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ABSTRACT

The paper presents literature related to the problems and promises of interdisciplinary work. Important characteristics of effective work groups are described, and origins of difficulty in groups are discussed. Most work on groups has been based on research on groups that come together only in the laboratory. These groups are different from natural groups in many ways. Interdisciplinary groups are usually natural groups and may experience some special difficulties because of the combinations of disciplines represented and the implications of disciplinary allegiance to problem representations and solution strategies. Examples of interdisciplinary teams are examined. To understand and influence group processes in interdisciplinary groups, we need a broader model of cognition within which we can interpret the individual-level and system- level variables and the interactions among these variables. Methodologies for studying interdisciplinary interaction are suggested. (Contains 103 references.) (Author)

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Angela M. O'Donnell, Lori Adams DuRussel, and Sharon J. Derry

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Cognitive Processes in Interdisciplinary Groups: Problems and Possibilities

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Contents

Abstract

The paper presents literature related to the problems and promises of interdisciplinary work. Important characteristics of effective work groups are described, and origins of difficulty in groups are discussed. Most work on groups has been based on research on groups that come together only in the laboratory. These groups are different from natural groups in many ways. Interdisciplinary groups are usually natural groups and may experience some special difficulties because of the combinations of disciplines represented and the implications of disciplinary allegiance to problem representations and solution strategies. Examples of interdisciplinary teams are examined. To understand and influence group processes in interdisciplinary groups, we need a broader model of cognition within which we can interpret the individual-level and system-level variables and the interactions among these variables. Methodologies for studying interdisciplinary interaction are suggested.

Introduction

The primary purpose of this paper is to provide the necessary background for framing a research agenda related to the study of cognitive processes in interdisciplinary teams. The National Institute for Science Education (NISE) comprises a number of interdisciplinary teams working on a variety of issues related to science, mathematics, engineering, and technology (SMET) education. Although interdisciplinary groups such as the NISE teams are common in government agencies and policymaking groups, we know very little about how such groups function and whether or not they are effective in capitalizing on the expertise available to them. Some groups in the workplace are dysfunctional and fail to take advantage of the resources available in the group, whereas other groups are very effective. How do effective and ineffective interdisciplinary teams differ in terms of the interactions of group members? This review of research on cognitive processes that may occur in interdisciplinary teams contributes to development of a related research agenda.

First, we outline the importance of groups and the nature of interdisciplinarity. Then we provide a brief review and synthesis of the research literature on factors that influence group effectiveness. The purpose of this review is to highlight the main categories of variables thought to be important to the analysis of groups and their outcomes. We then distinguish between laboratory-based groups and natural groups that occur in the world (e.g., management teams or surgical teams) and examine influences on the operation and effectiveness of natural groups, including interdisciplinary groups, by examining a number of examples of natural groups. Finally, we review a model of distributed cognition that may provide the basis for understanding the complexity of interaction in interdisciplinary teams. From this analysis, we hope to develop methods for analyzing the performance of interdisciplinary teams and provide the basis for improving the efficacy of such teams.

Background

Relevance of Group Work

Groups are ubiquitous phenomena in our lives and have been studied in a variety of disciplines—social psychology, sociology, cognitive psychology, educational psychology, communication, organizational psychology, business, industrial psychology, medicine, computer science, decision making, and education. In this paper we draw on research in peer reviewed journals in the various disciplines and in scholarly syntheses of such work in books in these disciplines.

Research in all of these areas has explored many facets of groups, including the nature of group interaction, discourse among group members, leadership style, and group effectiveness. In this paper, we are particularly concerned with interdisciplinary task-oriented groups. Many work teams, policymaking groups, and research teams are made up of individuals who represent a variety of disciplines. These teams are usually constituted for the purposes of framing problems or policies and for solving problems that transcend disciplinary boundaries. These types of problems are common not only in nonacademic fields, but also in educational areas such as science, math, and technology education (e.g., see Committee on Research in Mathematics, Science, and Technology Education [Committee], 1987). As a consequence of the different skills

and perspectives represented among group members, interdisciplinary groups have the potential to tackle broad issues, select problems that go beyond the confines of any one discipline, answer complex questions, frame problems with greater accuracy and breadth of understanding, combine resources and capitalize on differing skills in pursuing solutions to problems, and develop innovative solutions to problems.

With the increased specialization of knowledge and increased complexity of tasks in the workplace and other arenas, it is likely that the use of interdisciplinary teams will become more common (Schrage, 1990). Thus, it is important to describe, understand, and ultimately impact the communicative processes that influence productivity and the quality of outcomes from interdisciplinary collaboration. Although the focus of this paper is on the cognitive processes involved in interdisciplinary groups, cognitive processes (e.g., problem representation) are deeply wedded to the social structures in which they occur. As a result, we will inevitably discuss the social context within which groups operate.

Interdisciplinarity

The relationships between members of different disciplines working together on joint projects have been identified under a variety of terms, including *interdisciplinary*, *multidisciplinary*, *transdisciplinary*, and *polydisciplinary*. The term *interdisciplinary* is defined most broadly by the Office of Economic Cooperation and Development (a subdivision of the United Nations Educational, Social, and Cultural Organization, UNESCO) as ranging from "the simple communication of ideas to the mutual integration of organizing concepts, methodology, procedures, epistemology, terminology, data, and the organization of research and education in a fairly large field" (cited by Thompson-Klein, 1990, p. 63). According to Thompson-Klein, a noted expert on interdisciplinarity, the most important difference in terminology is between *multidisciplinary* and *interdisciplinary*. The term *multidisciplinary* often refers to teams or activities in which people in a group act from the perspective of their own discipline. *Interdisciplinary* groups are ones that consciously try to integrate knowledge from the different disciplines included; however, because of time demands and other variables, few groups in the real world achieve this integration. In this paper, we use the term *interdisciplinary* to refer to groups that begin as multidisciplinary groups as defined by Thompson-Klein, but that may develop more integrative views in the process of interaction and begin to approximate interdisciplinary groups.

Cognitive processing by members of an interdisciplinary group is very important, since group members must come to understand the goals of the group, represent the problem under discussion by group members, identify strategies for achieving goals, and decide on strategies for achieving goals. The group's ability to do these activities effectively depends on all members having the necessary information.

The importance of identifying the range of abilities and information needed in a group was emphasized in the STRAP model of interdisciplinarity, named for its dimensions, presented by Chubin, Porter, and Rossini (1986). The STRAP framework analyzes an issue according to five dimensions: Substantive knowledge (the subject area knowledge pertaining to the problem); Technique (methods of approach in analyzing the problem); Range of skills required for the

problem (intellectual or research area containing the necessary substantive knowledge and techniques); Administrative unit (complexity of the administration); and Personnel (the staffing requirements for the team). Instead of viewing a problem as belonging to a particular discipline or disciplines, the STRAP model describes the issue based on the types of knowledge (which might be common to several disciplines) and techniques of study required to solve it. It would be possible to define a problem by creating a STRAP profile and then to assemble a team of people with backgrounds in the required skills and techniques to solve the problem. Team members need not necessarily be from different disciplines, since a single individual with a broad background might meet all the requirements for the problem.

Although the STRAP framework provides a way of viewing the range of knowledge appropriate for interdisciplinary work, it does not shed light on how cognitive and social processes affect interdisciplinary collaboration and does not consider the constructive nature of knowledge or the indeterminacy of cognitive perspective in real-world problem solving—the idea that complex problems can legitimately be conceptualized and solved from numerous disciplinary perspectives. Thus, a more complex model is needed that considers social issues as well as cognitive or information processing ones. The analysis of cognitive and social processes in interdisciplinary groups then could identify mechanisms and strategies for facilitating the effective use of interdisciplinary teams.

Influences on Group Effectiveness

Although people often are expected to work successfully in a group to solve difficult problems, groups do not necessarily operate in productive ways. When a group is working on complex problems, conflict between group members inevitably arises and can take a variety of forms. For example, there may be differences in opinions about strategies for achieving group goals (Thomas, 1992) or difficulty in developing a shared understanding of the problem at hand (Journet, 1993). Conflicts might also arise as a result of assumed or actual status differences among participants (Meeker, 1981). These types of conflict can have a negative impact on a group: unresolved conflict between group members can erode effectiveness, and the time taken to negotiate solutions can be deleterious to group functioning (Thomas, 1992). In addition, it can be problematic for interdisciplinary groups both to identify appropriate courses of action and to agree on methodologies for implementing such plans. Studies of the interaction of groups provide keys to the cognitive and social processes that represent effective group functioning or are predictive of effective group outcomes.

Areas of Research on Small-Group Interaction

There is an extensive research base on small-group problem solving (e.g., Paulus, 1989) that is derived largely from the experimental analysis of small-group functioning in tightly controlled experiments. In much of this work, task-oriented groups are brought together to solve specific tasks in a laboratory context. Variables of interest in this literature include leadership style, communicative processes, conformity, group composition, and group effectiveness.

Sociologists have examined the influence of power, status, and ability on the interactions among members of small groups (Berger, Conner, & Fisek, 1974; Robinson & Balkwell, 1995). Power,

prestige, and status affect who talks in small groups and who influences final decisions or conclusions. Sociologists have also studied the effects of expectations in small-group functioning (Berger et al., 1974). A major thrust of the work on small groups has been in the analysis of expectation states (Meeker, 1981), expectancies about other members' competencies to contribute to successful task completion and their influence on interaction (number and frequency of engagements, predictions about influence, etc.). For instance, if a group of high school biology teachers and college faculty in biology discuss what kind of preparation in biology might be expected of entering freshman, the college faculty and the high school teachers may differ in their expectations of who can contribute effectively to such a discussion. These expectations will influence the direction and flow of discourse in the group.

Sociologists also have analyzed the interactions in groups as reflective of efforts to maintain or develop identity (Robinson & Balkwell, 1995; Robinson & Smith-Lovin, 1992). A person in a group who believes him or herself to have low status in the group and be lacking in the skills to contribute effectively to the group may interpret his or her own nonparticipation in the interaction as confirming this identity. In a sense, that person engages in a sustaining expectation (Cooper & Good, 1983), interpreting the situation according to an existing identity. Alternatively, individuals in a group can use the group context to develop new identities (e.g., leader).

The basic research on group interaction can contribute to an understanding of the functioning of interdisciplinary groups. It speaks to the broader question of how people from different backgrounds and experience can effectively interact with one another. The implication of this research literature is that the interactions of interdisciplinary groups might be examined for the influences of power, influence, and leadership in groups and to identify the purposes served by such interaction (e.g., maintaining existing identities). This literature has been applied to group functioning in airline crews, surgical teams, health care teams, business, and education. Among the key concerns related to group functioning in these applied settings are (a) identification of the components of effective teams, (b) analysis of key personality and cognitive variables important to group functioning, (c) identification of key variables in forming groups or maintaining groups, and (d) reward structures that influence group functioning. These concerns affecting the functioning of generic groups are also important to the understanding of interdisciplinary groups.

Characteristics of Effective Groups

Effective groups share many characteristics (Hackman, 1990, 1995; Johnson & Johnson, 1991). Group members must constitute a "real team" (Hackman, 1995), working on a challenging task that requires all members to contribute skill. A curriculum development team, for example, might be faced with the task of reducing the number of topics covered in the ninth-grade physics curriculum while amplifying the depth of coverage allocated to the topics retained. This type of task can be quite daunting as people struggle to select necessary knowledge and ensure that this material is taught in a way that emphasizes critical skills. This kind of task will be much more readily accomplished if all team members believe they have something to contribute to the final product.

Effective teams are also characterized by the interdependence of team members (Hackman, 1995), such as a surgical team in which all members (doctors and nurses) must support one another's activities in the interest of the patient's welfare. Having teams whose members all believe they have something to contribute and whose outcomes are interdependent implies that effective groups must be genuinely collaborative. In describing distinctions that exist among various forms of peer interaction, Damon and Phelps (1989) noted that genuine collaboration occurs when participants are equal in power and when interchange among group members is characterized by mutuality. In other words, all participants can be expected to contribute to the task and each one's opinion is as valuable as any other's. In such collaboration, there is an opportunity for introduction of dissonant information, the creation of disequilibrium or discomfort, and re-equilibration. Cognitive scientists believe that these processes are central to the intellectual growth of individuals and that they may be predictive of group growth as well.

However, groups in the real world often do not experience such mutuality and equality in interaction. In the surgical team there is little equality among participants. Status on a surgical team matters a great deal, and power is not shared. Although mutuality of influence and power might seem desirable, groups can nevertheless be effective even if they do not experience the types of collaboration delineated by Damon and Phelps (1989). Gray (1985) suggested that interorganizational collaboration can be inhibited if power is equally distributed among members of the collaborating group, since such a configuration can result in a stalemate. She posited that collaboration may be most effective in a situation in which power is distributed among some participants, but not necessarily equally among all. For most natural groups (i.e., groups outside the laboratory), there is invariably a power/authority structure in place and differential accountability for outcomes, making them not genuinely collaborative based on Damon and Phelps' model.

In their 1991 book on group theory and performance, Johnson and Johnson characterize an effective group as having three core activities: (a) accomplishing its goals, (b) maintaining good relations among its members, and (c) developing and adapting to changing conditions in ways that improve its effectiveness. Inherent in this characterization of effective groups is the notion that groups have multiple functions (McGrath, 1991). According to McGrath, groups function to produce something of worth, support group members, and promote members well-being. The Johnsons' activities of accomplishing goals and adapting to changing conditions map directly onto McGrath's function of producing something of worth. The activity of maintaining good relations, which most likely involves adapting to changing conditions, serves the function of supporting group members. When group members feel unsupported, a team or group may disintegrate into a cycle of frustration and avoidance (Eisenstat & Cohen, 1990). On occasion, the fulfillment of one function compromises the group's ability to serve another function; for example, if energy is spent on production activities to the neglect of social support, the group may fall apart as a team.

Influences of Group Task

The key variable in effective task-oriented group action is the task with which group members are engaged. The nature of the task makes particular cognitive and/or social processes salient, and these, in turn, can influence the functioning of the group; that is, the relationship between task type and group functioning is not always predictable. For instance, a group that is intended to be product-oriented may concern itself with member support as a direct consequence of group members' cognitive and affective responses to the task. For example, a management team charged with creating a plan for down-sizing may be redirected from the task by the need to provide reassurance to various members of the team about their prospects for continued employment.

Routine versus nonroutine tasks. The nature of the task also may influence team members' motivation levels. Tasks that are ambiguous can promote feelings of challenge and intrinsic motivation (Reeve, 1996). Also, nonroutine tasks are more interesting than routine tasks (Deci & Ryan, 1985), which may improve performance, since individuals are more likely to persist with an interesting task, even in the face of apparent failure or frustration. Individual performance is best under conditions of optimal challenge (Deci & Ryan, 1985), but finding the group equivalent of optimal challenge is difficult. When the challenge is too great, perhaps because of the importance of task completion or because of significant time pressure, group members can show significantly impaired information processing capabilities and an increase in selective attention to information (Frey, 1986). Task ambiguity will significantly add to the stress level, resulting in affective and cognitive conditions in the group that do not promote effective interaction (Doyle, 1983). The complexity of the task also influences the salience of specific cognitive, affective, or social processes. For example, if the task is complex, some members of a group may feel inhibited from participating effectively because of concerns about social comparison and maintaining status in the group.

Alternatively, group members may fail to engage in appropriate levels of self-monitoring, or metacognitive, activity in a routine task. Hackman (1995) explained a major accident with one airline on this basis. A normal part of a crew's routine is to go through a series of checks prior to take-off, including checking to see whether the plane needs to be de-iced. Although the crew members had a lot of flying experience, they were inexperienced in flying in icy conditions. Their routine response to the de-icing check had been negative, and the crew neglected to note that the plane needed to be de-iced. The failure of the group to sufficiently monitor and question their usual routine resulted in a major accident.

Task categorizations. One of the clearest frameworks for characterizing tasks was produced by Steiner (1972, 1976). According to Steiner, most tasks fall into one of four different categories: additive, compensatory, disjunctive, and conjunctive. In *additive* tasks, the contributions of each member of a group are combined to form a single group product. An example of an additive task is the preparation of a group report that can be divided among group members. The various parts of the report are added together to form the group's final report. For *compensatory* tasks, the efforts of group members are averaged to produce a single group outcome. For example, a group of students may combine their efforts to produce a single videotape for a class. The lack of technical knowledge of members may be offset by others who do have technical expertise. In

disjunctive tasks, the group's product is determined by the performance of its best or most competent member. Team quiz shows often use this format, requiring that any member of the team can have the right answer, but only one person need have it. When the task is disjunctive, larger groups increase the probability that one member will be competent to do the task. Finally, in *conjunctive* tasks the group's final product is determined by the its weakest link; a tug-of-war is a conjunctive task. Cooperative learning tasks in which all group members are expected to become accomplished at the target task and for which any student's paper can be selected as representative of the group's accomplishments can be considered conjunctive.

Some tasks, particularly more open-ended tasks such as those provided to policymaking groups, may be framed according to one of the four categories described above. The way in which the problem is framed may depend in part on the interaction patterns of the group. The nature of the task is important because it creates an arena for the social and cognitive processes brought to bear on the task by the members of the group. The pressures experienced by a group whose outcomes are determined by the weakest member of the group are markedly different from pressures in tasks in which only one person need be competent. It is against this backdrop of task type that variables such as the entering characteristics of the group members (e.g., ability, personality) and the conditions under which the task is performed (highly contingent or not) must be understood.

Social processes and task performance. Social and cognitive processes in group interaction are very tightly interwoven. Research on group interaction has often focused on either individual-level properties (e.g., leadership) or on system-level properties (e.g., norms of the group) but rarely on both (Hirokawa & Johnston, 1989; Poole, Seibold, & McPhee, 1985). Individual-level and system-level properties intersect at the task and the interpretation of the task. Effective task performance requires that the optimal cognitive, affective, metacognitive, and social skills be available in the group (O'Donnell & Dansereau, 1992). The group interaction may react and adapt to the need to create a balance of skills and activities in order to complete the task. For example, if one participant engages excessively in metacognitive activity such as overediting the production of intermediate products (Flower & Hayes, 1981), other participants must place greater emphasis on social and affective processes to maintain balance in the group.

The nature of the task (additive, conjunctive, disjunctive, compensatory) will contribute a great deal to the nature of the discourse among group members as they discover whose skills are needed for the satisfactory completion of the task. Morris (1966) and Sorenson (1971) demonstrated that interaction patterns in groups differed as a function of the type of task in which participants were engaged. Depending on the nature of the task, the relationships among group members, and the degree to which they experience interdependence (Deutsch, 1949; Johnson & Johnson, 1992), the group may suffer process losses (e.g., losses in attention, concentration, and "thought power") in which group members are diverted from their purposes (Steiner, 1972), or it may suffer reductions in productivity as a consequence of a lack of coordination.

Process losses also may occur as a consequence of social phenomena such as social loafing, free rider, or sucker effects. *Social loafing* occurs when one member allows other people to do the work (Karau & Williams, 1995; Latane, Williams, & Harkins, 1979). These effects are often

observed on additive tasks. When free riders or social loafers are detected in a group, individuals in the group may compensate for the lack of contribution by some members. In other cases, individuals in a group may react to the detection of free riders by actually reducing their own level of effort, a consequence known as the *sucker effect*. In circumstances in which some members of a group do not contribute, there are significant affective consequences to the group's functioning. The nature of the task can contribute a great deal to the possibility that social and affective processes will dominate group interaction, rather than cognitive and metacognitive interchange. One important consequence of task structure for group tasks is that it can signal to participants which members have status in the group and which members do not. The presence of such status differences (addressed in more detail below) can have important influences on the nature of the discourse among group members.

Social Influences on Group Effectiveness

Although groups have the potential to be more productive than individual's for many tasks, the vulnerability of effective group processing to cognitive and social influences must be recognized. Much of the previous discussion of the effects of the task on group functioning also is pertinent to a discussion of the social influences on group performance. Reactions to the nature of the task can provoke affective or cognitive responses that may take center stage in the group interaction. These responses can strongly impact the functioning of a group. For example, in a scathing critique of the emphasis on the use of teams in the workplace, Sinclair (1992) railed against "the tyranny of a team ideology" (p. 611) and argued that the emphasis on teams masked coercion and conflict in the workplace. If even some group members share such feelings, the possibility of productive interaction is in jeopardy.

Leadership. Leadership in a group has a significant influence on group productivity. Effective leadership in a group can maintain the productive direction of a group, whereas poor leadership can amplify the effects of cognitive and social limitations. Leaders are often classified as people- or task-oriented (Fiedler, 1978; Fielder & Garcia, 1987), although more recent studies of leadership behavior (e.g., Zaccoro, Foti, & Kenny, 1991) suggest that effective leadership requires more adaptability on the part of the leader than is involved in trying to fit a person-oriented or task-oriented style to the problem at hand.

Leadership skills are important to the coordination of cognitive and social processing of the group members. The task for a leader in a group is to provide the necessary amount of structure and direction to the group discussion or performance without limiting others' creativity and productivity. In analyzing differences between effective and ineffective teams in the real world, Hackman (1990) concluded that effective teams were generally characterized by effective leadership that set goals for the team, but that also allowed team members autonomy in determining the means by which such goals might be accomplished. Leaders also will play different roles in the group. McGrath (1991) noted that group interaction can be dedicated to a variety of goals, including production or maintenance of good relationships. Successful leaders seem to fit their style to the necessary function.

Status. Status differences are often very salient in groups. Status, as used here, denotes expected competency for the performance of the task at hand. For example, on a team designed to evaluate

college-level science curricula, a tenured professor with a degree in curriculum and instruction has a high status associated with his or her experience and previously demonstrated competence in designing or evaluating science curriculum. This high status is relatively clear when the professor is compared to a junior faculty member on the team. However, the professor's status in relation to that of a high-ranking engineer on the team is less clear. Different types of teams may have differing levels of clarity of status. For example, many health care teams have clear hierarchies of skill and influence, with status differentiating between nurses, attending physicians, and surgeons. Other teams, such as the curriculum team described above, initially may not have clearly defined status hierarchies. In groups in which such status differences are not immediately salient, status differentiation frequently emerges over time. In this process, some members become identified as having competencies necessary to the task, and other members are identified as having less competency for the task (Berger, Rosenholtz, & Zelditch, 1980; Cohen, Lotan, & Catanzarite, 1990).

High status individuals take and receive more opportunities to influence the group process, talk more, answer questions, are accorded power in the group, and can ignore others in the group (Meeker, 1981). Low status individuals in a group, in contrast, are often help seekers, are frequently ignored, say little, and, when they speak, their input is often ignored or devalued (Cohen, 1994; Cohen et al., 1990). Cicourel's (1990) analysis of the interaction during the process of medical diagnosis demonstrates that status differences strongly influence the nature of the discourse. When attending physicians interact with medical residents, they are evaluating the resident's knowledge and making judgments of competence. The clear status difference inexpertise and authority are manifest in the type of discourse in which the residents and attending physicians engage.

Groups with clear status boundaries often limit the exchange of information. In airline crews, for example, pilots have high status in comparison to the first officer or other crew members. Subordinates in such crews often agree with the interpretation of events provided by the leader (in this case, the pilot) even when they experience doubt about the decision being made (Foushee, 1984; Foushee & Helmreich, 1988). When a subordinate does provide information that is contrary to the high status individual's interpretation of events, the subordinate is often ignored. An airline accident in recent years illustrates this problem. The pilot of an aircraft was approaching the Dallas airport but was warned by his first officer that he might need to circle the airport one more time in order to improve the angle of descent. The first officer's warning was ignored by the pilot who attempted to land the plane and ran the plane off the runway. When status characteristics of group participants serve to limit disagreement and operate to increase the selectivity of information available to group members, the likelihood that the group will be ineffective is increased.

Status in a group serves both cognitive and social functions. It signals a stratification of worth, but it also influences the cognitive processing of the group in which only some people are regarded as reliable sources of information (McClane, 1991). Ability is the primary status characteristic (O'Donnell & O'Kelly, 1994). However, other characteristics of individuals are often assumed to be indicative of ability, although there is no necessary relationship between such characteristics and performance. Salient characteristics of individuals that are used to infer the presence or absence of ability are called diffuse status characteristics (Meeker, 1981). Gender

is an example of a diffuse status characteristic. Common stereotypes of women and men suggest that women will be less skilled than men at mathematics, whereas men will be less skilled than women at writing. When people enter into group interaction with expectancies that group members will have greater or less competence based on diffuse status characteristics such as race, ethnicity, or gender, group interaction will be influenced by those expectancies. Also, people with low status in a group often disengage from the group process. Their withdrawal of effort can be subsequently treated as social loafing, and a vicious cycle of low effort and recrimination can result.

Additional social influences on group productivity. Other limits on effective group processing include the propensity for individuals to move too quickly toward consensus (Foushee, 1984; Janis, 1982; Nemeth & Staw, 1989). "Groupthink" (Janis, 1982) is characterized by a decrease in the exchange of discrepant or unsettling information. Generally, arguments against ideas are less commonly shared (Stasser, 1992). The joint influence of a press toward conformity and an unwillingness to share information is likely to lead to process losses.

There are also certain social influences particular to interdisciplinary groups. Journet (1993) observed that belonging to a specific discipline brings with it valuing of specific types of events or data, concepts, problems, methodologies, and methods of argumentation and explanation. Such allegiances can obstruct effective discourse and team performance. If interdisciplinary teams are not to become exercises in futility or exasperation, groups must understand how people from different disciplines negotiate some shared understanding and common frame of reference.

Limits on Cognitive Processing

Even without status differences that limit exchange of and receptivity to information, effective processing of information available in groups is difficult. For example, there is extensive documentation of the selective nature of information intake and retrieval (e.g., Anderson & Pichert, 1978; Donald, 1987; Frey, 1986; Schwartz & Reisberg, 1991). People often pay attention to only that information that is aligned with or pertinent to their personal goals and perspectives. This type of information is identified as "schema-relevant" in that the information fits with the expectations, or schema, that the person applies in a given situation. As people do not necessarily always activate the same schemata (Anderson & Pichert, 1978), the information received by various members in a group can differ greatly. Information often is processed inaccurately as a consequence of phenomena such as the confirmation bias (Crocker, 1981), which is the universal human tendency to seek for and attend to bias-confirming data. Limitations on individual cognitive systems also constrain the efficacy of group processing. Leaders in groups are often cognitively overloaded (Ben-Bassat & Taylor, 1982), resulting in judgment errors.

To be productive, groups must have all the information necessary to solve problems and make good choices (Chubin et al., 1986). Influences such as a press for conformity or status differences may limit an individual's willingness to contradict other group members or may result in an individual devaluing the knowledge he or she has. Deficiencies in the information available to decision-making groups often result in poor decisions. Ball (1994) shows how such informational deficiencies permeated the decision making of President Kennedy and his advisors

in considering their policies on the conduct of the Vietnam War. Similarly, in an analysis of airline crew functioning, Foushee (1984) found that the unwillingness of subordinates to share information limited the effectiveness of teams.

Status is not the only reason why group members do not share information. A series of studies by Stasser and colleagues suggests that pooling information sources may be the exception rather than the rule (Stasser, 1992; Stasser, Taylor, & Hanna, 1989, Stasser & Titus, 1985, 1987). Stasser and Titus (1985) proposed the information sampling model of group discussion. This model suggests that information that is shared by members of a group is more likely to be mentioned in group discussion than information known only to a single individual. As a result, shared information is reiterated, and efforts to structure dialogue result in the known information being accurately retrieved. This reiteration of common information seems to be a natural consequence of attempting to make oneself understood. Under certain circumstances, individuals can be encouraged to discuss unshared information. In one experiment (Stasser & Stewart, 1992), half of the participants were informed that there was a correct solution to a problem and their task was to find it. The remaining half were informed that it might be possible to solve the problem but that this was uncertain. Beliefs about the whether the problem could be solved or not strongly influenced the degree to which participants shared information not known to the entire group. Participants who were informed that the solution could be found actually shared more information that was not jointly held at the beginning than did members in the uncertain solution group. Apparently, when participants were encouraged to think that the problem was insoluble, they reduced their efforts to solve the problem and were less likely to inspect the relevance of their privately held knowledge to the task at hand.

In sum, the literature available from basic research on group interaction indicates that effective group or team functioning is very complex and subject to influence by a wide variety of variables. However, answers to some key questions about natural groups cannot be answered in this literature. In the end, the groups we wish to understand are the groups that exist outside the laboratory. Laboratory-based research has, nevertheless, provided us with some basic frameworks for interpreting results and framing new questions and also with some insights into what might be important variables to consider when examining more natural groups.

Natural Groups

Despite the importance and prevalence of groups, the research on small group communications, interactions, and productivity suffers from a number of shortcomings (Frey, 1994). First, most of the research that documents the processes and products of small group interaction has been derived in laboratory-based research studies rather than natural groups (Scheerhorn, Geist, & Teboul, 1994). In a review of the literature published during the 1980s, Cragan and Wright (1990) observed that only 13% of the available studies in communication sampled groups in organizational or applied settings. There seems to be no reason to believe that the picture emerging from other disciplines would be radically different. Although much valuable information can be gleaned from work in laboratories, the conditions present in laboratory-based versus natural groups are sufficiently different that one might reasonably assume that the findings from the laboratory cannot always be imported directly into the analysis of the functioning of natural groups.

Tasks Faced by Natural Groups

Additional criticism of the type of research conducted on group processes relates to the fact that natural groups typically engage in a wider variety of tasks than the few tasks selected for study. McGrath (cited by Olson, Card, Landauer, Olson, Malone, & Leggett, 1993) categorized tasks into eight types: planning, creative, intellective, decision-making, cognitive conflict, mixed-motive, contests/battles, and performance. However, despite this wide variety of possible task types, one review (Frey, 1988) of group communication literature available from the 1980s found that less than 5% of studies were concerned with tasks unrelated to decision making. Scheerhorn et al. (1994) argue for the investigation of group tasks other than decision making to bring the research in closer agreement to the types of tasks in which natural groups are typically engaged.

Tasks used in laboratory groups and natural groups differ on a number of dimensions, including the complexity of the tasks involved, the commitment required of participants, the duration of the task involvement, task ambiguity and consequences, competing demands for time and commitment, and the necessity for groups to attend to multiple functions such as productivity, member well-being, and member support. As described earlier, these characteristics of the task in which people are engaged have implications for the kinds of social, affective, or cognitive processes brought to bear on the task. According to Hirokawa (1990), group performance will be largely dependent on input variables (e.g., personalities) when the task is simple. When tasks are complex or contingencies are high, process variables (such as resource allocation or coordinating activities) may become more important.

Many of the tasks in which people engage in the real world require extensive involvement over time. Participants may enter into the group without knowledge of one another, but they soon develop such knowledge, and the relationships that develop must be maintained over time. The duration of the members' involvement with one another requires more skill in coordinating activities, adjusting to changing environments, and coping with the dynamics of ongoing interaction. In addition to being affected by long-term relationships among members of the group, natural groups also typically are affected by a larger organizational context, and thus group development may also involve the relationships between specific groups and the larger organizations in which they are embedded (Olson, Card, et al., 1993; Wheelan, McKeage, Verdi, Abraham, Krasick, & Johnston, 1994). Natural groups may have members leave and new members enter, which disrupts established patterns of interaction (Schopler & Galinsky, 1990). In summary, natural groups differ from laboratory-based groups on a number of important variables that might be expected to influence the quality of interaction in groups and the products that emerge from them. They differ from laboratory-based groups in the types of tasks in which they engage, the duration of the group involvement, and the relationships among group members.

Natural Groups at Work

In studying natural groups in the real world, a variety of research methodologies are employed, such as case studies involving interviews and detailed observations, protocol analysis, surveys, and, on occasion, quantification and analysis of observed behavior.

In the pages that follow, we describe groups in a number of natural settings. Many of the problems that were seen in basic laboratory research can be identified in naturally occurring groups as well. Significant problems related to communication among group members, the operation of status in groups, and difficulties in coordinating group activities are common. If anything, these problems are exacerbated in the natural context. We present specific examples of natural groups in order to illustrate some of the general problems alluded to earlier.

Educational research organization. One example of a type of group common in educational research was described by Romberg (in press). Romberg discussed how the National Center for Research in Mathematical Sciences Education (NCRMSE) at the University of Wisconsin-Madison was designed around a model of group sociology that Crane (cited in Romberg, in press) called the "invisible college." The invisible college is a network of scholars in the same field of study, often centered around the one or two major academic leaders or theorists, who communicate with each other, define priorities for research, and monitor the development of knowledge in that field. The NCRMSE comprised seven separate teams, each focused on a different area of mathematics, that were intended to develop into invisible colleges for their respective branches of study. Members of some groups had pre-existing collaborative relationships with one another, while other teams were formed by people who had no history as a group. Each group was given the same set of tasks regarding their duties in investigating learning and knowledge of their mathematics domain.

The NCRMSE groups showed various levels of productivity, but there has not been an evaluation of the effectiveness of the invisible college strategy. However, institutions such as the NCRMSE could provide interesting insights into group interaction. Is there a correlation between the effectiveness of a group and the extent to which its members form an invisible college? How do groups with a history of collaboration differ from newly formed groups? Further study of these types of organizations could provide useful information regarding the sociocultural, organizational, and task-related factors influencing group effectiveness and productivity.

Educational advisory committee. A natural interdisciplinary group described by Dickinson (1987) was an advisory committee formed to evaluate an electronics vocational educational program. Business leaders, school officials, and teachers met over a period of three years to evaluate a local education program in electronics, determine the business need for employees in electronics, and modify the vocational program to improve employability for the graduates. As Dickinson indicated, "It took perseverance for the committee to coalesce into a workable group" (p. 31). There were some conflicts in expectations between the educators and the business people, with some business associates becoming frustrated with working in an educational environment. Teachers and administrators, on the other hand, needed to learn to be open to suggestions on changing practices that they may have used for years.

This group illustrates some of the conflicts facing interdisciplinary groups. Initially, the group members may have held differing expectations about what each person could contribute and how the group could work. Time was needed for the committee to work through the differences across disciplines and figure out not only how to work together, but also how to address the problem of improving the vocational educational program. However, the interdisciplinary committee eventually did succeed in designing and implementing a revised vocational program that better suited the needs of the community.

Business task force. Expectations also seemed to play a role in the productivity of a group studied by Davis-Sacks (1990). A federal agency had created a task force to analyze national credit programs. The team produced several reports, but by the end of the assignment, most group members—including the team leader—were dissatisfied with the team. In fact, the leader of the group tendered a letter of resignation after the project was completed, citing several reasons that were directly connected to the group work.

The group's problems seemed to stem in part from a mismatch between the expectations of the team leader and the team members. In most of the agency's teams, groups would evenly divide the work, make cooperative decisions about planning and completing tasks, and communicate with people in addition to the team leader. However, the team leader of this task force led the group using a "hub and spokes" design (Davis-Sacks, 1990, p. 135), in which the leader coordinated all of the group's efforts and dealt directly with each member of the team, project management, and the client. For the most part, the group did not operate as a real team. Team members were not given the chance to fully contribute, since they never had the opportunity to interact as a group and play off each others' strengths. The more limited interaction with the team leader restricted them to using only the skills the leader thought were appropriate. The result was that some team members felt underutilized, while the team leader felt overworked, since she was having to coordinate and create most of the work for the team. The misaligned expectations for the team also resulted in some interpersonal conflicts, as some team members, using their previous expectations of how a group should work, occasionally contacted the client or project manager directly. The team leader, who viewed the team as a hub-and-spokes organization, saw this as a challenge to her authority.

In this group, a misalignment of expectations between the team members and the team leader resulted in the eventual disintegration of the group. Although the group did complete its task, the group members as a whole were unsatisfied, and the project was behind schedule, so results were not as useful as they might have been.

Health care teams. One of the most researched type of interdisciplinary team is the health care team. Health care teams (HCTs) are made up of individuals from various occupations (e.g., nurse, pathologist) or disciplines (medicine, psychology, social work) to provide health care services. Because of the rise in the number of interdisciplinary teams in health care areas such as gerontology, there also has been emphasis on the need to educate students in how to work on such teams (Clark, 1994).

In discussing the importance of communication in the field of health care, Kreps (1988) noted that a central concern in HCTs is that "health professionals are often ethnocentric about the

legitimacy of their profession in comparison with other health care professional groups" (p. 253). Such beliefs can hamper communication and coordination of activities, especially when there are real status differences among participants. Effective delivery of services requires that members of interdisciplinary HCTs coordinate their activities in a manner that is logical, coherent, and efficient.

Many of the problems experienced in complex natural teams are illustrated by Berteotti and Seibold (1994) in their extensive case study of the operation of a hospice team consisting of volunteers and medical personnel. Two different strategies were used to coordinate team efforts: first, weekly team meetings were held to exchange information and plan the work; second, feedback was provided to team members through written and oral communication. Although over 100 volunteers worked at the hospice, they only had a single representative at the team meetings. This structural feature guaranteed the ineffectiveness of the feedback method of coordination. In addition, meetings invariably included hostility toward the director of the volunteers and the medical director, but the directors did not respond to complaints. Dissatisfaction with the two key administrators resulted in poor coordination of efforts. Finally, there was discontent among the general ranks of the hospice employees: medical personnel complained about the volunteers intruding upon their own roles, and volunteers, in turn, felt unappreciated and resentful of the inadequate communication.

The central problems in this particular health care team involved definition of roles and coordination of activities. Both issues required effective communication, which was apparently absent. The issue of role definition is an important one as it links to perceptions of status and legitimate authority. Medical personnel had expectations for the volunteers that excluded their adequate participation. Volunteers were viewed as transitory and not central to the mission of the team. Volunteers, however, wished to be involved and participate more, and they felt their roles were central to the delivery of services to patients and their families. This conflict in role definition among the two major sets of constituents hampered the effective functioning of the team. Communication among team members both in the group meetings and via other mechanisms was poor.

Operating room teams. Status is a particularly important variable in medical teams as there is such a clear hierarchy of skills, knowledge, and prestige. It is not comforting to realize that one arena in which status problems are played out is in the operating theater (Denison & Sutton, 1990; Helmreich & Schaefer, 1994). Denison and Sutton (1990) observed a team of operating room nurses for a week. The team structure had been implemented two years prior to the study, and it represented a huge improvement in the efficient use of the nursing staff, both in the scheduling of nurses for operations and in the continual learning and education of the nurses. Compared to the prior treatment of team members, nurses in this team had quite a degree of autonomy. However, despite the positive benefits of working in a team, nurses still felt very controlled in their work environment. In comparison to doctors and surgeons, nurses had very low status. In this instance, status and gender were utterly confounded. Nurses (all women) had a separate lounge from the doctors (predominantly men). In the operating theater, doctors could joke, talk, and laugh, but exercised tight control over when and whether nurses could say anything. Nurses rejected this notion of their role and were increasingly stressed as a consequence.

Surgical teams do not always have this clearly hierarchical status structure in which surgeons are in total control. In a study conducted in a European operating room (Helmreich & Schaefer, 1994), status conflicts emerged between the surgeon and the anesthesiologist and their associated support staffs. The central problem was that the anesthesiologist was unwilling to accept that the surgeon had higher status, his support staff of nurses, orderlies, and technicians supported him in turn. The support staff of the surgeon in like manner aligned themselves with their leader. Within this context of status competition, there was a breakdown in communication about the patient's needs. This particular study demonstrated that error in the operating theater can easily happen as a function of a breakdown in communication and coordination of activities. Some of this type of breakdown is associated with social processes related to status differentiation.

In these examples from the medical field, we can see the problems that arise in both natural groups and in laboratory-based groups, such as problems in communication as a result of status. We also see problems that do not arise in laboratory studies, such as those of role conflict and role definition problems over time, as in the case of the hospice team. Time and relationships among participants who must continue to interact result in problems that occur in natural ongoing groups.

Software development teams. Problems of coordination are also evident in other groups such as software design teams. In one collection of ten software design teams, the teams spent as little as 40% of their time on issues related to design but spent a great deal of time monitoring progress and orchestrating and sharing expertise (Olson, Olson, Carter, & Storrøsten, 1992). In designing a software product, participants often start with a reasonably good representation of the desired end product or the functions that the software is intended to accomplish. Many other natural groups have less initial clarity about their goals and intended products. The ten software teams studied by Olson et al. (1992) were surprisingly similar in the distribution of their cognitive activities in their team discussions. The discourse in meetings contained large amounts of clarification. Thirty percent of the time was spent on summarizing progress, which seemed to serve a coordination role. Many design alternatives were offered by participants in the groups, but few of the offered alternatives received any evaluation, possibly because participants had too much information simultaneously available.

Herbsleb, Klein, Olson, Brunner, Olson, and Harding (1995) note that software development places enormous cognitive, organizational, and management demands on team members. Developing software to suit client needs requires that the client's domain knowledge and needs be articulated and captured. The delineation of the client's goals can take a number of recursive episodes, and in the exchanges that go back and forth much information may be forgotten (Walz, Elam, & Curtis, 1993). Object-oriented design (OOD) has been touted as a solution to many of the problems that arise in traditional software design methods, particularly those associated with coordination and communication.

Although details of OOD are beyond the scope of this paper, we will present a brief outline of it. OOD involves categorizing the major components within a system or task into *classes* of objects. For example, in an object-oriented system for setting students' course schedules, the major classes might be *student*, *course*, *meeting times*, and *report*. Each object class is defined with

relatively abstract, high-level characteristics. The *student* class, for instance, might have attributes of *grade level*, *track or ability level*, and *special needs*. Within this class, there might be a variety of types of students—these are considered instances, or individual objects, within the *student* class. Individual objects inherit the characteristics of their object class, but they can also include other dimensions. For example, the object *high school student* would inherit the characteristics defined for the generic *student* class, but it might also include new categories specific to high school students.

Other important characteristics of objects are that (a) they communicate with one another by sending, receiving, and responding to queries, and (b) they can be designed and developed independently from one another once object classes, their information needs, and communication protocols are established Using this type of structure in analyzing a task (such as scheduling students) allows the team to view and coordinate highly complex tasks in an organized, hierarchical way. For many types of software design, this approach appears to enhance the quality and ease of product development.

Herbsleb et al. (1995) examined the use of object-oriented programming in an industrial context and conducted interviews with experienced practitioners of object-oriented design. Their study showed that OOD may have a variety of influences on the groups working with it. First, because of the strong, clear relationship between specific objects and the more abstract class, it is relatively easy for new group members to know where to look for information about an object. OOD centralizes the information—both procedural and structural—needed by programmers and designers, thus making it easier for members of the team to communicate about issues related to the object. OOD also can potentially enhance communication between members of the software teams and their clients, or users of the system. When the abstract categories used to define the classes are understood by both the programmers and the clients, both groups can collaborate more easily on design and application of the system. However, if the subject area is something more complex—such as a technical system architecture—communication between users and designers may be made more difficult by OOD, since the end user may not understand the abstractions used to define the objects. As a result, Herbsleb et al. concluded that OOD may be beneficial for some types of software teams, but problematic for others.

Tools to Facilitate Group Processes

The problems of coordination that are endemic to various kinds of work teams have resulted in the development and evaluation of a variety of tools to support the cognitive processing of individuals working together on complex tasks. Just as types of groups vary, collaborative support tools also vary depending on the type of group and task involved. Johansen (cited by Olson, Card, et al., 1993) divided group work into four categories based on the time and place involved: same time, same place (e.g., people meeting face-to-face); same time, different place (e.g., a conference call); different time, same place (e.g., different shifts occupying the same office); different time, different place (e.g., correspondence made via electronic or voice messaging). For the most part, the groups discussed here involve people meeting in the same place at the same time, so we focus mainly on tools that support that type of work.

At a very basic level, nontechnological tools such as whiteboards and flip charts can provide a medium for communication that can enhance collaboration. Technological tools such as shared text editors (e.g., Olson, Olson, Storrøsten & Carter, 1993), shared drawing media (e.g., Ishii, Kobayashi, & Grudin, 1993), and recording devices such as audio- or videotapes also can be used to facilitate communication among members of a group. More complex computer-based tools, including computerized group decision-support systems, provide even more support for group work. Kraemer and Pinsonneault (1990) identified two types of computer systems used to support group work: Group Communication Support Systems (GCSSs) and Group Decision Support Systems (GDSSs). GCSSs are systems primarily designed to support the communication process by including data storage and retrieval tools and representational tools such as large video displays. GDSSs, on the other hand, are systems that attempt to structure the group decision process through provision of decision models, usually in some automated form. From the perspective of cognitive and group psychology, the importance of both of these systems is their potential impact on human interaction. As Ishii et al. (1993) described, "We are interacting not *with* computers, but *through* computers" (p. 373).

The use of any tool in group work has the potential to affect group process. Even relatively simple communication tools such as electronic mail or teleconferencing can affect group dynamics or the culture of an organization or meeting (e.g., Finholt, Sproull, Kiesler, 1990; Olson, Card, et al., 1993). More complex systems that are designed specifically to facilitate collaboration may also impact the social and productive processes within a group. For example, one study (Olson, Olson, et al., 1993) showed how a shared text editor (ShrEdit) affected the work of groups designing a business service. The editor allowed group members to edit the design simultaneously, track other people's contributions, and view any part of the design. In comparing the products and work habits of supported groups (those using ShrEdit) to those of unsupported groups, Olson, Olson, et al. (1993) found that the supported groups' designs were of higher quality. An analysis of the work process revealed a somewhat surprising result: although it was expected that ShrEdit might allow participants to generate and retain more ideas, the ShrEdit groups actually generated fewer ideas than the unsupported groups. However, the ideas raised by the ShrEdit groups seemed to focus more on core design issues, resulting in higher quality products.

Olson, Olson, et al. (1993) noted that these results challenge many people's preconceptions about what can result in a quality product. For instance, in this case, generating a lot of ideas did not always result in a higher quality product. Possibly the tool itself changed the nature of collaboration in the group. Schrage (1990) suggested that, because this type of tool displays conversation in pictorial format, it brings digressions or off-track comments into clearer focus, thus encouraging people to stay closer to the core issues under discussion.

Another example of how technological support changed the nature of group interaction and activities was described by Olson, Card, et al. (1993). In a traditional meeting, time is spent merely planning or organizing the work to be done; participants then leave the meeting and do the work on their own. With a collaborative computer workspace, however, people can actually do some of the work in the meeting, allowing for more collaborative designs or products. The use of a technological tool not only can enhance existing working relations among people at a

meeting; it can also change the nature of those relations by allowing different types of work to occur.

Other tools such as GDSSs not only facilitate communication and retrieval of data during a meeting, but also help structure the actions of the group. GDSSs guide groups through various stages of decision making such as brainstorming versus organizing or evaluating ideas (Olson, Card, et al., 1993). Alavi (1994) describes how GDSSs can provide an environment that increases the group productivity in comparison to individual performance (process gains) while minimizing certain factors that can inhibit productivity (process losses). For instance, GDSSs that provide anonymity can decrease a process loss such as the participants' fear of evaluation, while they increase a process gain such as the overall number of responses. In Kraemer and Pinsonneault's (1990) review of research on group support systems, they concluded that both GDSSs and GCSSs can increase the depth of analysis of the problems under discussion by group members and increase participation by members. However, they also found that, for some groups using GCSSs, cooperation is decreased, and the quality of decision making actually decreases. It is possible that the decrease in cooperation might cause a lack of trust that results in a lesser quality of decision making.

According to Olson, Card, et al. (1993), more research on the nature of group collaboration is needed in order to develop better technological tools that will enhance group interaction and productivity. They suggest revisiting traditional studies on leadership, interaction styles, and participation roles to see how those behaviors or dynamics might affect or be affected by computer support.

In summary, natural groups suffer from many of the problems seen in small laboratory-based groups (e.g., status problems), but, in addition, they are characterized by significant problems related to communication and coordination. Difficulties in communication and coordination are exacerbated in naturalistic settings by the time frame in which groups operate, changes in conditions under which they operate, and issues related to status and control that contaminate relationships. Recent efforts in the arenas of software design and business have attempted to reduce some of these problems of communication and coordination through the use of various tools to support information processing and communication in groups. The use of these tools has resulted in positive outcomes on specific tasks, but several negative consequences have been observed, including impaired decision making. More research on both group behavior and tool development is needed to enhance the development of technology to support group collaboration.

Interdisciplinary Teams as Natural Groups

What can we learn from the preceding discussion about the functioning of interdisciplinary teams? First, interdisciplinary teams are more likely to share the characteristics of natural groups than groups in laboratory settings. Thus, more research on natural groups is needed, especially as interdisciplinary teams are very common in human service delivery and are becoming increasingly so (Schrage, 1990). Groups that represent different disciplines are often brought together for specific tasks such as developing policy or making decisions that affect a variety of people. Teams involving personnel from a variety of disciplines are also common in other work environments such as business, medicine, and education. Members of such teams typically interact with one another over an extended period of time.

We described some of the problems faced by such groups in our discussion of natural groups. Among these problems are difficulties with communication, managing group composition issues that may involve status differentiation, and difficulties in coordinating activities including the appropriate exchange of information. Depending on the disciplines represented in such natural groups as task forces, seniority and status may be totally confounded with diffuse status characteristics such as gender or race. In a previous section, we examined some of the cognitive and social constraints on effective teamwork in groups in general and illustrated these problems by reference to particular examples of groups in natural settings. Interdisciplinary teams pose special risks in these regards.

Difficulties Specific to Interdisciplinary Research Teams

Each individual in an interdisciplinary team presumably works from the perspective of his or her own discipline. Journet (1993) identifies some of the problems in interdisciplinary interaction as resulting from individuals' allegiance to a discipline. Disciplines differ in what events or data are interpretable, what methods they espouse, and what kinds of explanations are deemed satisfactory. Such differences can give rise to perceived status differences among representatives of different disciplines, and we have seen in preceding sections how such status differences can affect interaction. In addition, differences between disciplines may affect group members' perceptions of the urgency or appropriateness of the task (Committee, 1987). For example, people may be highly motivated to work on a task directly related to their own discipline and less interested in an issue that crosses disciplines. As was discussed previously, these discrepancies in group members' view of the task also can affect group social functioning.

Journet (1993) also characterizes disciplines as differing in their contents, the persona of the investigator, and what constitutes a significant event. She proposes that efforts to integrate across disciplines require the development of what she terms a "boundary rhetoric," one that negotiates the boundaries of the various disciplines involved. Journet describes the difficulties involved clearly. As a consequence of these difficulties, most teams involving members from different disciplines never function as interdisciplinary, integrative teams as described by Thompson-Klein (1990) in her description of interdisciplinarity.

Interdisciplinary teams must solve what Krauss and Fussell (1990, 1991) refer to as the "mutual knowledge" problem. They must come to understand what their collaborators intend. Experts

within a discipline share a common referential base, and communication among such experts is facilitated by the use of common referents. In interdisciplinary groups, such common ground must be developed (Clark & Brennan 1991). It may be that the need to develop such a common ground is not recognized by all members of the team, further adding to the difficulty of the interdisciplinary discourse. Team members must come to understand what their teammates know or do not know, which is not a simple task. Stasser and his colleagues (e.g., Stasser, 1992) found that people in groups often rehearsed already shared information and did not reveal less-distributed knowledge. In interdisciplinary teams, such reluctance to share different knowledge would pose tremendous problems in negotiating a shared knowledge base.

Interdisciplinary Team Development

Sverre Sjölander (cited by Thompson-Klein, 1990) described ten stages or phases through which an interdisciplinary group or project passes. Presumably these stages are not fixed and serve to describe common patterns that might be observed during interdisciplinary interaction. Not all interdisciplinary teams might be expected to follow the pattern described by Sjölander. However, interdisciplinary teams that work together over extended periods of time may experience many of these phases.

During the first phase of interdisciplinary group development, people in different disciplines spend time "singing the same old songs" (Thompson-Klein, 1990, p. 71). In this stage, participants demonstrate allegiance to their own disciplines (Journet, 1993). Each person represents his or her own discipline's viewpoint and interprets the group's common problem according to the cognitive and social schemata they understand in their own discipline (Thagard, 1994). Shifting perspective is often uncomfortable (Heider, 1958), and in the next stage, participants' adherence to their disciplinary views may result in their regarding those from different disciplines as having nothing to contribute. Attitudes such as these may result from an adherence to status hierarchies. Studies of the influences on group learning have shown that, when members of a group assume such attitudes, negative reactions occur. The third stage of Sjölander's development is that of retreating into abstractions. Discussion at the abstract level is safer and less likely to be challenged. When groups can discuss very general ideas that do not involve concrete actions, there is little disagreement. Few people would argue with the principle of improving safety on our streets. It is only at the level of details of implementing the improvements (and who pays for them) that we can observe disagreement.

At stage four, participants attempt to develop a common language of discourse and may develop "definition sickness" (Thompson-Klein, 1990, p. 71). Participants engage in an effort to move groups forward or come to a common language by defining terms, limits of engagement, etc. Inevitably, too much time is spent on this activity. In curriculum meetings related to discussions of new standards in mathematics and science, participants often get trapped in esoteric discussions of the differences between assessment, evaluation, and testing. Too much of this kind of discussion can result in "definition sickness" as the group may not be able to progress to general understandings of common concepts. Stage five marks the beginning of fruitful discussion that tends to skip from topic to topic in somewhat incoherent ways. Participants find points of connection in their various points of view and may skip around among subtopics. In stage six, the effort to develop a common jargon continues in what Sjölander refers to as the

"glass bead game" (after a Herman Hesse novel). This continued effort to develop a common understanding through a common jargon is abandoned in stage seven, in which participants, frustrated by wallowing in abstraction and constructing unfamiliar jargon, experience great failure. Group members who have not yet abdicated begin to appreciate other perspectives in stage eight but feel like traitors to their own disciplines. Sjölander refers to this stage as the "what is happening to me" stage. Stage nine marks the continued engagement with the perspectives of people from different disciplines. This stage is referred to as "getting to know the enemy" and involves becoming educated about others' perspectives. Finally, in stage ten, having negotiated a path through the borders of the various disciplines, participants in these teams are ready to begin a real discussion of the problem at hand.

Sjölander (cited by Thompson-Klein, 1990) clearly delineates the problems associated with mutual knowledge building (Krauss & Fussell, 1990). In expert groups (Krauss & Fussell, 1990), participants communicate almost telegraphically, using technical terms as referents for entire constellations of knowledge and strategies. When experts in a variety of fields are placed in interdisciplinary groups, their normal (within discipline) discourse is altered, and they must work to derive new referents as facilitators of complex and rapid communication. From the analysis presented above, the problems experienced by interdisciplinary groups are most likely to include the development of an appropriate task or problem representation and the development of shared knowledge. DuRussel and Derry (1996) observed those problems in an interdisciplinary team whose task was to specify issues relevant to the design and evaluation of systemic educational reform. Because of the various backgrounds of team members, the group experienced some initial difficulty in reaching a common definition of systemic reform. In addition, the participants' differing views and opinions resulted in some heated discussions of the type of approach appropriate to evaluating reform efforts.

The social and affective consequences of these problems may be significant, returning the group's purposes to functions other than productivity. The use of tools and procedures to facilitate the construction of mutual knowledge or to communicate about what is known might be very important to the effective functioning of such groups. For example, the practice of illustrating technical ideas in graphical or pictorial format using computer graphics or even a simple blackboard might be very successful in helping all members of a group gain a common understanding of the topic being discussed.

Models of Group Cognition

Analyses of group cognition and performance fall into two major types: information processing models, which focus on the transfer and transformation of information as it flows among members of a group, and sociocultural theories, which view a group's thought and action as being grounded in social, institutional, and cultural influences. Both represent frameworks that fall within a broad class of theories focusing on distributed cognition.

Information Processing Model

One of the most influential models of human information processing was proposed by Atkinson and Shiffrin (1968). Although major criticisms of this model have been made and significant

modifications to it have been advanced (Baddeley, 1990), the basic descriptions of the functions of human information processing described in that model are still valid. These functions include storage and retrieval of information in long-term memory and working memory and executive control of the transfer of information from short- to long-term memory and vice versa. Criticisms of information processing approaches (often referred to as symbol processing approaches) have failed to dislodge the utility of these constructs.

In examining some of the difficulties natural groups experience in terms of communication and coordination, we can see that some problems may be exacerbated by limits on individual cognitive processing. For instance, without additional support, the software design teams could not keep track of proposed alternative designs so that they could evaluate options. Communication among members of the hospice team was hampered by the reliance of the large number of volunteers on a single source of information, the volunteer director, for information related to the conditions at the hospice. The introduction of computer-based tools to support some aspects of individual information processing (e.g., memory and retrieval) in the software design teams improved the quality of decisions made and produced more equality in the distribution of participation. Earlier in the paper, we also discussed the importance of informational deficiencies in a group. When important relevant information is not available to all members of the group, decision making or problem solving can be impaired. As a result, identifying the flow of information within a group can be useful in understanding the cognitive and productive processes of a group.

Although many analyses of group functioning stem from an input-process-product model (e.g., Kraemer & Pinsonneault, 1990), they rarely can meaningfully interpret the interaction among variables. Models of group functioning that revolve around a collection of individual information processors do not provide effective descriptions of complex group processing. Krauss and Fussell (1990) argue convincingly for the importance of the development of mutual knowledge in order to communicate effectively. But what does it mean to develop mutual knowledge? Can this occur in interdisciplinary teams whose members converse with the referential basis of their own disciplines (Krauss & Fussell, 1990) and with allegiance to their own disciplines (Journet, 1993; Shalinsky, 1989)?

One information processing model, Smith's "collective intelligence" model (1994), seems to address this problem of how people develop mutual knowledge. Smith began by delineating the types of information that people exchange in groups. First, there is the tangible knowledge in a group, including the target products (e.g., policy statement) that provide evidence of the successful completion of the group's task. En route to the production of these targets, groups may produce instrumental products (e.g., accompanying graphs of supporting evidence) that support the work but are not part of the target product. A second kind of information that is transmitted in groups is intangible. Intangible knowledge may be public (shared as conversation) or kept private (remaining in people's heads). Ball (1994) provides some interesting insights on the costs of too much intangible knowledge remaining private. Groups also produce ephemeral products, transitory representations (such as whiteboard diagrams) produced to facilitate communication during collaboration. They typically are destroyed and do not become part of the final product. According to Smith (1994), the task of collective intelligence in groups is to effectively manage the appropriate flow of information within groups from one form to another and to preserve the

important features through accurate storage and retrieval of information, activation of appropriate knowledge, and control of the flow of information. In earlier parts of the paper, we described some of the influences that can limit such information flow and hence the intelligent performance of groups.

Smith's (1994) model of group intelligence provides a novel way of considering the interactions within interdisciplinary groups. The research questions that stem from such a consideration include whether the flow of information in a group can be modeled to allow us to pinpoint problem areas in the maintenance of an adequate flow of information. Smith's model suggests that there is need to examine intangible, ephemeral products (such as conversation) to determine how they are transformed into more tangible outcomes.

Sociocultural Model

Although an information processing model can provide some insight into the processes underlying group development, it typically does not provide a full picture of the external influences on group functioning. An alternative view is provided by a sociocultural model of group functioning that analyzes group interaction based on the social and cultural forces that shape it. Sociocultural theories of cognition highlight the relationship between mental processes and the cultural environment within which the mental processes develop.

DuRussel and Derry (in press) explore how sociocultural theories can be applied to the development of an interdisciplinary group. They found that an apprenticeship metaphor (Collins, Brown, & Newman, 1989; Lave, 1991; Lave & Wenger, 1991; Wenger, 1990) seems to provide a useful lens for analysis of interdisciplinary discourse. In the team being studied, some members were experienced in the topic under discussion, while other members (typically from other disciplines) were less familiar with the terminology and concepts being discussed. The first few meetings included a process similar to apprenticeship, in which members unfamiliar with the topic acknowledged feeling like newcomers, while experienced members consciously tried to explain new terms and ideas to facilitate intragroup communication. Recognizing the applicability of the apprenticeship model may help researchers better understand or identify patterns in interdisciplinary group behavior.

Another sociocultural perspective discussed by DuRussel and Derry (in press) is based on the existence of multiple "voices," or speakers' perspectives, in a group. This model is based on the Bakhtinian notion of voice (as cited in Wertsch, 1991). According to this theory, a comment may have a basis in the ideas or values of a particular group or "voice." For instance, a person may begin a meeting speaking with the voice of a parent, shift to the voice of a scientist, and conclude using the voice of a teacher. Understanding the cultural history of different voices in the discussion may reveal patterns of interaction that influence group process. For instance, in one interdisciplinary group that contained a mix of engineers, educators, mathematicians, and social and natural scientists, DuRussel and Derry identified two contrasting voices: the voice of the natural sciences and the voice of the social sciences. At times, both scientists and nonscientists seemed to speak in the voice of the natural sciences, calling for strict research methods, isolation of variables, and calibration control in evaluating the problem. The other view, that of the social sciences, seemed to stress the complex, situated nature of the social system being discussed,

implying that a more rigid approach from the natural sciences might not be appropriate for this problem. Identifying the voices in conversation helped to understand the development of concepts and decisions made in the group. For example, the choice of group products (such as paper topics) seemed to be influenced by the interaction of different voices in the group.

Both of the sociocultural theories described above can provide researchers with ways to examine group processes in the context of the institutional, social, and cultural foundations in which the group exists. However, DuRussel and Derry (in press) note that neither view provides a complete picture of group processes. Existing apprenticeship metaphors do not fully explain the interaction between team members of relatively equal status, in which no participant is an obvious novice striving to join a mature community of experts. Similarly, the voices metaphor is a useful tool in linking comments and ideas to the cultural elements or identities that may have prompted them, but it does not provide a way to fully understand how information is transformed and generated in a group.

Distributed Cognition

Theories of small group performance have tended to focus on individual level properties of the group (e.g., members' attitudes, personalities) or on system level properties (e.g., group norms, decision rules) but not both, even though effective group performance involves a complex interaction between individual and system level processes (Hirokawa & Johnston, 1989; Poole, Seibold, & McPhee, 1985). A broader view of group functioning—possibly a view containing elements of both information processing and sociocultural theories—is necessary to describe interdisciplinary group performance. One type of model that may eventually accommodate both of these views is the distributed cognition model, which posits that cognition does not have a single locus inside one individual but is spread over entire systems of interacting individuals (Salomon, 1993, p. 114). Similar to OOD, the concept of distributed cognition implies that intelligent activity, such as problem solving or decision making, is an emergent product representing the work of many different cognitive components (objects, people, etc.) that send information back and forth to one another but that otherwise operate as relatively independent cognitive entities. Each such component receives information from other components, processes that information, may alter itself in response to the information it receives, then responds by submitting informational output that other cognitive components process. Although the capacity of individual components operating alone is limited, when information processing components operate together, highly intelligent behavior emerges. Thus, the mind "extends beyond the skin" (Wertsch, 1991, p. 27), making it appropriate to attribute such ideas as "development," "thinking," "remembering," and "knowledge construction" to working groups.

Interactions (human/human, human/machine, human/tool/human, etc.) of any complexity can appropriately be conceptualized as the activity of distributed information processing. For example, the behavior and thoughts of a single individual working on conceptualizing a design for evaluating systemic education reform are viewed as the outputs of a distributed cognitive system whose processing components represent a subset of the individual's knowledge and capacities—those activated and used during the writing session. If that individual joins with other individuals and uses a computer system to create the evaluation design, then the distributed

information processing system includes all the capacities and processes that are contributed by different components, including the computer system, in an effort to achieve the goal.

Discussions of the distributed nature of cognition (e.g., see Hutchins, 1991; Levine & Moreland, 1991; Salomon, 1993) show the potential for both regarding the social forces behind group interaction and tracing the information path as knowledge is transformed within the group. The application of distributed cognition to the analysis of interdisciplinary teamwork has strong potential and should be developed further.

Conclusion

Groups are a central fixture in today's business, educational, and social spheres. In particular, interdisciplinary groups may become more common and more vital as our society faces more problems—educational, environmental, social, or otherwise—that extend across disciplines. Small group research has explored how factors such as status, leadership, conflict, task type, and cognitive limitations influence group effectiveness. This research has provided us with some information about how effective groups handle complex problems. However, more case studies and research on natural groups—groups of people in real situations facing real problems—are needed to generate a more complete understanding of how the complexities of the real world influence group processes and how people interact in real situations. Our discussion of several types of groups at work illustrates how different these groups can be, although they often share common characteristics and difficulties. A more extensive research literature on natural groups will help us both to better understand group functioning and to create tools that can enhance that functioning.

A distributed cognition theory of interdisciplinary collaboration may be able to combine aspects of both sociocultural and information processing theories; group cognition and interaction can then be explained both at a processing level (how information is transformed in a group) and at a sociocultural level (how group interaction is informed by existing cultural, institutional, or social structures). A model that incorporates both of these elements would provide a means of analyzing group interaction that does not discount either the flow of information within a group or the source of that information in cultural and social foundations. This tool would be especially useful in studying interdisciplinary groups, in which participants may have a variety of backgrounds (implying potentially nonshared cultural foundations) but still perform knowledge- and information-processing tasks similar to other groups.

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