Small Group Research
43(5) 527–558

DOI: 10.1177/1046496412453622
http://sgr.sagepub.com

Facilitating Innovation in Diverse Science Teams Through Integrative Capacity

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Abstract

Knowledge integration in diverse teams depends on their integrative capacity—the social and cognitive processes, along with emergent states, that shape a team's ability to combine diverse knowledge. We argue that integrative capacity represents the potential that a team has to overcome various compositional, team, and contextual barriers to generating integrated and novel knowledge. This article focuses specifically on the unique challenges facing diverse science teams that have the goal of generating novel knowledge at the intersection of disciplinary, practice, and organizational boundaries. The integrative capacity of a science team is argued to help facilitate the social and cognitive integration processes necessary for effective team processes that enhance the likelihood of innovative team outcomes. Implications of our theoretical framework for practice and research on fostering innovation in diverse science teams are discussed.

Keywords

team science, teamwork, knowledge integration, interdisciplinary

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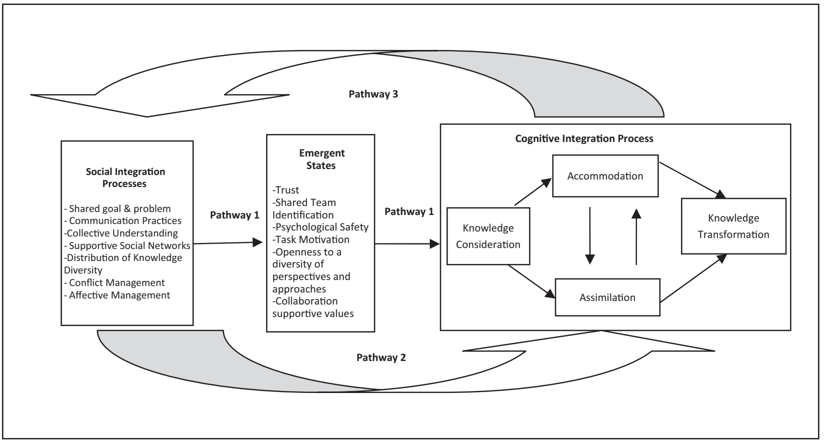

Figure 1. Integrative capacity

Introduction

The ability to transform knowledge through integration is a core competence of innovative teams. "Integration is defined as the extent to which a [science] team combines its distinct expertise and work into a unified whole" (Balakrishnan, Kiesler, Cummings, & Zadeh, 2011, p. 2). It plays a critical role in facilitating knowledge creation in teams that bring together diverse experts from across disciplinary, professional, functional, and organizational domains. In this article, we define a team's *integrative capacity* as a capability that is sustained through an interactive system linking social, psychological, and cognitive processes. We argue that this capacity enables teams to build effective communication practices, a shared identity, and a shared conceptualization of a problem space that helps them recognize how their unique knowledge resources can be potentially combined to create an integrated knowledge product (see Figure 1).

The importance of integrative capacity varies, depending on the degree of knowledge integration needed to reach a team's objectives. In cross-functional, cross-disciplinary, and multidisciplinary teams, which pursue a common goal by combining independent or sequential work, collaborative efforts focus on information sharing and learning from one another to facilitate coordination across boundaries (Bunderson & Sutcliffe, 2002; Rink & Ellemers, 2010). The contributions of each functional or disciplinary area are not intended to be integrated, but rather to complement one another (Eigenbrode et al., 2007; Klein, 1999). Hence, the need for integrative capacity is nominal. In contrast, integrative capacity is critical for teams seeking to generate a knowledge product that builds on and combines diverse expertise. For instance, interdisciplinary and transdisciplinary science teams often have an overarching objective to create knowledge that extends beyond the scope of a single discipline through the integration of diverse ideas, perspectives, and approaches (Eigenbrode et al., 2007; Fiore, 2008; Stokols, Hall, Taylor, & Moser, 2008a).

Unfortunately, knowledge-diverse teams often find the goal of integration elusive (Balakrishnan et al., 2011; Cronin & Weingart, 2007; Okhuysen & Eisenhardt, 2002). Theoretical models of integration in knowledge-diverse science teams tend to be linear, beginning with the identification of a research question and ending with the decision for action or implementation (DeWachter, 1982; Gold & Gold, 1985; Newell, 1999). Klein's (2005) model provides a richer and more complex view of integration, by linking an ongoing triangulation between depth (e.g., competence), breadth (e.g., multiple perspectives), and synthesis (e.g., integrative social actions). Others draw on a traditional input-process-output framework to explain how team, task, and environmental factors shape collaboration in science teams (Fuqua, Stokols, Gress, Phillips, & Harvey, 2004; Paletz & Schunn, 2010; Stokols, Harvey, Gress, Fuqua, & Phillips, 2005).

Taken together, this body of research broadly outlines the relationship between social and cognitive variables that influence science team outcomes. Nonetheless, they do not fully delineate the underlying mechanisms by which these variables are related. They also do not isolate the integrative capacity of a team from its composition, task features, or environmental context. Our model of integrative capacity draws on the work of Marks, Mathieu, and Zacarro (2001) and differentiates between team processes and emergent states. We conceptualize emergent states as products of team experiences that become new inputs to subsequent processes and outcomes. Building on Klein (2005), we take a temporal view to argue that knowledge and social integration coevolve through the continuous establishment of emergent states, such as trust and a shared team identity. The potential result of this process is the transformation of the team's dispersed knowledge into a knowledge product that is both integrated and novel. We suggest that integrative capacity enables a science team to overcome the compositional, team process and contextual barriers that inhibit their ability to generate cutting-edge research and clinical care insights (see Figure 2).

In the sections that follow we describe our model of integrative capacity. We begin by providing background on the diverse composition of science teams and the contextual environment in which their work is conducted. We then outline several team and task-based barriers that affect knowledge

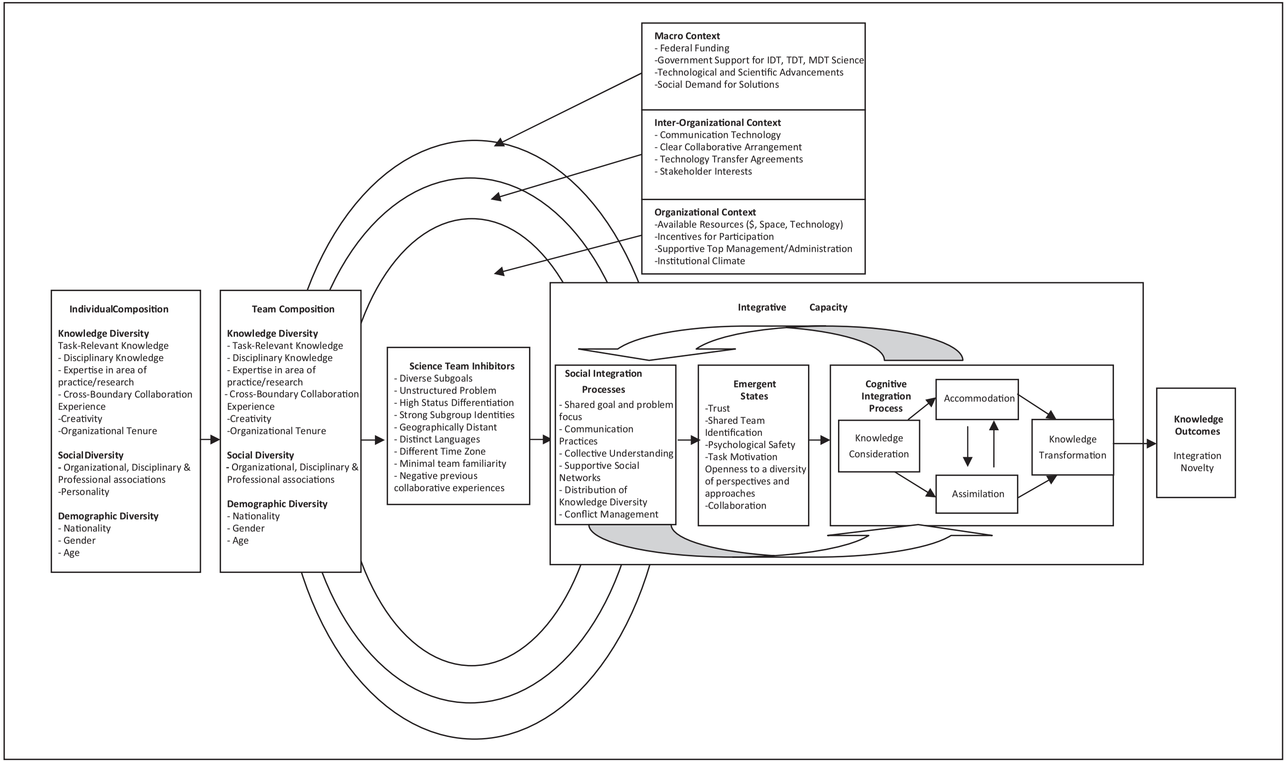

Figure 2. An ecological perspective on integrative capacity

integration in teams seeking to create integrated knowledge products (hereafter referred to as *outcomes*). Finally, we describe integrative capacity and how it can enable knowledge-diverse science teams to overcome these inhibitors and integrate their available knowledge resources.

Composition and Context of Science Teams

Although integrative capacity might be helpful to innovation teams in general, we argue that it is critical in science teams seeking to integrate diverse knowledge due to compositional and contextual factors. In addition to surface-level differences that are present in many types of teams, such as age, race, or gender (Harrison, Price, Gavin, & Florey, 2002), additional deep-level differences are present between science team members (Harrison & Klein, 2007). This deep diversity can lead to knowledge and social gaps that hinder integration due to the variation in members' knowledge and separation between the groups with which they are associated (Harrison & Klein, 2007).

Compositional factors that make integration in science teams difficult are numerous. Science teams often include both researchers and practitioners who approach problems from different basic and applied levels (Stokols, Misra, Hall, Taylor, & Moser, 2008). Disciplinary differences in training, education, tools, approaches, and conceptual frameworks among team members are also sources of heterogeneity. Underlying these differences are often divergent values, goals, interests, methods, and approaches. Years of socialization within a discipline, profession, or organization can enhance the strength and importance of one's identification with the norms, practices, values, and philosophies associated with the scientific communities to which they belong (Journet, 1993). Rigid adherence to these discipline-specific ways of conducting science can limit the ability of team members to recognize the value of alternative approaches. Furthermore, status and power differences distinguish individuals (Rhoten & Parker, 2004) and scientific communities, stemming from a long history of interaction and contentious claims to knowledge, can spill into the science team setting, further inhibiting the willingness to integrate knowledge (Stokols et al., 2008a).

Contextual organizational and professional factors surrounding science teams also create divergence that is difficult to overcome. Members can come from within a single organization or from different organizations (Cummings & Keisler, 2005). The organizations represented within a science team may operate in various academic, government, or industry sectors (Adler & Stewart, 2010; Altman, 1995) and can affect the emphasis placed on scientific discovery, public policy and commercialization. Team members can often work from distinct geographic locations quite distant from one another, broadening the geographic scope of science teams (Olson & Olson, 2000). Disciplines vary in terms of tenure standards, availability of funding, and professional status. Time pressure, limited resources, competing institutional demands, and insufficient training deter participation in interdisciplinary science teams (Salazar, Lant, & Kane, 2011; Stokols et al., 2008a). However, pressure from funding agencies for scientists to collaborate with others who hail from different disciplinary, practice, and professional areas has motivated organizational initiatives to foster participation in team science by investigators who work independently or with others within their own discipline (Salazar, et al., 2011). Thus, contextual factors can also influence the outcomes of science teams.

Investigating the influence of composition and context in science teams provides an opportunity to better understand the conditions under which professional identities, deep-rooted knowledge differences, and resource constraints affect knowledge integration. We posit that integrative capacity helps to overcome the challenges that science teams face when working together to integrate knowledge across their disciplinary, professional, and organizational boundaries.

Science Team Barriers and Facilitators to Knowledge Integration

Factors that influence the potential of science teams to integrate knowledge include (a) social identification, (b) team goals, (c) problem conceptualization, (d) location and time, (e) breadth of knowledge, (f) distribution of knowledge, and (g) team member familiarity. These factors can affect the functioning of many types of teams; however, the characteristics of science teams exacerbate these factors. For instance, strong professional identities and deep disciplinary knowledge create unique opportunities and challenges for knowledge integration in these teams. Furthermore, the simultaneous confluence of so many of these features in science teams differentiates these teams from others. When these factors are operating to inhibit effective team processes, greater barriers to knowledge integration and creation exist. We elaborate on the inhibiting aspects of these factors in the section below and argue that integrative capacity will be critical for overcoming these barriers to knowledge integration in science teams.

Social identification. Scientists commonly identify strongly with their disciplines and hold allegiance to the discipline's values, approaches, and norms (Journet, 1993). Social identity theory suggests individuals perceive and evaluate members of their own groups more favorably than others (Brown, 2000; Hewstone, Rubin, & Willis, 2002; Tajfel & Turner, 1986). Identification with one's own group, and the need to positively differentiate it from others (Brown, 2000; Hewstone et al., 2002; Tajfel & Turner, 1986), may limit the trust and perception of value in the contributions of scientists from other scientific communities. Strong identification with in-groups is likely to limit science teams' effective use of their available knowledge resources and foster divisive, rather than integrative, interaction among diverse team members.

> *Proposition 1*: Ingroup favoritism toward one's own disciplinary or practice community will limit the willingness to share knowledge with or value the contributions from team members who belong to other disciplines or areas of practice.

Team goals. One unifying factor in science teams can be a common goal to solve a complex problem (Sherif, 1958; Tajfel & Turner, 1986). Unfortunately, agreeing on this goal can be a challenge because members of science teams tend to vary in their dominant educational background (Bunderson & Sutcliffe, 2002). Eigenbrode et al., (2007) suggest that underlying philosophical differences shape the motivations, methods, evaluative criteria, and values associated with doing scientific work across disciplines. For instance, basic scientists tend to have the goal of identifying the foundational mechanisms underlying complex problems, whereas applied scientists aim to provide the effective delivery of a service or treatment (Stokols, et al., 2008a). Members of science teams representing academic, industry, and community stakeholders may also have conflicting interests because of external pressures to advance science, make a profit through commercialization, or meet the broader needs of the community (Altman, 1995; Klein, 1996, 2004a, 2004b; Pretty & Smith 2004). Failure to understand these fundamental differences between members of science teams can foster subgroups that can be divisive and hinder progress towards identifying a common superordinate goal (Campbell, 2005; Jakobsen, Hels, & McLaughlin, 2004). Clarifying the goal by resolving differences between groups can help to foster the desired outcomes of a science team's collaborative work (Sonnenwald, 2007; Stokols, 2006).

> *Proposition 2*: Different approaches, interests, and priorities among science team members will reduce their ability to agree on a common goal and collaborate effectively.

Problem conceptualization. Defining the problem around which collaboration will be focused is critically important in science teams (Fiore & Schooler, 2004). Most importantly, a team's comprehension of the problem should contain elements that substantially overlap to enhance a team's ability to build problem representations that enable the generation of a quality solution (e.g., Fiore & Schooler, 2004). Unfortunately, different conceptual schemes of diverse team members can constrain questions, differentially frame observations, and lead to varied methods of interpretation and standards for conducting scientific work (Galison, 1997; see Lélé & Norgaard, 2005). Without some overlapping conceptualization of their shared problem, teams are limited in their ability to find connections across the different scientific and applied communities represented (Henagulph, 2000; Klein, 2004a, 2004b; Wickson, Carew, & Russell, 2006).

Proposition 3: Interdisciplinary science teams that have less overlapping conceptualizations of the team's shared problem will be less likely to forge connections across their various communities than teams with at least a modest degree of overlapping conceptualizations.

Breadth of knowledge. The promise of interdisciplinary teams lies in their breadth of knowledge, cross-fertilization of ideas, and the integration of this knowledge (Amabile, Conti, Coon, Lazenby, & Herron, 1996; Perry-Smith & Shalley, 2003; Tesluk, Farr, & Klein, 1997). However, a team may have a sufficient breadth of knowledge, but an inability to leverage it. Although individuals in the team may perceive that there is substantial distance between their own understanding of a problem and that of other team members (Lyanage & Barnhard, 2003), they may not be able to communicate their diverse perspectives or effectively understand and use these differences (Dougherty, 1992). Teams with a moderate breadth of knowledge, neither too similar nor too different may best be equipped to advance research in their problem area of focus.

Proposition 4: Interdisciplinary science teams with a great breadth of knowledge diversity will be less able to exchange and build on their diverse knowledge compared with teams with a moderate breadth of knowledge.

Location and time. The physical and temporal work structure of a science team can also influence their capability to integrate. Cummings and Keisler (2005) identify the importance of colocation on the quality of collaborative outcomes in science teams. These researchers demonstrate that interdisciplinary scientific collaborations spanning many universities were less able to coordinate their work and less able to reap the benefits of their diverse expertise than colocated teams. Olson and Olson (2000) identify challenges to working across geographic distances due to time zone differences. Their research suggests that time zone differences, if too great, can threaten progress in distal collaboration because greater coordination is needed, for example, to identify a time to talk and to develop a structure for continuously making progress toward a shared goal.

> *Proposition 5*: Great geographic dispersion of team members can inhibit effective collaboration in diverse science teams compared with teams with moderate or low geographic dispersion.

Distribution of knowledge. Generating new knowledge entails a process of creating social connections between people, and the ideas that they carry (Obstfeld, 2005). When social connections exist between people whose perspectives are prealigned, they tend to be better equipped to effectively exchange ideas and resources (Granovetter, 2005). Unfortunately, the redundancy of information circulating within a network of people with strong ties can limit the possibility for knowledge creation because there will also be limited exposure to new and fresh perspectives (Granovetter, 1973; Perry-Smith, 2006). Research suggests a tendency for scientists to interact more with scientists within their own knowledge communities (Hughes, Peeler, & Hogenesch, 2010), creating dense networks, but offering little opportunity for cross-fertilization. Although science teams with networks that are neither overly dense nor overly sparse may have a greater potential for creating innovative knowledge, research that identifies the optimal network structures to facilitate innovation in science teams is still needed (Haines, Godley, & Hawe, 2011).

> *Proposition 6*: Science teams with social and informational networks that are neither overly dense nor overly sparse will have more potential for creating knowledge than teams with highly dense or sparse networks.

Team familiarity. Similarity and familiarity among team members can create both cohesion and solidarity (Moreland & Zajonc, 1982). In interdisciplinary and transdisciplinary teams, members tend to have little familiarity with one another, which can create divisiveness and conflict. However, members with extensive familiarity may have a great deal of cohesion, but be less willing to consider new perspectives or approaches. Research suggests that a prior positive collaborative experience in science teams facilitates trust, collaboration readiness, and enhances the team's prospects for success (Cummings & Kiesler, 2005; Fuqua et al., 2004; Hall, Feng, Moser, Stokols, & Taylor, 2008; Stokols et al., 2005). Consequently, too little or too much familiarity between members and negative previous collaborative experience are likely to inhibit knowledge integration in diverse science teams.

Proposition 7a: Too little or too much familiarity among members is likely to inhibit knowledge integration in diverse science teams.

Proposition 7b: Previous negative collaborative experience is likely to inhibit knowledge integration in diverse science teams.

The combination of these above mentioned features pose particular challenges for science teams. For instance, science teams are often comprised of team members who hail from diverse disciplinary areas with the aim of accomplishing a common goal. Unlike other teams, where members may have a moderate degree of professional training, roughly a decade of training and education garner each member of science with deep disciplinary knowledge and associated beliefs and values about how scientific work should be conducted (Journet, 1993). The degree to which members possess unique versus shared knowledge can vary depending on a science team's composition and can influence their ability to make connections to one another's ideas and perspectives. Moreover, in science teams that are newly formed, members may have limited interaction and familiarity with one another. This feature of science teams, combined with their aim of solving complex problems at the intersection of disciplines and professions, can limit the degree to which these team members develop a common problem conceptualization and their potential and ability to agree on team goals.

These unique barriers affect a science team's ability to leverage their diverse composition and influence the degree to which they have the potential to create novel and integrated knowledge. The organizational, interorganizational, and macro context can further hinder innovation in science teams. In the following section, we suggest that integrative capacity enables a science team to overcome these challenges, harness their potential, and achieve their goal of creating integrated and novel knowledge.

Integrative Capacity

In the following section, we define and elaborate the integrative capacity construct, which we suggest can explain why some science teams are better able to overcome barriers to knowledge integration than others. Specifically, we delineate the three pathways that comprise a team's integrative capacity: (a) The social integration processes that facilitate emergent states and support cognitive integration processes; (b) the social integration processes that are direct antecedents to cognitive integration processes, such as knowledge sharing and consideration; and (c) the cognitive integration processes that foster the transformation of knowledge and can lead to the improvement of the team's integrative capacity over time. We argue that these three pathways constitute a continuous interactive cycle between social, cognitive, and psychological processes in science teams that are constantly evolving and shaping one another. Although science team leaders are critically important for the facilitation of these social and cognitive integration processes, team members are also essential to maintaining and sustaining the team's integrative capacity.

Pathway 1: Social Integration Processes and Emergent States—Antecedents to Cognitive Integration

This section focuses on social integration processes that establish the conditions necessary for knowledge integration through the establishment of emergent states. We address how a common vision, knowledge sharing, communication practices, the management of social networks, conflict and affect management, and the creation of a common identity facilitate emergent states, such as trust and positive emotions, that support cognitive integration processes.

Shared Goal and Problem Conceptualization

Social integration processes are essential for the formation of a shared goal and problem representation. Leaders and instructional interventions can be useful for establishing a common goal (Hackman, Brousseau & Weiss, 1976; Wittenbaum,Vaughan, & Stasser, 1998). Building consensus through team developmental strategies such as experiential learning and appreciative inquiry can help to develop agreement around goals and problem definition, ultimately facilitating integrative knowledge creation (Stokols, 2006). Visioning and framing can also enable leaders to alter the cognitive structures of team members to be more amenable to influences from outside of their particular disciplinary or practice domain (Gray, 2008). The ability of team members to partially relinquish their own goals and approaches and be willing to adopt a shared objective and understanding of the problem is critical for collaboration in diverse science teams where members possess both strong identification with their disciplines and allegiance to their approaches to conducting science (Adler & Stewart, 2010; Guzzo & Dickson, 2010).

Proposition 8: Leader and team interventions can be instrumental in helping diverse science teams to identify a shared goal and reach a common problem conceptualization.

Communication Practices

In science teams, knowledge that is *owned* by individual members of the group (Spender & Grant, 1996) must spiral up to the group level where it can be used to advance the team's goals (Nonaka, 1994). Unfortunately, effective communication of knowledge in interdisciplinary science teams is often inhibited by status hierarchies and uneven power relationships that also reflect a history of intergroup relations among scientific communities. Individuals and groups with expert status may be unwilling to seriously consider the contributions of lower status members, whereas lower status members may be inclined to give more credence and *air time* to higher status members (Beersma et al., 2003; Hackman & Morris, 1983; Littlepage, Robison, & Reddington, 1997). To facilitate equal access to dialogue that is often hindered by status and power differences (Bacharach, Bamberger, & Munger, 1993; Ridgeway, 1991), research suggests that leaders can use an empowering leadership style to enhance the use of the team's intellectual resources (Kumpfer, Turner, Hopkins, & Librett, 1993). In science teams, when knowledge is distributed among members whose disciplinary groups may have different claims to knowledge and status and where junior and senior researchers are participating, this use of an empowering leadership style may be particularly critical to foster psychological safety among members and encourage interpersonal risk taking and speaking up about ideas and opinions (Edmondson, 1999).

Proposition 9: Empowering leadership can minimize the power and status differences that exist within science teams to foster communication and collaboration.

Collective Understanding

Once information is shared among members, the team must try to achieve sufficient understanding of one another's diverse perspectives before they can begin to integrate their knowledge. Leaders can also help to bridge gaps in communication through the establishment and use of boundary objects (Star & Greisemer, 1989), artifacts that loosely embody meaning across social worlds, and efforts to clarify concepts that may hold different meanings across disciplinary, professional, sector, and organizational boundaries. By encouraging the representation of specialized knowledge through boundary objects (Star & Griesemer, 1989), leaders can help team members to gain a more accurate perception of others' cognitive schemas (e.g., Bernstein & Davis, 1982). When knowledge is displayed, it enables specialists from other areas to access the knowledge and bring it to bear on their collective work (Dougherty, 1992). In the context of team problem solving, Fiore and Schooler (2004) suggest that "the degree the team-task requires the construction of a shared understanding, external representational tools can act as a scaffolding to facilitate the building of that shared representation" (p. 134). Olson and Olson (2000) also emphasize the importance of clarification during the negotiation and development of common understanding in science teams characterized by both a breadth of disciplinary knowledge and geographic dispersion. They provide evidence of the effectiveness of team leaders who listened for places where clarification might be needed as knowledge was communicated across these boundaries.

> *Proposition 10*: Leaders can enhance the collective understanding of diverse science teams by facilitating the representation of specialized knowledge with boundary objects.

Management of Social Networks

In teams with dense social networks, innovative potential may be low, but the ability to integrate will not be as critical to performance. Transdisciplinary science teams, however, are likely to have sparse social networks, as members hail from different professional communities. Social integration processes will be critical for these teams to facilitate the integration of team members' knowledge. Obstfeld (2005) demonstrates that communities with individuals who have an orientation toward joining two other people together in their network via introducing them or by facilitating new coordination between them tended to enhance involvement in innovation processes. Gray (2008) also emphasizes how leaders can serve as brokers between disparate and unconnected groups of researchers, helping to clear up misunderstandings, mediate conflict, and translate scientific jargon to advance their shared goal of creating new and integrated knowledge. This type of network-oriented leadership is particularly crucial in science teams where subgroups of clinical and basic researchers exist and connections between them must be forged to facilitate knowledge generation.

Proposition 11: Leader and team member behaviors oriented toward bridging disparate networks within science teams can help to facilitate knowledge generation.

Distribution of Knowledge Diversity

The strength of the subgroups represented within teams can inhibit the degree to which members are motivated to collaborate across these group boundaries (Lau & Murningham, 1999). In teams with strong subgroups, team members may be more likely to view the team as having a divide, and favor the contributions of in-group members more than out-group members (Brewer, 1991; Brown, 2000; Hewstone et al., 2002; Tajfel, 1982). In contrast, information sharing in diverse teams is more likely in teams where the divide between subgroups, such as teams from distinct disciplinary departments, is mitigated by shared attributes (Brewer & Brown, 1998; Homan, Van Knippenberg, Van Kleef, & DeDreu, 2007; Phillips, Mannix, Neale, and Gruenfeld (2004) also find evidence that having overlapping knowledge with members of social out-groups can facilitate information sharing across subgroups. Extrapolating this finding to the domain of science teams, we suggest that scientists who have received education and training from more than one disciplinary or professional group may facilitate knowledge integration in diverse science teams.

Proposition 12: A greater number of team members who belong to more than one of the disciplinary or professional groups represented in a science team can help to bridge differences and promote collaboration.

Conflict Management

In problem solving science teams, diverse members often assume that they have a shared representation of the problem (Fiore & Schooler, 2004). As differences are revealed, such as how problems are defined or methodologies used, conflict can arise (Cronin & Weingart, 2007). In science teams seeking to integrate and extend knowledge, conflict can become detrimental when it threatens to destabilize the practices or interests of the parties involved (Hall Stevens & Torralba, 2002). At the same time, debating points can facilitate divergent thinking and the consideration of alternative ideas from different points of view, which is linked to idea generation (Brown & Duguid, 2001; Nemeth & Nemeth-Brown, 2003; Tushman, 1977). Hence, the management of conflict is essential for innovation and scholars suggest that the communication of disagreement is more likely to foster knowledge integration and creation if it is done in a collaborative, rather than in a contentious manner (Lovelace, Shapiro, & Weingart, 2001). Furthermore, Klein, Knight, Zeigert, Lim, and Saltz (2011) found that leaders who were task-focused rather than person-focused in their conflict management approaches were more effective in reducing conflict in diverse teams. Such conflict management skills can help to resolve questions of legitimacy, ameliorate power differences, and integrate perspectives to create new knowledge (Gray, 2008). In science teams, where task-related conflict can be focused on reaching a shared conceptualization of a research problem or deciding on an approach to scientific work, it is often the case that the legitimacy of disciplinary, professional, or practice areas are also at stake. For this reason, science team leaders should be especially mindful of the critical role that conflict management plays in facilitating effective team processes and knowledge integration.

Proposition 13: Conflict management skills by leaders and members can help minimize the conflicts that arise within science teams to foster collaboration and knowledge generation.

Affective Management

Stokols et al., (2005) reveal cyclical patterns of affective experiences, ranging from positive to negative, among members of transdisciplinary science teams over the course of their collaboration. Calibrating the emotional levels of team members may be a key social process that can affect integrative capacity. Research suggests that a negative emotional climate can hinder cognitive processing (Isen, Daubman, & Nawicki, 1987), which is critical for knowledge integration and creation. Specifically, negative affect may result in premature cognitive closure, which could result in the failure to see or make useful connections between disparate knowledge. When people perceive or interpret stimuli as a threat, such as evaluative feedback from diverse teammates (Stephan & Stephan, 1985, 1996), negative affect may arise. In contrast, positive affect is thought to lead people to see relatedness and interconnections among thoughts and ideas and to process material in a more integrated and flexible fashion (Isen et al., 1987; Isen & Daubman, 1984). In addition, others have found that positive affect, such as trust, can lead to knowledge exchange and shared understanding (Sonnenwald, 2003). In science teams, the facilitation of a positive emotion through affect management might facilitate the experience of flow, which arises from the shared intrinsic pleasure of working on a challenging problem (see Csikszentmihalyi, 1994), which in turn helps teams generate knowledge that is integrative and novel.

Proposition 14: Affect management, such as the facilitation of trust between team members, will foster collaboration and knowledge generation.

Team Identification

Leaders may reduce in-group favoritism and out-group bias and also enhance team members' willingness to consider the contributions of diverse members by creating a common superordinate identity around the team's goals and outcomes (Kane, 2010). Evidence suggests that team member perceptions of group boundaries are not static and that they can be affected by contextual conditions (Gaertner & Dovidio, 2000). When a team identity is salient (e.g., interdisciplinary science team), favoritism toward one subgroup (e.g., discipline or organization) is reduced and one's identity is expanded to include those members originally perceived to be outside of subgroup boundaries. Research also suggests that knowledge shared by an out-group member is more likely to be considered and used when a shared team identity is made salient (Kane, Argote, & Levine, 2005). In science teams where historic intergroup relations between disciplines, professions, and organizations may inhibit the willingness to share and integrate their knowledge, particular emphasis should be placed on establishing shared incentives, a common goal, and a problem definition that requires drawing on the distinctive contributions of each subgroup. Drawing on dual identity theory (Gaertner, Mann, Murrell, & Dovidio, 1989), the simultaneous emphasis on a problem-focused scientific team identity and on members' subgroup identities (e.g., disciplinary or professional), can be effective at reducing intergroup bias because it enables members to see themselves as both part of the problem-focused science team and as a part of their disciplinary or professional group. A consequence of these common and dual identity strategies is that team members will be motivated to draw on their diverse disciplinary, professional, and practice areas to provide the science team with unique perspectives and skills.

Proposition 15: Facilitating dual identification, both with one's own disciplinary, professional or practice area and with the problem-focused science team, can help to facilitate collaboration and knowledge generation.

Pathway 2: Social Integration Processes: Direct Antecedents to Cognitive Integration

In addition to creating favorable psychological states, social integration processes can directly influence whether and how knowledge is integrated within science teams. Differences in training, education, and work-related experiences across members of a science team can shape how they view a task or problem and can result in "representation gaps" (Cronin & Weingart, 2007) or what Postrel (2002) calls, "islands of shared knowledge in a sea of mutual ignorance (p. 303)." The extent to which these representations or mental models are unshared and misaligned with fellow team members can negatively affect members' ability to approach a shared problem from complementary perspectives (Cannon-Bowers, Salas, & Converse, 1983; DuRussell & Derry, 2005), which is critical when seeking to identify points of connection to integrate their diverse perspectives. In this section, we identify how interventions and norms, along with the development of infrastructures and use of technology resources, can help to overcome these challenges to facilitate knowledge consideration, which is an essential first step in the cognitive integration process.

The management of information exchange and process of mutual adjustment requires monitoring of the synchronous and simultaneous activities taking place within the team (Brannick, Prince, Prince, & Salas, 1992), such as knowledge sharing and integration. The formulation and implementation of strategies to facilitate communication and coordination can help overcome the challenges of discovering adequate similarity among participants' cognitive schemas (Okhuysen & Eisenhardt, 2002; Woolley, 1998). As a first step to overcoming these challenges, teams need to identify experts within the team. This is argued to be a critical antecedent to sharing unique knowledge within a team and establishing a transactive memory (Stasser, Stewart, & Wittenbaum, 1995). Okhuysen and Eisenhardt (2002) found that teams were more likely to use and combine knowledge effectively when formal interventions encouraged team members to ask questions about one another's knowledge and to manage their time effectively. Innovation in teams often requires phases of both convergence and divergence; that is, phases where members broadly generate ideas and then narrow down their selection to the best ideas (De Dreu & West, 2001). Paletz and Schunn (2010) suggest that this, too, should be managed such that team members structure interaction to include both convergent and divergent phases, tasks, and processes to facilitate knowledge integration and creation.

Norms for interaction can also help to facilitate the types of coordination processes central to knowledge sharing and consideration. In the study of science teams, researchers note the importance of operating norms, which encourage open communication, respect, inclusiveness, and shared decision making (Stokols et al., 2008b). These authors identify how constructive debate and intellectual engagement help to facilitate effective collaboration in science teams. Similar studies find that teams were better at making decisions when norms for critical thinking were established, compared with norms for consensus (Postmes, Spears, & Cihangir, 2001). Similarly, research at the creative design firm, IDEO, suggests that the firm's success at innovation can be attributed to norms for asking for help, sharing knowledge, and giving help that promotes these behaviors (Hargadon & Sutton, 1997).

In teams that are distally located or operating in different time zones, creating knowledge integration opportunities requires careful structuring of interaction. For example, research suggests that better collaborative outcomes across geographically distributed teams can be attained by carefully configuring the distribution of collaborators (O'Leary & Mortenson, 2010). For instance, better outcomes were achieved when individual investigators engaged in distributed work compared with entire teams of investigators trying to work on the same tasks. Last, a critical factor found to improve communication and collaboration in geographically distributed science teams is their technology readiness. This is described as the extent to which participants have the infrastructure and knowledge to develop and maintain electronic information exchange and coordination across geographic boundaries (Olson & Olson, 2000).

Proposition 16: Formal interventions, norms, and infrastructures to support social interaction in science teams can help to facilitate knowledge sharing.

Cognitive Integration Processes and Knowledge Outcomes

In our model, cognitive integration processes are composed of knowledge consideration, assimilation, and accommodation. Knowledge consideration is the extent to which members take into account and thoughtfully process the knowledge contributions of one another. The consideration of knowledge from others depends not only on the characteristics of the knowledge itself, but also on the source of the knowledge as well. For instance, Kane (2010) found that when different subgroups shared a superordinate identity the knowledge from one was more likely to be considered and used by the other. A common identity was not a critical factor when the benefit of another group's knowledge was obvious. These findings shed light on the importance of team members' willingness to demonstrate the apparent merits of their knowledge contributions when they do not share a common disciplinary, professional, or organizational identity.

After the careful consideration of the knowledge contributions of fellow team members, team members may either assimilate others' knowledge into their own cognitive structures or accommodate one another's knowledge and create new ways of understanding. The process of knowledge assimilation may occur if the new idea fits a person's cognitive schema and is only slightly altered and incorporated into their existing cognitive structure (Marshall, 1995; Piaget, 1952). During assimilation, the cognitive schema itself is not altered; rather knowledge is adjusted to fit an individual's existing knowledge structure (Piaget, 1952). The degree to which knowledge can be assimilated into one's cognitive schema depends on the existing knowledge that a person possesses. We suggest that in a science team, where diverse experts have distinct cognitive representations of a problem or task, individual members will attempt to assimilate new information into their existing knowledge structure (Dougherty, 1992; Weingart, Cronin, Houser, Cagan, & Vogel, 2005). Assimilation depends on the extent to which existing cognitive schemas facilitate the interpretation and comprehension of new ideas, insights and perspectives, which is likely much easier in science teams comprised of homogeneous experts. Multidisciplinary science teams are not homogeneous, and thus it is crucial to establish shared cognitive schemas, which have been shown to be central to the ability of science teams to integrate diverse perspectives (DuRussel & Derry, 2005).

Individuals can also engage in a process of accommodation when new ideas or knowledge cannot be altered to fit within existing cognitive schemas or knowledge structures (Marshall, 1995; Piaget, 1952). Accommodation is a process by which individuals integrate their perceptions, judgments, and opinions to generate new knowledge (Gibson, 2001). It requires making knowledge and interpretive schemas visible to others so that members can better understand one another (Habermas, 1979; Mohrman, Gibson, & Mohrman, 2001). The awareness and understanding of the similarities and differences in knowledge within science teams helps to avoid misunderstandings and foster more in depth consideration of how available knowledge can be accommodated and integrated (Huber & Lewis, 2010).

Assimilation and accommodation both require reflexivity, or the extent to which team members explicitly reflect on their own and the team's knowledge, strategy, and processes (West, 1996). This enhanced reflexivity in science teams can promote knowledge integration and creativity where members are being exposed to new knowledge and perspectives (Choi & Thompson, 2005). For instance, reflexivity can lead to the redistribution of knowledge among team members (West, 1996) and the effective use of knowledge from new team members (Lewis, Belliveau, Herndon, & Keller, 2007). Both of these factors are likely to enhance the likelihood that team members will make novel associations between their ideas and those of fellow teammates (Amabile, Conti et al., 1996; Gilson & Shalley, 2004). As a result, novel and integrated knowledge can emerge from the combination of heterogeneous ideas, perspectives and insights (Amabile, 1996; Argote, Gruenfeld & Naquin, 2001; Moorman & Miner, 1997).

> *Proposition 17*: Reflexivity will enhance both assimilation and accommodation, which facilitate knowledge integration and generation.

The outcomes of science teams seeking to create integrated and novel knowledge will vary depending on the barriers to knowledge integration and their integrative capacity. Without the social integration processes, emergent states, and the cognitive integration processes they facilitate, a team might not be able to transform knowledge when facing inhibitors such as competing goals or distributed work arrangements. Recalling that innovation depends on making novel and unique connections between the knowledge that individual team members possess, we suggest that a low integrative capacity is one that has insufficiently leveraged individual resources to generate knowledge at the team level. Specifically, absent or ineffective social and cognitive integration processes can hinder knowledge integration. This, in turn, can hinder individual creativity (Woodman, Sawyer, & Griffin, 1993) and limit the potential for making connections between heterogeneous knowledge at the team level (De Dreu & West, 2001; Hargadon & Sutton, 1997). As a result, the knowledge produced may be complimentary, rather than integrative.

In contrast, when the level of integrative capacity is high, the likelihood of connecting diverse knowledge, insights, ideas, and perspectives will be high. Exposure to different backgrounds, approaches, and perspectives can stimulate divergent and flexible thinking (Coser, 1975; Granovetter, 2005), and it may not only enhance the team's innovativeness, but also that of individual members. This, in turn, can lead to the development of novel ideas and innovations within the team (e.g., Amabile, 1983; De Dreu & West, 2001; Watson, Kumar, & Michaelson, 1993). A team with a high integrative capacity has greater potential to create novel knowledge that is not only integrated, but also extends the state of the science and opens up new areas of investigation.

Proposition 18: By helping to overcome barriers to collaboration, high integrative capacity will lead to enhanced innovation in science teams compared with teams with low integrative capacity.

Pathway 3: Integrative Capacity as a Dynamic Capability

Finally, we suggest that continuous collaboration provides opportunities to regularly improve on and refine social and cognitive integration processes to improve integrative capacity over time. Through the promotion of psychological states that facilitate effective interaction among diverse team members, such as shared trust, identity, and understanding, science teams enhance their potential to integrate and create knowledge. As social and cognitive integration at the team level evolves, it in turn affects subsequent social and cognitive processes and the psychological states within the science team. Thus, integrative capacity can develop and increase over time.

Proposition 19: A team's integrative capacity can develop and improve over time through shared collaborative experience.

Discussion

Science teams share characteristics with many other types of teams that seek to draw together members with diverse backgrounds to accomplish a common purpose. However, the magnitude and combinatory affect of these characteristics is often significantly different in science teams. Thus, the opportunities as well as barriers to knowledge integration are often much greater and difficult to surmount. For instance, the formation of a problem-focused team comprised of members from diverse disciplinary and practice areas requires team members to adjust allegiances with their disciplinary and professional areas and to consider alternative perspectives, approaches and methods. In addition, the task of reaching a common conceptualization of a problem and identifying a shared goal is often difficult when team members have spent many years approaching their work in a way that aligns with their own training and education. Threats to power, legitimacy, and control can arise among team members, requiring that these teams have the ability to overcome these barriers to reach their potential.

This article argues that a team will have the most potential to successfully integrate and create knowledge when it possesses integrative capacity—an enduring capability at the team-system level—to work across disciplinary, professional, and organizational divides to generate new knowledge. This capability is sustained through the continuous interplay of social, psychological, and cognitive processes within a team. Over time, the development of this capability provides teams with the ability to overcome challenges that science teams face due to their unique team composition, task, and contextual environment. Depending on the extent to which barriers to cognitive integration exist, we suggest that a science team's potential to integrate knowledge and generate novel outcomes will be predicated on their collective level of integrative capacity.

As a capability and a potential at the team level of analysis, we suggest integrative capacity relies not on any individual team member, but on the interaction of the social, psychological, and cognitive systems within the team. Throughout this manuscript we present several opportunities for investigating the affect of various social processes that can affect cognitive processes (e.g., knowledge assimilation and accommodation) and psychological states (e.g., trust and shared identity). We also posit that cognitive processes can, in turn, affect social processes (e.g., knowledge sharing) and psychological states (e.g., shared understanding and perspective taking). Further empirical investigation of these relationships and their effect on knowledge integration are encouraged and necessary for the advancement of our understanding of how to support knowledge generation in science teams.

The capability to integrate knowledge across specialized communities of work and practice in science teams can foster innovation or facilitate the generation of new knowledge. Drawing on the definition of a dynamic capability as a learned pattern of collective activity that a team or organization can draw on in the pursuit of improved effectiveness (Zollo & Winter, 2002), we posit that integrative capacity may be a source of competitive advantage for science teams. The ability to adapt, integrate, and reconfigure knowledge from across disciplines can help to create cutting-edge outcomes that will differentiate those science teams with an integrative capacity from those who do not. Moreover, the unique configuration and interaction among social, cognitive, and psychological states within a team may function as an inimitable resource that other teams may not be able to replicate to produce the same results.

Conclusion

Integrative capacity enables teams to make connections between experts, ideas, and approaches to answering complex scientific problems. The social integration processes outlined in this article facilitate emergent states and cognitive integration processes that facilitate knowledge integration and creation of novel outcomes. Ongoing investment in integrative capacity, in the form of empirical research, evaluative metrics, and team training, is needed to ensure science teams have the critical skills necessary to harness the potential benefits that can be derived from their diversity. We argue that this is particularly the case for compositionally diverse science teams where team and task inhibitors, along with external organizational, interorganizational and environmental forces, that pose barriers to integrating knowledge across disciplinary, professional, sector, and organizational boundaries.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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