of their life cycle (newly formed vs. longstanding) we identified two different problem types underlying difficulties in the knowledge integration process: structure-based and procedural problems.

The prevalence of structure-based problems in our sample points to the difficulty of individuals to tailor their communication to the requirements and previous knowledge of other

team members, suggesting a lack of *audience design* (Clark & Murphy, 1983). While in teams just starting their cooperation the degree of structure-based problems cannot surprise, in longer-standing teams this deficiency in audience design seems to indicate that team members were not able to develop a clear appreciation of the degree and type of common ground established so far. In new teams, assumptions about others are usually based on stereotypes or default models which are frequently imprecise. In the duration of the team cooperation individuals should test these assumptions and thus develop a more precise knowledge by including information based on shared context, common work history, observations, and disclosures (Nickerson, 1999). It seems, however, that members of highly interdisciplinary teams have difficulties to establish a solid common ground even over the long term.

A possible explanation may be found in the tendencies of speakers to use only minimal efforts when communicating with others (*principle of least collaborative effort*, Clark, 1997). As Horton and Keysar (1996) confirmed, individuals usually do not proactively design their utterances towards a listener's assumed common ground, but rather tend to monitor for mishaps and misunderstandings. If knowledge areas are too far apart, however, the realization of misunderstandings might not be easily possible, which could then lead to the long-term lag of grounding observed in our teams.

The procedural problems identified in our sample could provide a further possible explanation for the seeming lack of grounding in the teams. Avoidance behaviors or lack of acceptance, for instance, are strategies that prevent conflict between or within team members but also knowledge integration in the long term. Due to the cross-sectional design of the study it remains unclear, however, how exactly these two problem types are related as procedural problems could be the cause as well as an effect of structure-based problems.

As our observations in Team 5 indicate, instability of team composition in highly heterogeneous teams seems to be particularly problematic. Integrating a new member into an existing team challenges the existing common ground and mutual assumptions of ‘who knows what’. Team 5 chose to largely ignore the issue with the consequence of highly problematic interactions and considerable levels of frustration.

Implications, Limitations, and Further Research

So far investigations into team learning and task related problems in cross-functional teams have concentrated on the relationship between amount of problems and indicators like performance, stress, or turnover (e.g., Jackson, Sessa, Copper, Julin, & Peyronnin, 1991; Jehn, Northcraft, & Neale, 1999; Keller, 2001). This study adds to the literature on team learning by providing qualitative insights into the type of problems interdisciplinary teams face during ‘real-life’ work processes. Being aware of the type of problems teams face over the duration of their life can help prepare and support team members and team leaders, especially with respect to the management of specific events like turnover in long-standing teams. Team trainings to improve team processes and knowledge integration (e.g., Kremer & Bienzeisler, 2004) can also profit from a more precise understanding of challenges specific to interdisciplinary teams.

A major limitation of this study is the small sample size of only seven teams, which was motivated by the considerably work related to the in-depth analysis of work processes and interactions. The study further considered a very specific domain, namely academic research teams. While we believe that the differentiation of structure-based versus procedural problems is applicable to a wide range of domains of knowledge work, it remains unclear how representative the individual problem causes identified in our study are for other domains. Due to the cross-sectional design, no information could be obtained on the relationship between structure-based

and procedural problems. The same reason also precludes more definite statements on the impact of stage of a team's life-cycle on problem occurrence that has been suggested in our study.

Longitudinal studies are needed to clarify both points. The limitations in the length of this paper did not allow us to discuss differences of strategies or approaches in dealing with disciplinary diversity in the individual teams. A more detailed analysis and presentation especially for teams with similar degrees of heterogeneity but different degree of problems is in preparation.

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Figure Captions

Figure 1. Structure-based and procedural problems in the sample (top: total frequency; bottom: relative percentages of 100%).

Figure 2. Problem types in newly founded and long-standing teams.

Table 1. Team characteristics and problem occurrence.

	Team 1	Team 7	Team 2	Team 4	Team 6	Team 3	Team 5
Heterogeneity [Teachman index]	low [0.56]	low [0.68]	low [0.67]	high [1.32]	high [1.30]	high [1.01]	high [1.25]
Tenure	new	new	old	new	new	old	old (1 new Member)
Structure-based problems	5 [100%]	5 [100%]	31 [91.2%]	9 [100%]	25 [92.6%]	71 [80.7%]	127 [83.0%]
Procedural problems	0	0	3 [8.8%]	0	2 [7.4%]	17 [19.3%]	26 [17.0%]
<i>Total [weighted by length of sessions]</i>	<i>5 [1.38]</i>	<i>5 [1.71]</i>	<i>34 [6.09]</i>	<i>9 [1.66]</i>	<i>27 [7.11]</i>	<i>88 [16.99]</i>	<i>153 [26.29]</i>

Table 2. Knowledge integration problems found during observations.

A. STRUCTURE-BASED PROBLEMS	
A1. Technical language	
<i>Unfamiliar technical terms</i>	technical terms used are unfamiliar to team members
<i>Different technical terms</i>	technical terms carry different meanings for different team members
A2. Methods	methodological approaches are unfamiliar or differ
A3. Approaches	team members have a different view on how to approach the task or where the focus should be
A4. Objectives	team members differ in what they want to achieve short-and/or long-term
A5. Theories	theoretical assumptions are unfamiliar or differ

B. PROCEDURAL PROBLEMS	
B1. Ineffective grounding	
<i>Avoidance behavior</i>	decisions and clarifications are postponed or purposely held vague to maintain a positive atmosphere
<i>Work in sub-teams</i>	part of the team works apart from the whole team; only end results are presented
B2. Lack of acceptance	content presented by a team member is seen as invalid or incorrect by other team members
B3. Unclear Argumentation	team members' argumentations are contradictory and/or confusing so that others experience problems understanding the argument