Virtuality and Team Science

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Abstract

Building on Kirkman, Gibson, and Kim’s (2012) recent virtual organizational teams review, I extend their work by examining the virtual organizational team research published since the conclusion of their study and integrating it with the smaller (but growing) research on the science of science teams. The aim of the integration is to improve virtual science team effectiveness by determining what elements of the virtual organizational teams literature can be generalized to the virtual science teams field. I highlight the applicability of Kirkman et al.’s (2012) five major themes from their review (i.e., issues related to virtuality and geographic dispersion; team development over time; virtual team leadership; levels of analysis; and multi-disciplinary approaches) to virtual science teams (also relying on Falk-Krzesinski et al.’s, 2011, seven critical research areas for the science of team science). I also provide practical recommendations for approaches to support effective virtual collaboration for science teams, drawing specifically on the differences between these teams and virtual organizational teams. I conclude with research recommendations to improve our understanding of how to effectively approach and organize virtual collaboration for science teams.
Virtuality and Team Science

In February of 2013, Marisa Mayer, CEO of Yahoo, made a startling announcement regarding Yahoo’s policy on working remotely and virtually:

“To become the absolute best place to work, communication and collaboration will be important, so we need to be working side-by-side…That is why it is critical that we are all present in our offices.” (http://money.cnn.com/2013/02/25/technology/yahoo-work-from-home/index.html)

An announcement such as this, from a well-known high technology company (in Silicon Valley no less), instituting a policy essentially banning telecommuting and virtual teamwork beginning June 1, 2013, flies in the face of the increasing trends toward working virtually over the last two decades. While various reasons for the policy have been debated, Ms. Mayer’s stated rationale for invoking the change is that “People are more innovative when they’re together.” (http://www.dailymail.co.uk/femail/article-2311875/People-innovative-theyre-Yahoo-CEO-Marissa-Mayer-finally-addresses-unpopular-work-home-ban.html).

While the full repercussions of Ms. Mayer’s policy change at Yahoo are not currently known (although it should be noted that in August 2013, Yahoo surpassed Google in the level of web traffic), such a reversal in the trend toward virtual working based on a belief that innovation occurs primarily as a result of face-to-face (FTF) contact has direct implications for science teams. Science teams are defined as collections of interdependent individuals that combine specialized expertise, theoretical approaches, and research methods across disciplinary boundaries to solve complex problems and produce high-impact science (Borner et al., 2010). Science teams are typically formed to address the “inherent complexity of contemporary public health, environmental, political, and policy challenges…and the realization that an integration of
multiple disciplinary perspectives is required to better understand and ameliorate these problems” (Stokols, Misra, Moser, Hall, & Taylor, 2008, as cited in Falk-Krzesinski et al., 2011, p. 145). As such, science teams are often charged with generating new knowledge, scientific discovery, and breakthrough innovations (Jones, Wuchty, & Uzzi, 2008; see Olson, Zimmerman, & Bos, 2008, for examples of these team types).

Given that science teams are also often interdisciplinary (note that even though I adopt Fiore’s, 2008, use of the term interdisciplinary, rather than multidisciplinary or cross-disciplinary, to connote a true systematic integration of ideas, some science teams may also be purposefully multi- or cross-disciplinary in nature), globally diverse, and geographically dispersed, science team members rely heavily on electronically-mediated communication and work tools to carry out their tasks (I will refer to these types of science teams as “virtual” science teams hereafter) (Olson et al., 2008). One limitation of the existing research on virtual teams more generally is that most previous research and reviews have focused almost exclusively on organizational/business virtual teams (Kirkman, Gibson, & Kim, 2012; Martins, Gilson, & Maynard, 2004) without addressing the unique aspects of teams composed mainly of scientists. As a result, little is known about how the findings from organizational research generalize to these specific types of science teams. And, in a parallel problem exacerbating the lack of knowledge transfer between fields, those in the sciences have not yet attempted to fully integrate the large amount of knowledge contained in the organizational psychology and organizational behavior literatures about the factors leading to virtual team success (Fiore, 2008).

As a result of these limitations and questions, my purpose is to extend Kirkman et al.’s (2012) recent review of the literature on virtual organizational teams to address the extent to which findings from organizational research generalize to virtual science teams. Key questions
addressed in this review include: (a) what factors at the team, center, or institute level (e.g., team size, team membership, geographic dispersion) influence the effectiveness of virtual science teams; and (b) how do different management approaches and leadership styles influence the effectiveness of virtual science teams? The paper is organized as follows. First, I present a general overview of how the review was conducted. Second, I distinguish between virtual organizational teams and virtual science teams on eight dimensions to help frame the discussion on the generalizability of virtual organizational teams to virtual science teams. Third, I present the major themes emerging from the review followed by how these themes relate specifically to virtual science teams (and, as will be discussed in this section, I use Falk-Krzesinski et al.’s, 2011, research agenda for science teams to assist with integration of virtual organizational and science teams). Fourth, I provide practical recommendations for approaches to support effective virtual collaboration for science teams, drawing specifically on the differences between these teams and virtual organizational teams. Finally, I conclude with research recommendations to improve our understanding of how to effectively approach and organize virtual collaboration for science teams.

Overview of the Review of the Virtual Teams Literature

The review used to generate themes in this paper was based on an extension of the recent review by Kirkman et al. (2012). I used the exact same methodology to extend the earlier review (which covered scholarly journal articles published from 1986 through 2008) to the present date (June, 2013). Therefore, I used library search engines such as ABI-Inform and EbscoHost as well as Google Scholar, and I searched high quality empirical journals within the fields of management (e.g., *Academy of Management Journal, Administrative Science Quarterly, Organization Science*), psychology (e.g., *Journal of Applied Psychology, Personnel Psychology,*
Small Group Research), information technology (IT)/information systems (IS) (e.g., MIS Quarterly, Information Systems Research, Journal of Management Information Systems), and communication (e.g., Journal of Communication, Communication Monographs, Human Communication Research). I also searched for articles, chapters, and books on science teams and virtual science teams in various outlets and incorporated those key publications recommended by members of the National Research Council. Similar to Kirkman et al. (2012), I omitted research in related fields such virtual gaming, virtual reality, immersive collaborative virtual environments (e.g., Second Life), online communities, research related to technology acceptance in the IT field or individual differences related to communication media preferences in the communication field, thus restricting the review to virtual teams and groups. For a detailed description of the original 197 articles contained in their review, please see Kirkman et al. (2012).

Incorporating the review framework found in Kirkman et al. (2012), I also relied heavily on the four key elements found in an updated version of the classic input-process-output (IPO) framework (Hackman & Morris, 1975; McGrath, 1984) applied in hundreds of team studies over the last few decades (see Mathieu, Maynard, Rapp, & Gilson, 2008, for a review). Rather than restricting the mediators in the IPO model to only team processes, Ilgen, Hollenbeck, Johnson, and Jundt (2005) argued for a more inclusive input-mediator-output (IMO) framework, with the “M” (i.e., mediator) portion of the model encapsulating both team processes as well as emergent states. As I will refer to inputs, processes, emergent states, and outputs throughout the manuscript, I provide definitions of each term here.

Inputs are often referred to as factors that are controllable by organizations such as leader behaviors, team composition, human resource policies, and job design. Team processes are
“interdependent team activities that orchestrate taskwork in employees’ pursuit of goals” (Marks, Mathieu, & Zaccaros, 2001, p. 358). Emergent states are defined as “constructs that characterize properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes” (Marks et al., 2001, p. 357). Team outputs include organizationally relevant outcomes such as performance (e.g., quality, productivity), attitudes (e.g., job satisfaction, organizational commitment), and behaviors (e.g., turnover, absenteeism) (Cohen & Bailey, 1997). Importantly, many of the above inputs, processes, emergent states, and outputs can be applied to science teams as well as organizational teams.

Virtual Organizational vs. Science Teams: What are the Key Differences?

In what will be a key theme for the remaining parts of this manuscript, there are several key differences between virtual organizational and science teams that influence the ability to generalize from the review of virtual organizational teams to those that are more scientific in nature. As Table 1 shows, I argue that there are eight key dimensions on which virtual organizational and science teams can be differentiated. For example, compared to virtual organizational teams, virtual science teams are typically characterized by: (1) time horizons that are longer rather than shorter; (2) leadership that is facilitative and shared rather than formal and directive; (3) membership boundaries that are permeable rather than stable; (4) work that is focused on knowledge sharing and idea generation rather than problem-solving and job tasks; (5) interdependence that is low to moderate rather than high; (6) structures that are emergent rather than designed; (7) accountability that is enforced by internal, social sanctions rather than external, formal sanctions; and (8) interdisciplinary rather than low to moderate discipline heterogeneity.

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Insert Table 1 about here
It should be clear (as Table 1 shows) that these differences do not represent an “either-or” classification but more of a continuum on which virtual teams range from more organization-like to more science-like. As such, some virtual science teams can actually resemble typical virtual organizational teams and vice-versa (Bietz et al., 2012). And, certainly, virtual organizational and science teams can vary within their own specific dimensions and classifications found in Table 1. However, again, these differentiating dimensions will be used to guide how the research on virtual organizational teams can be applied to virtual science teams in the remaining sections of this review.

**Major Themes Emanating from the Review and Relevance to Virtual Science Teams**

Kirkman et al.’s (2012) comprehensive review of the virtual teams literature yielded five major themes including: (a) issues related to virtuality and geographic dispersion; (b) team development over time; (c) virtual team leadership; (d) levels of analysis; and (e) multidisciplinary approaches. Importantly, reviewing articles published between 2009 and 2013 did not produce significant additions to these major themes. Additional articles found served to emphasize or reinforce the themes identified in their previous review.

Interestingly, in their recent article focused on mapping a research agenda for the science of team science and using a concept-mapping methodology with a variety of team science stakeholders, Falk-Krzesinski et al. (2011) identified seven research areas critical to the future of better understanding the science of team science (including virtual science teams). The seven areas included: (a) measurement and evaluation of team science; (b) structure and context for teams; (c) characteristics and dynamics of teams; (e) management and organization of teams; (f) institutional support and professional development for teams; (g) disciplinary dynamics and team
science; and (h) definitions and models of team science. Fortunately, five of the seven dimensions of future research on science teams map onto the five areas identified by Kirkman et al. (2012) as critical for better understanding organizational virtual teams. As a result, I will briefly summarize each of the five major themes from Kirkman et al. and follow each summary with specific implications for virtual science teams using Falk-Krzesinski et al.’s science team research areas. Thus, implications for virtual science teams will be achieved by integrating a review of the much smaller (but growing) literature on science teams.

*Brief Summary of Theme #1 – Virtuality/Geographic Dispersion.* Kirkman et al. (2012) conclude that there has been a continuing pattern of comparing completely virtual and completely FTF teams, mainly in laboratory settings, with only a modest degree of theoretical advancement emanating from these studies. While the earliest studies of virtual teams may have benefited from artificially creating these two conditions at opposite ends of a virtuality spectrum to begin to understand the basic differences between these two types of teams, all researchers now agree that entirely virtual or entirely FTF teams rarely exist today (Bell & Kozlowski, 2002; Griffith, Sawyer, & Neale, 2003; Kirkman & Mathieu, 2005; Martins et al., 2004). As a result, researchers are paying increasing attention to the construct of virtuality, or the degree to which a team is more or less virtual.

While little consensus has emerged on the exact conceptualization or specific dimensions of virtuality, one dimension common to all existing virtuality constructs is the degree of electronic communication dependence among team members (Chudoba, Wynn, Lu, & Watson-Manheim, 2005; Gibson & Gibbs, 2006; Gibson, Gibbs, Stanko, Tesluk, & Cohen, 2011; Griffith et al., 2003; Kirkman & Mathieu, 2005; Schweitzer & Duxbury, 2010; see Stanko & Gibson, 2009, for a review). While some researchers also include geographic dispersion as another
important dimension of virtuality (e.g., Chudoba et al., 2005; Gibson & Gibbs, 2006; Griffith et al., 2003; Schweitzer & Duxbury, 2010), others rely exclusively on electronic communication dependence (e.g., Gibson et al., 2011; Stark & Bierly, 2009) or view dispersion as an antecedent to virtuality (Kirkman & Mathieu, 2005); that is, the degree of physical separation positively influences the extent to which team members rely on electronically-mediated communication.

For example, in addition to the extent of reliance on electronic communication forms, Kirkman and Mathieu (2005) include the informational value (e.g., communication richness) and synchronicity of the communication tools as additional dimensions of virtuality. A team that relies heavily on an asynchronous communication tool of low informational value (e.g., email) would be considered more virtual, while a team that relies heavily on a synchronous communication tool of high informational value (e.g., videoconferencing) would be considered less virtual. Thus, using this conceptualization, the classification of a team as more or less virtual does not necessarily depend on geographic dispersion. Indeed, Gibson et al. (2011) found that perceived electronic dependence and co-presence were only moderately correlated, suggesting that collocated team members often rely heavily on technology-mediated communication, and geographically dispersed ones may rely predominantly on FTF meetings.

In a recent meta-analysis of Kirkman and Mathieu’s (2005) three-dimension conceptualization of virtuality, Mesmer-Magnus, DeChurch, Jimenez-Rodriguez, Wildman, and Schuffler (2011) examined virtuality as a moderator of information sharing and team performance. They found that team virtuality increases the sharing of more unique information but decreases the overall openness of information sharing; unique information sharing is more important for FTF teams than open information sharing, whereas open information sharing is more important to virtual teams than unique information sharing; and the effects of virtuality on
information sharing are curvilinear, such that at low levels of virtuality, informing sharing is improved, but at high levels it is hindered.

Whether geographic dispersion is considered a part of the conceptualization of virtuality or an antecedent, researchers have made considerable progress understanding the exact nature of geographic dispersion as well as its effects (Cramton & Webber, 2005; Olson & Olson, 2000). For example, moving beyond the commonly used Euclidean distance measure of geographic dispersion (e.g., Gibson & Gibbs, 2006), O’Leary and Cummings (2007) conceptualized geographic dispersion along three distinct dimensions including: spatial (i.e., geographic distance among team members); temporal (i.e., time difference among team members); and configurational (i.e., location where team members work including the uneven distribution of team members). The authors theoretically argued that each dimension will likely influence team outcomes in different ways, have different antecedents, and may play different roles at different times during a team’s lifecycle.

In support of their contention, using a sample of virtual teams in a Fortune 500 semiconductor manufacturing organization, Cummings, Espinosa, and Pickering (2009) found that time-zone and spatial dispersion were both positively related to coordination delays, and that desktop synchronous communication (and, opposite to their prediction, asynchronous email communication) reduced coordination delays more when teams had overlapping vs. non-overlapping work hours; and Espinosa, Cummings, and Pickering (2012) found that time-zone dispersion was more strongly negatively related to team performance than spatial dispersion, and that the effects of time-zone dispersion were mediated by team coordination (i.e., time-zone dispersion reduces coordination which, in turn, hurts team performance).
Implications of Research on Virtuality/Geographic Dispersion for Virtual Science Teams.

Using Falk-Krzesinski et al.’s (2011) map of a research agenda for the science of team science, the virtuality/geographic dispersion theme from Kirkman et al.’s (2012) review most closely aligns with their structure and context for teams theme. For example, drawing from a list of representative topic statements on the structure and context for teams theme, the authors include such statements as “the network characteristics of productive science team members and subgroups,” “how research networking tools can enhance team science,” and “whether collaborative spaces for team science encourage collaboration.” Statements such as these all relate very closely to the technology-based aspects of virtuality as well as to the challenges introduced by geographic dispersion.

Based on Falk-Krzesinski et al.’s (2011) structure and context for teams theme, there are several implications for virtual science teams emerging from the virtual organizational team research on virtuality and geographic dispersion. First, because information sharing is at the heart of most virtual science team activities (Olson et al., 2008), the research on the relationship between virtuality and information sharing is critical. For example, Mesmer-Magnus et al.’s (2011) finding that virtuality increases the sharing of unique information but, ironically, decreases the openness of information sharing suggests that increased virtuality could be a “double-edged sword” for virtual science teams. On the one hand, since virtual science teams are typically interdisciplinary in nature, they rely heavily on team members’ ability to share unique (i.e., non-overlapping) information. So, in that sense, increasing levels of virtuality can actually assist virtual science teams in their primary focus on unique information sharing.

On the other hand, increasing virtuality actually decreases the openness of information sharing, which could harm virtual science team performance. Complicating matters is Mesmer-
Magnus et al.’s (2011) finding that unique information is actually more important for FTF teams, whereas open information sharing is more important for virtual teams. Consequently, the fact that higher levels of virtuality decrease open information sharing, coupled with the fact that open information sharing is more important in virtual teams, represents a potential “double whammy” effect for virtual science teams. That is, increasing virtuality actually reduces open information sharing, which Mesmer-Magnus et al. (2011) find is absolutely critical for virtual teams. The positive effects of virtuality on unique information sharing may not be realized because this type of sharing is less important for virtual, compared to FTF, science teams. While research by Walther and colleagues (e.g., Walther, 1995; see Kirkman et al., 2012, for a full review of their work) has demonstrated that computer-mediated communication may not actually harm the transmission of relational (i.e., interpersonal) communication as much as once thought, other research has challenged this more positive view (e.g., Stanton et al., 2010). Importantly, increasing virtuality may be more problematic in virtual science teams, specifically, due to the types of information needed by these teams.

Second, Gibson and Gibbs (2006) found that geographic dispersion was negatively related to innovation in a study of aerospace engineering teams. Using a multi-dimensional measure of geographic dispersion, Cummings et al. (2009) found that time-zone and spatial dispersion increased coordination delays in virtual teams. Because coordination of divergent viewpoints, backgrounds, and information is critical in an interdisciplinary virtual science team environment (Cummings, Kiesler, Zadeh, & Balakrishnan, in press; Hinnant et al., 2012; Stvilia et al., 2011), the negative effects of geographic dispersion on these types of teams is likely to be exacerbated. These findings reinforce Yahoo’s Marisa Mayer’s statements that suggest that physical dispersion harms the innovation process.
One of the major questions of interest here is whether increasing virtuality and geographic dispersion is likely to harm the performance of virtual science teams as has been found in organizational virtual teams. Based on this review, the answer to this question is likely to be a resounding “yes.” Indeed, Cummings and Kiesler (2005) examined a set of interdisciplinary National Science Foundation sponsored projects finding that, on average, distributed team projects performed worse than FTF ones. The main reason for such difficulties is that virtual science teams represent a more complex and dynamic form of virtual teaming than is traditionally found in organizational settings (cf. Fiore, 2008). The typical interdisciplinary composition of virtual science teams, team members often being housed and affiliated with a wide variety of distinct institutions (e.g., universities, research centers, etc.), more permeable team boundaries, emergent structures, and long time horizons (see Table 1) means that disruptions to innovation and coordination so critical to virtual science teams are highly likely to occur with increasing levels of virtuality and geographic dispersion, even more so than for virtual organizational teams (Agrawal & Goldfarb, 2006; Olson et al., 2008).

While the research on virtual organizational teams certainly suggests that virtual science teams are particularly vulnerable to process losses due to increasing virtuality/geographic dispersion, the very same research points to possible solutions. For example, Gibson and Gibbs (2006) found that teams that had a climate of psychological safety were able to overcome the decrements in innovation caused by high levels of geographic dispersion. Psychological safety is defined as the degree to which a collective is perceived as being safe for interpersonal risk-taking (Edmondson, 1999). Kirkman, Rosen, Tesluk, and Gibson (2004) found that teams with high levels of virtuality had higher levels of team learning to the extent that the teams were empowered, defined as increased task motivation due to team members’ collective, positive
assessments of their tasks within an organizational context (Kirkman & Rosen, 2000). Kirkman, Rosen, Tesluk, and Gibson (2006) also found that virtual team trust was a key determinant in whether virtual team training actually transferred to team outcomes such as customer satisfaction. While those who study trust in virtual organizational teams have consistently demonstrated its importance for team success (Jarvenpaa & Leidner, 1999; Jarvenpaa, Knoll, & Leidner, 1998), those researching virtual science teams, specifically, have suggested that establishing and maintaining trust is also absolutely critical for this team type (Jirotka, Lee, & Olson, 2013). I discuss specific ways to enhance psychological safety, team empowerment, and trust in virtual science teams in the practical recommendations section below.

Similarly, Cummings et al. (2009) found that the coordination delays created by both time-zone and spatial dispersion were actually reduced if the team members relied more heavily on desktop synchronous communication (and also, surprisingly, email communication) when the teams had a higher level of overlapping work hours. This solution bodes well for virtual science teams whose members are in the same (or similar) time zones and reinforces Walther’s (1995) finding that electronic communication does not harm the amount or quality of relational communication. However, for those teams that have members more spatially dispersed across numerous time zones, disruptions to coordination may be more difficult with which to deal.

**Brief Summary of Theme #2 – Team Development.** The study of team development involves examining how teams and their members develop as a team over time, necessitating the use of longitudinal studies. Unfortunately, as Kirkman et al. (2012) conclude, there has been very little progress made in regards to the study of virtual team development over time. One of the most important conclusions emanating from their review is that even though one study found that virtual teams followed the same developmental stages as FTF teams (Bordia et al., 1999), the
bulk of existing research demonstrates that most virtual teams do not follow the most widely known and studied existing models of team development such as Tuckman’s (1965) forming-storming-norming-performing-adjourning model or Gersick’s (1988) punctuated equilibrium model (Johnson, Suriya, Yoon, Berrett, & La Fleur, 2002; Maznevski & Chudoba, 2000). Rather than the linear models typical of FTF teams, Kirkman et al. (2012) found that virtual team development is described as non-linear and dependent on additional elements of team functioning such as communication media used (Nemiro, 2002), temporal coordination mechanisms (Massey, Montoya-Weiss, & Hung, 2003), transactive memory systems (Kanawattanachai & Yoo, 2007), and the alignment between organizational environment, group structure, and technology (Majchrzak, Rice, Malhotra, King, & Ba, 2000).

In an in-depth case study of virtual team development, and consistent with the team developmental work of Marks et al. (2001), Maznevski and Chudoba (2000) found that virtual teams develop by moving through repeated temporal patterns of periodic FTF meetings during which interaction intensity is extremely high (i.e., action), followed by a period of a few weeks in which interaction is less intense (i.e., transition). Ratcheva and Vyakarnam (2001) found that virtual teams follow self-energizing developmental processes that are non-linear and inconsistent with prevalent FTF team developmental models.

*Implications of Research on Team Development for Virtual Science Teams.* Using Falk-Krzesinski et al.’s (2011) map of a research agenda for the science of team science, the team development theme from Kirkman et al.’s (2012) review most closely aligns with Falk-Krzesinski et al.’s *characteristics and dynamics of teams* theme. For example, drawing from a list of representative topic statements on the characteristics and dynamics of teams theme, the authors include such statements as “issues to consider when initiating or building a new team,”
and “how teams grow, shrink, and expire over time.” Statements such as these all relate very closely to the manner in which virtual science teams develop over time.

Given the often higher levels of complexity inherent in virtual science teams due to high levels of interdisciplinarity (Sá, 2007), different member affiliations, long time horizons, permeable member boundaries, and emergent team structures, a case could certainly be made that virtual science team development is likely to be even more non-linear and “messy” than virtual organizational teams. However, whether virtual science team development is likely to be more (or less) complex than virtual organizational teams is not straightforward and may depend on other elements present in these teams. Indeed, there may exist, a priori, standard protocols, routines, norms, and practices for some virtual science teams. For example, if an academic science team is conducting research and writing an article to submit to a journal that has a generally accepted set of these types of standards across all team members, then the typical storming and norming stages characteristic of some organizational teams (Tuckman, 1965) may not occur because the norms for productive team action are already in place and accepted by team members. Similarly, the stage of inactivity characteristic of many organizational project teams, particularly in the first half of a team’s life span (Gersick, 1988), may also not be realized due to existing norms and protocols inherent in academic research.

However, if a particular virtual science team is highly interdisciplinary in nature, norms for productive teamwork might not already exist. Keeping with the example of an academic science team, different fields may have widely different expectations and norms for how research should be conducted and how results should be written up for an article. Thus, team development is likely to be prolonged in such a team and may exhibit the type of non-linearity found in the some of the previous research on virtual organizational team development. Such a phenomenon
is consistent with Cummings et al.’s (in press) findings about the difficulties that large, heterogeneous science teams have with productivity losses due, perhaps, to difficulties reaching a positive team development cycle. In summary, the nature of team development in virtual science teams largely remains an empirical question, as Kirkman et al. (2012) concluded about organizational virtual teams.

**Brief Summary of Theme #3 – Virtual Team Leadership.** While virtual team leadership has been referred to as “the number one key success factor for virtual teams” (Blackburn, Furst, & Rosen, 2003, p. 102), Kirkman et al. (2012) conclude that not enough has been done to truly understand the role of leaders of virtual teams. Previous research has primarily applied leadership theories from dyadic (i.e., one-on-one), FTF leadership models, such as transformational leadership (e.g., Hambley, O’Neill, & Klein, 2007; Sosik, Avolio, & Kahai, 1998), without a true understanding of how these dyadic theories apply to virtual team leadership, and team leadership more broadly. Two studies did find support for shared leadership in virtual teams (Carte, Chidambaram, & Becker, 2006; Johnson et al., 2002), or leadership that is distributed among team members themselves with various members taking on leadership roles for different tasks and/or at different points in time. Such findings support the notion that geographic dispersion may necessitate more distributed forms of leadership (Kirkman et al., 2012). Because virtual teams represent such a different and unique form of teaming, novel leadership theories will have to be developed in order to truly understand the key aspects of virtual team leadership (see Schiller & Mandviwalla, 2007, for a discussion of theories that have been applied in virtual teams research). Kirkman et al. (2012) also suggest that researchers will need to develop contingency based virtual team leadership models to discover key leadership
behaviors (see Carte et al., 2006), and that this approach will make research offering lists of virtual team leader behaviors obsolete.

**Implications of Virtual Team Leadership for Virtual Science Teams.** Using Falk-Krzesinksi et al.’s (2011) map of a research agenda for the science of team science, the team leadership theme from Kirkman et al.’s (2012) review most closely aligns with Falk-Krzesinski et al.’s *management and organization for teams* theme. For example, drawing from a list of representative topic statements on the management and organization for teams theme, the authors include such statements as “the management of scientific teams,” “value of rotating team leadership,” and “formal vs. informal organizational structures of institutions.” Statements such as these all relate very closely to the manner in which virtual science teams are lead.

One of the key research questions introduced earlier in this manuscript was how do different management approaches and leadership styles influence the effectiveness of science teams? Based on Kirkman et al.’s (2012) virtual organizational teams review, it should be very clear that the leadership of virtual science teams is one of the most important, if not the most important, elements in whether or not these teams live up to their full potential. Commenting on the science of team science and quoting Stokols et al. (2006, p. 21), Fiore (2008, p. 260) stated, “One of the high-priority directions outlined for the science of team science was to ‘examine the impact of interpersonal processes and leadership styles on scientific collaboration.’” Fiore (2008) also discusses the role played by a single, formal leader of a science team versus the notion of shared leadership.

For example, Fiore (2008) notes Stokals et al.’s (2006) argument that science teams require strong leaders, particularly those with a collaborative orientation that can both use team building to enhance cohesion but also help their teams through the often-difficult conflict
management process required of most teams. So, on the one hand, Stokals et al. seem to imply that science teams would be best served with an active, involved, formal leader who takes most of the leadership responsibility onto him or herself. On the other hand, Fiore (2008, p. 270) states, “The notion of shared leadership also fits well in the context of science teams in that it can sometimes be more effective than the more typical forms of vertical leadership (see Pearce & Sims, 2002).” These two perspectives suggest that there may be conflicting advice given to virtual science teams; that is, should these teams have a single, formal leader who exhibits most of the leadership for the team or should leadership activities be shared and distributed among different members of the team as various team needs arise and shift around?

Based on Kirkman et al.’s (2012) review and the complex nature of interdisciplinary virtual science teams, the answer is likely to be both. Supporting the need for the presence of a formal leader, complex teams that operate virtually typically benefit from an active, involved leader who supports the team in a variety of ways (Malhotra, Majchrzak, & Rosen, 2007). Rather than a dictator or micro-manager, a formal virtual science team leader serves a resource getter, barrier buster, champion, and sponsor of this team type (Spencer, Zimmerman, & Abramson, 2011; Williams, 2002). Thus, a formal leader would perform most of the “external” leadership duties needed by a virtual science team. Virtual teams of any type, because members are not frequently FTF for any length of time, are more susceptible to the loss of goal clarity, motivation, and vision that are all critical for team success (Kirkman, Rosen, Gibson, Tesluk, & McPherson, 2002). A single, formal leader can help to keep a virtual science team “on track,” particularly when these teams are interdisciplinary and global in nature. Thus, the findings of this review suggest that a formal designated leader will be critical to the success of a virtual science team.
A caveat to the recommendation that virtual science teams should have a formal leader (just like virtual organizational teams) is that a key difference between the science versus organizational virtual team type is that in the former type, leaders may not have much (or any) formal authority over the team, particularly if a leader emerges from the team based on expertise for a given project. So, even though a formal leader is desirable in a virtual science team, that leader will have to rely on certain leadership skills to a greater extent than those with formal authority such as persuasion, negotiation, influence, and empowering skills. Getting things done without formal authority (i.e., managing as if you have no power) in a virtual science team will present unique challenges not encountered by most virtual organizational teams. I elaborate on best practices for virtual science team leaders in the practical recommendations section below.

In addition to the external leadership duties that are so critical for virtual science team success, there are many internal leadership duties to be performed (e.g., agenda setting, meeting minutes, facilitator, coach, time keeper, scheduler, etc.). The need to successfully perform these duties suggests that shared/distributed leadership will be critical in virtual science teams. Rotating various leadership tasks will also enhance the skill set of the various team members meaning that these broader skill sets can be “transferred” to future team experiences. The need for shared/distributed leadership is even greater in virtual science teams (compared to many organizational virtual teams) because the former type are more likely to be interdisciplinary and thus have members with few overlapping skills, knowledge, or expertise. The very high level of complexity and the presence of team members with non-overlapping, complementary knowledge and skills means that, at different times, different members will have to take on a leadership role for tasks that are applicable to his/her specific area of expertise.
The need for both a formal, external leader of a virtual science team and internal leaders who share leadership duties among one another introduces the problem of external vs. internal leader conflict in virtual science teams. In order to minimize such conflict and maximize the benefits of shared leadership (both between the external and internal team leaders and between the internal team leaders themselves), there has to be agreement between all leaders as to which responsibilities are those of the external leader and those of the internal leaders and, also, which responsibilities belong to which internal team member at what time. Expectations should be established about the duration of the various internal leadership roles, how these roles will be rotated and transitioned between team members, and how leadership success should be measured. As discussed below in the practical recommendations section, a formal team charter established at the beginning of a team’s lifespan can help delineate specific leadership responsibilities.

*Brief Summary of Theme #4 – Levels of Analysis.* Despite the growing interest in the management and psychology literatures to examine organizational phenomena at multiple levels of analysis as well as relationships across levels, virtual organizational teams research has largely not been conducted in this manner (Kirkman et al., 2012). Not surprisingly, most of the research on virtual organizational teams has been conducted at the team level of analysis. Conspicuously absent in the virtual organizational teams literature is attention devoted to the individual level of analysis, despite the fact that there is a rich track record of such research in the FTF teams literature (Cohen & Bailey, 1997; Kozlowski & Bell, 2012; Mathieu et al., 2008). One line of research that could prove promising is attempting to understand the individual differences that make certain people more or less suited for virtual teamwork. For example, Shin (2004) theoretically argued that willingness to trust, trustworthiness, lateral skills, and virtual
communication skills should all be related to person-group fit in virtual teams. And, because many virtual teams are composed of people from different nations, another conspicuously absent line of research is any attention to individual cultural value differences in virtual organizational teams. While a small number of studies assessing cultural values do exist, Kirkman et al. (2012) reported that they are all laboratory experiments conducted with student teams. While such research is certainly useful and informative, the studies cannot capture the intricacies and contextual elements present in actual organizations.

Another area that lacks a consistent line of substantive research is the manner in which virtual teams influence (and are influenced by) organizational level factors. While organizations make larger and larger investments in adopting and implementing virtual team structures including the many support factors necessary for their effective functioning (e.g., training and development, technological work and communication tools, bandwidth required for communication, etc.), little research has been able to ascertain the financial organizational benefits accruing from virtual team use. Kirkman et al. (2012) state that research designs that incorporate archival data and objective measures of organizational performance will need to be used to assess these effects.

Finally, even though there is a large and growing body of research at the team level of analysis, many important questions remain. Kirkman et al. (2012) show that while trust has received the bulk of attention at the most important emergent state for virtual team success, there are literally dozens of other emergent states that have yet to be examined. While virtual team processes have received more attention than emergent states, one conspicuously absent line of research is that on knowledge management processes.
Implications of Levels of Analysis for Virtual Science Teams. Using Falk-Krzesinski et al.’s (2011) map of a research agenda for the science of team science, the levels of analysis theme from Kirkman et al.’s (2012) review most closely aligns with Falk-Krzesinski et al.’s measurement and evaluation of team science theme. For example, drawing from a list of representative topic statements on the measurement and evaluation of team science theme, the authors include such statements as “measuring effectiveness of team science on multiple levels: individual team, impact of research, effectiveness of team science funding programs, etc.,” “strengthening the research methods for studying scientific teams,” and “importance of developing multi-method strategies to assess processes and outcomes of team science.” Statements such as these all relate very closely to the manner in which virtual science teams are measured and evaluated at multiple levels of analysis.

One of the key research questions introduced earlier in this manuscript was what factors at the team, center, or institute level (e.g., team size, team membership, geographic dispersion) influence the effectiveness of science teams. While some of the attributes are discussed elsewhere in the manuscript (and will be elaborated on also in the practical recommendations section), it is worth noting that Falk-Krzesinski et al.’s (2011) concept map incorporating their seven research themes for science teams yielded a multi-level approach to virtual science teams research. Indeed, the authors state, “The final interpreted map suggests a comprehensive and multi-level framework that had broad applicability for helping to shape future directions of [science teams] research and practice” (p. 153).

Based on their multi-level approach, Falk-Krzesinski et al. (2011) argue that a systems framework approach is ideal for furthering a multi-level research program for understanding virtual science teams. The authors state that a systems approach “is a general conceptual
orientation concerned with interrelationships between parts and their relationships to a functioning whole, often understood within the context of an even greater whole…” (p. 153). Borner et al. (2010) agree that a multi-level framework should be “capable of organizing the diverse forms of inquiry and interlink research on individual scientists, teams, and populations of teams” (p.2). I wholeheartedly agree with Falk-Krzesinski et al.’s approach (and I will elaborate on this approach in the future research section below) and Borner et al.’s strong endorsement of multi-level (and multi-method) research. Suffice to say now that a true understanding of virtual science teams will not be achievable without a comprehensive, multi-level, systems-oriented approach to scholarly examination (Spencer et al., 2011).

**Brief Summary of Theme #5 – Multi-disciplinary Approaches.** In this review and that of Kirkman et al (2012), in order to conduct a thorough search of the research on virtual teams, it was necessary to review the literature from multiple disciplines including management, psychology, IT, communication, and science teams. A troubling development in the virtual organizational teams research is that each of these disciplines has pursued answering research questions independently without much attention to a cross-disciplinary focus. This has resulted in either redundant research streams because the different disciplines do not draw from research located outside their own domains or sometimes completely different research questions that could, in fact, benefit from a more inter-disciplinary approach.

**Implications of Multi-Disciplinary Approaches for Virtual Science Teams.** Using Falk-Krzesinksi et al.’s (2011) map of a research agenda for the science of team science, the multi-disciplinary theme from Kirkman et al.’s (2012) review most closely aligns with Falk-Krzesinski et al.’s disciplinary dynamics and team sciences theme. For example, drawing from a list of representative topic statements on the disciplinary dynamics and team sciences theme, the
authors include such statements as “how to overcome disciplinary traditions to move toward interdisciplinary traditions,” “applying what is known about teams in different disciplines (e.g., management) and contexts (e.g., international),” and “relationships and connections between multi-, inter-, and transdisciplinary research efforts and team science.” Statements such as these all relate very closely to the inherently interdisciplinary composition of virtual science teams.

It is ironic that while virtual science teams are often interdisciplinary in nature (Sá, 2007), as Kirkman et al. (2012) point out, the research on virtual organizational teams has occurred mainly within, and not across, multiple disciplines. For example, as stated earlier, any comprehensive review of virtual organizational teams must include research from management, psychology, IT, and communication. And, while each of these disciplines has contributed important and valuable information regarding the performance of virtual organizational teams, the lack of inter-disciplinary research has impeded the “systems-based” approach that Krzesinski et al. (2011) argued is so critical for a better understanding of virtual science teams.

Some of the interdisciplinary barriers that impede the performance of virtual science teams are the exact same ones that have impeded collaboration of organizational researchers from different disciplines. This is not too surprising as a virtual academic research team is a form of virtual science team and thus likely to encounter similar challenges. For example, each of the four disciplines that has attempted to better understand virtual organizational teams – management, psychology, IT, and communication – all have unique disciplines with different training, foci, and, perhaps most importantly, publications outlets that are considered top tier. For example, even though management and psychology are the most closely related of the four disciplines, even within business schools, applied psychology journals are sometimes de-emphasized in favor of more management-oriented journals, and the same is true in many
psychology programs. What might be considered an “A” level journal in the fields of IT or communication is not likely be considered as such in the management or psychology disciplines. So, there is an actual disincentive, particularly for more junior scholars, to pursue research activity with faculty from a different discipline (cf. Fiore, 2008). Again, this is an ironic problem, because the very researchers that are providing advice and assistance to interdisciplinary virtual science teams cannot themselves work effectively in an interdisciplinary fashion!

**Practical Recommendations for Improving Virtual Science Team Collaboration**

As mentioned, virtual science teams are a very specific and complex type of virtual team. The complexity arises because virtual science teams often cross a variety of borders and boundaries including discipline, organization, expertise, function, nation, and institution. Such a high degree of diversity tends to exacerbate the typical problems associated with virtual organizational teams. What follows is a summary of practical recommendations for improving the collaboration and performance of virtual science teams. My recommendations are based on the entire review outlined here and in Kirkman et al. (2012) synthesized with the literature review on science teams more generally and break down into the following categories including: (a) leadership (including team design, team building, and team process); (b) task and organizational structures; (c) communication (including norms, protocols, and roles; uses of technology; and distance meetings); and (d) virtuality.

**Leadership.** As stated earlier in this review, one of the most important ingredients for virtual team success is highly effective team leadership, and virtual science teams are no exception. And, the most important action a science virtual team leader can take is to focus a great amount of attention on *team design*. In fact, while I discuss team building (which includes team coaching) next, most researchers agree that team design is much more important than
coaching to maximize team success (although both are key factors leading to successful teams; see Wageman, 2001, for a summary of team design factors). One of the most important elements of team design is making sure goals and expectations are clear. For example, leaders should ensure that the team has: a clear, engaging direction; a high level of task interdependence (i.e., team members actually need to work together as a team to accomplish tasks); the proper authority to manage the work; and clear performance goals for the team as a whole.

While team design is difficult enough in virtual organizational teams, it is particularly challenging in virtual science teams. For example, establishing a clear, engaging direction would be especially problematic when virtual science team members come from different disciplines and are housed at various institutions. In addition, compared to virtual organizational teams, virtual science teams have longer time horizons and are focused on knowledge sharing, idea-focused tasks that may not lend themselves easily to clarity of direction. If the goal is discovery, rather than task completion, it may be more difficult for leaders to motivate member engagement. As a result, virtual science team leaders are encouraged to employ members of their teams to reinforce and communicate direction for the team. More meetings devoted to direction setting will be required compared to virtual organizational teams whose direction may be mandated by a single organization. The interdisciplinary nature of virtual science teams might make leaders’ attempts to promote task interdependence challenging as well, particularly early in the team’s life span. Leaders are encouraged to create interdependent tasks for smaller subsets of members and then rotate sub-group membership on a regular basis (see, also, my structural recommendations below). While granting the proper authority to manage work may be less problematic in virtual science teams (i.e., members with high levels of expertise typically embrace greater autonomy), setting overall team performance goals will be critical to get
members with different training, expertise, agendas, and host organizational pressures to be motivated to work toward common team goals.

Another important aspect of team design is the composition of the team. Virtual organizational leaders are typically encouraged to make sure that there is the right amount of skill and demographic diversity on their teams. Skill diversity is almost a moot point in virtual science teams because they are often inherently interdisciplinary, but demographic diversity may be more of a challenge. Regarding team size, most virtual organizational team researchers have converged on the 5-7 member range for optimal team size, and this should also apply to virtual science teams. Some of these teams, however, are likely to be larger due to the complexity of their projects; however, leaders are encouraged to create core or parallel teams of smaller size to take advantage of the cohesion and commitment typical of smaller teams. Indeed, Hinnant et al. (2012) found a negative correlation between number of published article authors and number of citations suggesting a “watering down” of impact associated with larger author teams (see, also, Stvilia et al., 2011). In addition, Cummings et al. (in press) found that group heterogeneity moderated the effects of group size on productivity in research teams such that the positive effects of discipline and institutional diversity were better leveraged in smaller, rather than larger, research teams. Because most virtual science teams are heterogeneous in disciplines and institutions, team leaders must curtail their desire to increase team size (e.g., to gain more expertise) or suffer the deleterious consequences of large, diverse teams. Finally, even though virtual science teams generally have more permeable membership boundaries than virtual organizational teams, to the extent possible, leaders should ensure that the team has as much stable membership as possible.
One of the most common recommendations made to motivate participation in virtual organizational teams is providing some level of group rewards so that there is “something in it for the team to succeed” (Martins et al., 2004). Organizations typically offer team bonuses or other types of valued rewards to motivate beyond individual incentives (DeMatteo, Eby, & Sundstrom, 1998). Group rewards may be especially difficult for virtual science teams as there may be no actual source or mechanism in place to create or distribute monetary or other valued rewards. Virtual science team leaders would likely need to get creative with regard to this form of motivation. And, just like in virtual organizational teams, virtual science team leaders also need to ensure that their teams have enough resources to accomplish tasks such as information, availability of training, and basic materials.

As mentioned above, another key leadership action necessary for virtual science team success is team building. For virtual science teams, team building is likely to be a true challenge (Spencer et al., 2011). For one, getting all team members together for FTF interaction is likely to be problematic. Unfortunately, there remains a dearth of on-line tools that virtual teams can use to team build, so FTF team building is still necessary. Leaders should also work hard to understand and make sure all members understand the style, context, goals, responsibilities, and challenges of other members (Volpe, Cannon–Bowers, Salas, & Spector, 1996), particularly if the team is nationally diverse. There are a variety of personality and cultural value instruments that can be used to ascertain team diversity and prepare teams for potential trouble spots. GlobeSmart is a commercially-available tool that assesses members’ cultural values and highlights likely areas of conflict.

Finally, a leader should also focus on developing and maintaining effective team processes and team emergent states. Team processes include such team aspects as problem
solving, decision-making, conflict management, goal setting, planning, and communication. Team emergent states include such aspects as psychological safety, team empowerment, and trust. As stated earlier in the review, and curiously consistent with Marisa Mayer’s admonition at Yahoo that physical separation harms innovation, previous research has found that geographic dispersion does indeed have a negative relationship with virtual team innovation (Gibson & Gibbs, 2006). So, one recommendation for leaders of virtual science teams is to get team members in FTF meetings as much as possible, particularly when engaging in idea creation or other innovative team behaviors. However, this recommendation is oftentimes not feasible due to the high cost of travel, team member schedules, conflicting roles, or other barriers. Fortunately, research has also shown that the negative relationship between geographic dispersion and innovation/learning in virtual teams can be mitigated by creating effective team emergent states.

For example, Gibson and Gibbs (2006) found that when leaders create a climate of psychological safety in virtual teams, the negative relationship between geographic dispersion and innovation is reduced to a minimal, non-significant level. They also found the same positive effects of psychological safety on other innovation-hindering aspects of virtual teams such as electronic communication dependence, nationality diversity, and teams with frequent membership changes. Kirkman, Cordery, Mathieu, Rosen, and Kukenberger (2013) also found that increasing psychological safety can help to offset some of the process losses associated with virtual communities of practice that are higher in nationality diversity. Virtual science team leaders can enhance psychological safety by being consistently accessible, frequently asking for members’ input, and encouraging team members to discuss their own mistakes and ideas in a constructive manner (see Edmondson, 2012; Edmondson, Bohmer, & Pisano, 2001).
In addition to psychological safety, Kirkman et al. (2004) found that highly virtual teams (i.e., those that relied heavily on electronically-mediated communication) were better at learning-oriented tasks when they had high levels of team empowerment, or increased task motivation due to team members’ collective, positive assessments of their tasks within an organizational context (Kirkman & Rosen, 2000). In order to increase team empowerment, virtual science team leaders need to make sure that members feel a collective sense of: competence in carrying out tasks, intrinsic meaningfulness in their work, freedom and autonomy to pursue innovative approaches, and impact of their ideas on the team and the team member’s respective organizations. Kirkman et al. (2004) provide detailed leader recommendations for enhancing team empowerment in virtual teams.

Leaders should also not forget about the importance of trust in virtual science teams, or what has been called the glue of the global workspace (O’Hara-Devereaux, & Johansen, 1994). Kirkman et al. (2006) found that training proficiency in virtual teams had a stronger positive impact on team performance when the teams had high levels of trust. While building trust is difficult in most any type of team, geographical dispersion magnifies and intensifies issues of trust in virtual science teams (cf. Kirkman et al., 2002). As Jarvenpaa and her colleagues (Jarvenpaa et al., 1998; Jarvenpaa & Leidner, 1999) and others (e.g., Kirkman et al., 2002) have found, there are multiple mechanisms through which trust develops including relationship-based trust that develops over time (more commonly found in FTF teams) and task-based trust that is often described as swift, depersonalized, and action-based (more commonly found in virtual teams). Due to the prevalence of strong scientific norms within and often across different scientific disciplines, trust in virtual science teams will likely take the form (particularly initially) of task-based trust. Thus, leaders of these teams will need to reinforce timeliness and consistency
of team interaction, ensure that members rapidly respond to one another when using electronic communication, and encourage members to exhibit high levels of performance and expertise to gain legitimacy. Establishing and reinforcing norms around communication patterns is also key.

Bietz et al. (2012) have developed a tool called the Collaboration Success Wizard (CSW) that uses leader and member survey data to identify potential collaboration problems in virtual science teams and provide strategies for leading and handling collaboration issues. Such a tool allows members to reflect on the important collaborative processes and emergent states that are critical to the successful functioning of virtual science teams. While I support the use of the CSW, specifically, for many virtual science teams, leaders can also adapt it to include team processes and emergent states not captured by the CSW but shown to be critical for healthy collaboration (e.g., psychological safety, team empowerment).

**Task and organizational structures.** Because many virtual organizational and science teams are parallel in nature – that is, they exist outside of any formal structure of a single organization and are only part of a team member’s formal role responsibilities – getting team members fully engaged in team activities can be difficult. For virtual science team leaders, there are task and organizational structures that can be used to enhance participation in these teams. For example, regarding the issue of dual loyalties in a virtual science team (i.e., a team member is torn between his/her obligations and responsibilities to his/her organization and the work s/he is doing on a virtual science team), each team member’s formal organizational supervisor could be assigned as a high-level sponsor of the virtual science team. Such a structure solves the issue of a particular team member’s concern that his/her supervisor is not aware of the many tasks that the member is performing for the team. To avoid burnout (of both the team leader but also team members), important leadership tasks can be rotated among team members including such tasks
as agenda creation, meeting facilitation, knowledge management activities, leading electronic
discussions, keeping track of schedules, and making external presentations. To avoid problems
emanating from the lack of knowledge of fellow team members’ areas of expertise, science
virtual team leaders can “pair up” members of the team to carry out short term projects and then
rotate these pairings at selected intervals so that each member gets to work closely with other
members. Knowing who knows what on the team (i.e., transactive memory) is also critical for
effective virtual science team performance.

Communication. Since virtual science teams both rely heavily on electronically-mediated
communication and are charged with generating novel ideas and breakthrough innovations,
communication is clearly critical. Particularly relevant for leaders of these teams is building trust
through communication norms, protocols, and roles. Leaders will need to get answers to such
questions as: how will members work together both in and out of meetings; who will be
responsible for capturing and sharing knowledge, when will such knowledge be gathered, and by
whom and how quickly; how will decisions get made and by whom; and what are the generally
accepted norms of behavior in the team? Roles will also have to be decided. All of the above can
generally be decided very early in the team’s lifecycle by way of a team charter. The more that
can be captured and articulated early, the higher the chances for team success will be later. A
team charter can be used to formalize the answers to these questions at the beginning of a team’s
lifespan (Mathieu & Rapp, 2009).

In terms of appropriate uses of communication technology, there is no generally
accepted set of principles for which technologies to use for which purposes. One common rule of
thumb in the communication literature is that for highly controversial, emotional, or complex
messages, richer communication media (e.g., FTF, videoconferencing) are typically better than
leaner media (e.g., email, chat). For routine information, the reverse is true. Based on a study of dozens of teams in a variety of industries, Majchrzak et al. (2004) found that the most successful virtual teams *banned the use of email* for team communication (i.e., members used it only for one-to-one member communication). Other tools such as electronic discussion threads proved to be much more efficient for communication between team members. Kirkman et al. (2013) found that highly diverse virtual organizational teams performed much better the more the team’s members used richer communication media, underscoring a link between the diversity of a team and a team’s need for FTF and video-conferencing. Given the demonstrated problems that highly virtual teams have innovating (Gibson & Gibbs, 2006), virtual science teams are encouraged to have FTF contact and use richer media, particularly when engaging in innovative processes.

When virtual science teams do engage in video- or audio-conference meetings, leaders are encouraged to practice effective meeting facilitation behaviors. Before such meetings occur, leaders should make sure agenda items are assigned, conflicts are surfaced before the meeting takes place, and that timelines are highly visible. At the beginning of each meeting, leaders should take 5-10 minutes to recreate team feelings by perhaps discussing celebratory personal events or having members update one another on significant accomplishments. During the meeting, leaders should attempt to ensure inclusiveness of all members and use innovative techniques such as electronic voting tools. At the end of the meeting, leaders should make sure there is a clear allocation of action items and that meeting minutes are posted rapidly in knowledge repositories. Between meetings, leaders should initiate and facilitate electronic discussion threads, track progress on a timeline, and follow up with one-on-one discussions with team members.
**Virtuality.** In line with Yahoo CEO Marisa Mayer’s comments about the potential negative impact of working virtually on innovation, virtual science team leaders and members may face similar challenges due to the lack of physical co-presence. For example, a scientist who is co-located with team members receives relatively intangible benefits, such as bumping into fellow team members and other scientists, which could engender unanticipated idea creation and breakthrough innovations (Harris & Holley, 2008). Geographically dispersed science team members do not have access to these serendipitous encounters, and thus their efforts to generate new knowledge must come through more formal interaction mechanisms. Relative to co-located members, virtual science team members miss out on these “free” benefits so common among scientists working in FTF contexts. Indeed, in recent University of Michigan study, Owen-Smith, Kabo, Levenstein, Price, and Davis (2012) found that researchers who were co-located in the same building were 33 percent more likely to form new collaborations than researchers who occupy different buildings, and scientists who were co-located on the same floor were 57 percent more likely to form new collaborations than investigators who occupy different buildings. Many have also written on the difficulty of building trust when working virtually (Kirkman et al., 2002). An initial reaction to these disadvantages may lead one to conclude there is nothing to be done to try to capture these free benefits in virtual science teams. However, there are certain steps that leaders can take to mitigate the negative impact of geographic dispersion.

For example, richer communication tools, such as Cisco System’s Telepresence, can be used to simulate FTF interactions due to the use of high definition video and realistic audio tracking. While such tools still require intentional scheduling of meetings, unlike chance hallway encounters, there is still much to be gained from using communication tools of high fidelity and richness. A second tool that might help to simulate idea exchange for geographically-dispersed
members is the use of electronic discussion threads, which should be accessible to members both inside and outside virtual science teams. Electronic discussion threads have proven much more efficient than other tools such as email for effective virtual team communication (Majchrzak, Malhotra, Lipnack, & Stamps, 2004). Discussion threads can be used as part of an overall virtual community arrangement that incorporates a variety of tools by which members can exchange valuable ideas. Finally, virtual science team members would benefit from some level of FTF contact in regular meetings and also team building opportunities. In short, while geographically dispersed scientists do miss out on the opportunistic chance encounters afforded FTF science teams, there are steps to be taken to recapture some of these benefits when working virtually.

In Table 2, I summarize the existing recommendations for leaders of virtual organizational teams and then provide an additional column indicating how these organization-based recommendations need to be altered or modified for virtual science teams. As Table 2 shows and, perhaps not surprisingly, many of the recommendations for virtual organizational teams can be applied without modification to virtual science teams. However, due to their unique characteristics, some recommendations do need altering for leaders of virtual science teams.

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**Research Recommendations for Improving our Understanding of Virtual Science Team Collaboration**

As described and used throughout this manuscript, Kirkman et al. (2012) provided five themes emanating from the existing research on virtual organizational teams (i.e., virtuality, team development, leadership, levels of analysis, and multidisciplinary approaches), and these five themes were used to generate directions for future research on virtual organizational teams in
their review. Concurrently, Falk-Krzesinski et al. (2011) provided what they referred to as a “road map” for future research on the science of team science using a concept mapping methodology based on data from various science team stakeholders that yielded seven topics (i.e., measurement and evaluation of team science, structure and context for teams, characteristics and dynamics of teams, management and organization for teams, institutional support and professional development for teams, disciplinary dynamics and team science, and definitions and models of team science). Next, using a synthesis of these two sets of future research themes, I outline what I believe to be the most important research areas that need addressing on virtual science teams. The seven areas include: examining virtual science teams “in the wild,” employing multidisciplinary research teams, focusing on how virtual science teams develop over time, investigating effective external/internal leadership behaviors, identifying important emergent states and team processes, highlighting key institutional support mechanisms, and defining measurable performance metrics.

**Examine virtual science teams “in the wild.”** The dearth of research studies on virtual science teams leads to a perhaps rather obvious future research direction; that is, virtual science teams must be empirically investigated “in the wild.” By this, I mean that laboratory studies of virtual science teams are not as likely to lead a true understanding of their performance as are field studies. Because virtual science teams are very complex and have properties and elements distinct from virtual organizational teams (see Table 1), researchers need to examine these teams first-hand. This will mean breaking from the long-standing tradition of studying virtual teams in laboratory settings (Martins et al., 2004). In addition, embarking on a research agenda to truly understand virtual science teams will necessitate the use of qualitative and ethnographic studies (Olson et al., 2008). Embedding researchers into team meetings; capturing, coding, and
analyzing team interactions using electronic communication tools (e.g., email, video-conferencing); and conducting in-depth interviews with team members are all techniques likely to generate novel insights into virtual science teams. Such investigations will be time consuming and, by necessity, longitudinal in nature. As a result, research team members must be willing and able to devote substantial time to designing and executing such a research strategy.

However, there are unique challenges awaiting researchers willing to undertake research programs to better understand virtual science teams. For example, as Borner et al. (2010) point out, “the field must define how to safeguard the anonymity of the scientists being studied and protect their ideas while ensuring that the data necessary to understand and improve team science are accessible” (p. 3). Jirotka et al. (2013) point out “that further significant methodological challenges of studying [virtual science teams] in action lie in the heterogeneity of the types of researchers, research settings, materials, technologies and institutions involved” (p. 9). Hine (2007) has argued that the ethnography methodology will have to be significantly adapted in order to handle the spatial complexity of virtual science teams and the distributed nature of work. However, as Mathieu et al. (2008) stated in their review of the general teams literature, researchers are invited to “embrace the complexity,” which will certainly also be true of examining virtual science teams (p. 463).

**Employ multidisciplinary approaches to study virtual science teams.** As Kirkman et al. (2012) pointed out, research on virtual organizational teams has developed primarily in a siloed fashion with separate research streams evolving in management, psychology, IT, and communication fields. And, in a parallel fashion, most virtual science teams are highly interdisciplinary, with team members expected to work together, as a team, despite widely different backgrounds, training, experience, and education (Fiore, 2008). Thus, I argue that the
interdisciplinary virtual science teams represent a unique opportunity for interdisciplinary research teams to carry out an integrated research program (Falk-Krzesinski et al., 2011). The drawbacks of such an approach are well known, with perhaps the most important one being the different publication outlets that exist across the disciplines. Researchers will need to identify outlets that are valued by their respective disciplines when embarking on an interdisciplinary research program. A multi-study approach, with multiple manuscripts targeted to journals in different disciplines, may be an effective remedy to at least one of the barriers to interdisciplinary research.

**Focus on how virtual science teams develop over time.** Research on virtual organizational team development is still in its infancy, but researchers generally agree that these team types do not follow traditional team development models such as Tuckman’s (1965) or Gersick’s (1988) frameworks. Beyond that conclusion, there is not much that can be offered from the virtual organizational team research to benefit virtual science teams. Knowing how teams develop over time is critical because certain leadership behaviors would be more important at different points along a team’s lifecycle. Without such knowledge, leaders may be behaving in ways that have no impact on team performance, or worse, in ways that might actually harm team success. In keeping with our first recommendation above about qualitative, longitudinal research, understanding the development of virtual science teams will necessitate rich, qualitative data gathering over time (Olson et al., 2008). Given the often-long time horizons of many virtual science teams, this may involve a multi-year research program.

**Investigate effective external/internal leadership behaviors.** As discussed, most researchers agree that leadership is absolutely critical to virtual organizational team performance, and science team researchers agree that the same is true for virtual science teams. Research on
virtual science team leadership is likely to be more complicated than that on virtual organizational teams, however, because leadership in the former type is likely to be more informal, emergent, and shared compared to the latter type. For example, in some virtual science teams, the leader of the team may be synonymous with a principal investigator role (as would be the case for funded grant research). However, a scientist in the role of principal investigator is not likely to have the same leadership mechanisms available to him/her as would a virtual organizational team leader (e.g., formal authority, higher level in the hierarchy). Thus, research on virtual science team leaders would rely more heavily on related leadership areas such as power, influence, and leading without formal authority. As with team development, examining emergent and shared leadership will necessitate a longitudinal approach, and similarly qualitative, observational research will likely be advantageous (Olson et al., 2008).

Identify key emergent states and team processes. As discussed earlier, teams are likely to perform at optimal levels when they have effective emergent states (e.g., psychological safety, empowerment, trust) and team processes (e.g., decision-making, problem solving, communication). As earlier reviews of organizational teams (Cohen & Bailey, 1997; Mathieu et al., 2008) and virtual organizational teams (Bell & Kozlowski, 2002; Martins et al., 2004) suggest, various emergent states and processes are likely to be more (or less) important for different types of teams. For example, Cohen and Bailey (1997) found that while autonomy is a critical ingredient for work team success, lower levels of autonomy (and stronger leadership control) are actually more beneficial for problem solving/cross-functional teams. Thus, a critical stream of research for virtual science teams is understanding which emergent states and processes must be enacted for team success. Some emergent states, such as psychological safety and team empowerment, and some team processes, such as decision-making and conflict
management, can be intuited as critical for virtual science teams due to the nature of the tasks these teams perform. However, it remains an empirical question as to the exact array of critical emergent states and team processes relevant to virtual science teams and, perhaps as important, how these choices differ from (or overlap with) virtual organizational teams.

**Highlight key institutional support mechanisms.** In one of the more dramatic departures from virtual organizational teams, virtual science teams are likely to operate within and across various centers, research institutes, and/or universities. And, complicating matters, these teams will often span multiple entities of these types creating resource confusion and ambiguities. Rather than relying on internal organizational funding and support, many virtual science teams will be dependent on outside, grant-based funding also adding to the ambiguity around resource support and distribution. Thus, any research program for examining virtual science teams must include an investigation into the key institutional support mechanisms undergirding virtual science team activity.

**Define measurable performance metrics.** Because virtual science teams have deliverables and products that are quite distinct from virtual organizational teams, researchers should work to identify the key performance metrics most relevant to virtual science teams (Porter, Roessner, Cohen, & Perreault, 2006). In fact, this set of research is needed first before any of the above areas because before drivers of virtual science team effectiveness can be identified and investigated, a clear definition of virtual science team performance must be articulated. So, it is incumbent upon virtual science teams researchers to “start with the end in mind.” A possible starting point to work from in terms of team effectiveness is Cohen and Bailey’s (1997) three-dimensional organizational team effectiveness model, which includes performance (e.g., productivity, customer satisfaction, efficiency, quality, innovation, response times), behaviors
(e.g., absenteeism, turnover, safety), and attitudes (e.g., organizational commitment, team commitment, job satisfaction, trust in management). While some of these indicators may be highly relevant for virtual science teams (e.g., productivity, innovation, quality, team commitment), others appear to have more limited utility (e.g., safety, organizational commitment, trust in management). What is important about using a typology of effectiveness like Cohen and Bailey’s (1997) is that virtual science team effectiveness is most likely to be multi-dimensional. That is, there are likely to be metrics assessing performance, behaviors, and attitudes of virtual science teams and their members. Importantly, as team researchers have discovered, these different dimensions of team effectiveness are likely to have different antecedents. As a result, once the different dimensions and sub-dimensions of virtual science team effectiveness have been fully elucidated, researchers will need to identify those specific levers of effectiveness that can be, in turn, used selectively by virtual science team leaders to maximize the specific area of performance in question.

**Conclusion**

One conclusion that should be clear from this review is that there are a great number of lessons learned from the virtual organizational literature that can be generalized to virtual science teams. In areas such as virtuality, team development, leadership, levels of analysis, and multidisciplinary approaches, virtual science team leaders can feel relatively confident that at least some behaviors leading to the success of virtual organizational teams will also help to ensure virtual science team success. However, what should also be clear from the review is that virtual science teams are different in many important and fundamental ways from virtual organizational teams (Fiore, 2008). Thus, there is an inherent danger in simply assuming that whatever works for virtual organizational teams will work in exactly the same way for virtual
science teams. Virtual science team leaders and members will have to familiarize themselves with best practices because many of the behaviors and actions required for virtual science teams do not come naturally to those who have been trained to think and operate relatively autonomously as scientists in various disciplines. The key to virtual science team success will be to understand the levers of effective virtual organizational teams, the key antecedents for virtual science team success, and the wisdom to know the difference.
References


empowerment on virtual team performance: The moderating role of face-to-face

Kozlowski, S. W. J., & Bell, B. S. 2012. Work groups and teams in organizations. In I. B.


case of a computer-supported inter-organizational virtual team. *MIS Quarterly, 24*, 569-600.


Mathieu, J.E., & Rapp, T.L. (2009). Laying the foundation for successful team performance


Marks, M.A., Mathieu, J.E., & Zaccaro, S.J. (2001). A temporally based framework and


Pearce, C. L., & Sims, H. P. (2002). Vertical versus shared leadership as predictors of the effectiveness of change management teams: An examination of aversive, directive,


Table 1  
Dimensions of Differences on the Continuum from Virtual Organizational Teams to Virtual Science Teams*

<table>
<thead>
<tr>
<th>Dimension</th>
<th>More “Organization Team”-Like</th>
<th>More “Science Team”-Like</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time Horizon</strong></td>
<td>Shorter</td>
<td>Longer</td>
</tr>
<tr>
<td><strong>Leadership</strong></td>
<td>Formal, directive</td>
<td>Facilitative, shared</td>
</tr>
<tr>
<td><strong>Membership</strong></td>
<td>Stable boundaries</td>
<td>Permeable boundaries</td>
</tr>
<tr>
<td><strong>Task Type</strong></td>
<td>Problem-solving, task-focused</td>
<td>Knowledge sharing, idea-focused</td>
</tr>
<tr>
<td><strong>Task Interdependence</strong></td>
<td>Higher</td>
<td>Lower to moderate</td>
</tr>
<tr>
<td><strong>Structure</strong></td>
<td>Designed</td>
<td>Emergent</td>
</tr>
<tr>
<td><strong>Accountability</strong></td>
<td>External, formal sanctions</td>
<td>Internal, social sanctions</td>
</tr>
<tr>
<td><strong>Disciplines</strong></td>
<td>Low to moderate heterogeneity</td>
<td>Interdisciplinary</td>
</tr>
</tbody>
</table>

*Note that this table represents a continuum of virtual teams from more organization-team-like to more science team-like. Importantly, it does not suggest that there are two distinct types of teams, but rather teams that span a continuum from organizational to science teams. There is also a great deal of variety within each of these two ends of the continuum, such that not all organization or science teams necessarily have all (or equal amounts) of these key features.
Table 2
Summary of Practical Recommendations for Leading Virtual Organizational Teams and Modifications of the Recommendations for Leading Virtual Science Teams

<table>
<thead>
<tr>
<th>Recommendation/Team Type</th>
<th>Virtual Organizational Teams</th>
<th>Modifications Needed for Leading Virtual Science Teams</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leadership</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Team design</strong></td>
<td>- Leaders establish clear, engaging direction</td>
<td>- Leaders do this but also involve team members to do this also; more meetings to set direction are needed</td>
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<tr>
<td></td>
<td>- Leaders structure tasks interdependently</td>
<td>- Challenging because of multiple disciplines with high levels of expertise; leaders need to create smaller subsets of interdependent members and rotate members through the subsets</td>
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<tr>
<td></td>
<td>- Leaders grant the proper authority to manage work</td>
<td>- Little modification needed as virtual science team members will typically embrace autonomy</td>
</tr>
<tr>
<td></td>
<td>- Leaders set overall team performance goals</td>
<td>- Challenging due to members with different training, expertise, agendas, and host organizational pressures; leaders will have to constantly reinforce goals with team as a whole and individual members</td>
</tr>
<tr>
<td></td>
<td>- Leaders ensure that there is the right amount of skill and demographic diversity</td>
<td>- Skill diversity is typically not a problem for virtual science teams; demographic diversity should also be emphasized</td>
</tr>
<tr>
<td></td>
<td>- Leaders make sure the team is the right size (in general, 5-7 members)</td>
<td>- Many virtual science teams are likely to have more than 7 members; leaders should create core or parallel teams of smaller size to facilitate commitment and cohesion</td>
</tr>
<tr>
<td></td>
<td>- Leaders should strive for stable membership</td>
<td>- Where possible, leaders should ensure stability</td>
</tr>
<tr>
<td></td>
<td>- Leaders establish group rewards (i.e., something in it for the team as a whole)</td>
<td>- Leaders will have to get creative with regard to group rewards because they may not have control over organization-specific reward systems</td>
</tr>
<tr>
<td></td>
<td>- Leaders ensure members have sufficient resources such as information, training, and materials</td>
<td>- Little modification needed although some resources (i.e., financial) might be externally driven</td>
</tr>
<tr>
<td><strong>Team building</strong></td>
<td>- Leaders provide team-building opportunities, particularly with initial and periodic face-to-face interaction</td>
<td>- Leaders should encourage team building during face-to-face meetings (if possible); electronic communication tools (i.e., videoconferencing) can be used to simulate face-to-face interaction and sharing</td>
</tr>
<tr>
<td><strong>Processes and emergent states</strong></td>
<td>- Leaders ensure high levels of psychological safety (e.g., be accessible, frequently ask for members’ input, encourage members to discuss mistakes and ideas constructively), team empowerment (i.e., potency, meaningfulness, autonomy, and impact), and trust (e.g., reinforce timeliness and consistency of team interaction, ensure that members rapidly respond to one another when using electronic communication, and encourage members to exhibit high levels of performance and expertise to gain legitimacy).</td>
<td>- Little modification needed although there may be higher barriers to psychological safety, empowerment, and trust due to inter-disciplinarity; leaders will need to make consistent efforts in both team interactions as well as one-on-one, off-line interactions with members; leaders can use survey instruments designed specifically for collaboration in geographically-dispersed science teams (e.g., Collaboration Success Wizard, CSW; Beitz et al., 2012) or develop their own instruments capturing processes and emergent states not in the CSW</td>
</tr>
<tr>
<td><strong>Task and Organizational Structure</strong></td>
<td>- Leaders deal with divided loyalties caused by simultaneous membership on a virtual team and one’s formal job responsibilities</td>
<td>- Leaders can involve each member’s formal, organizational leader or supervisor as a high level sponsor of the team</td>
</tr>
</tbody>
</table>
Leaders assign and rotate various leadership tasks to avoid leader and member burnout

- Leaders can “pair up” members into dyads for special projects and assignments and rotate dyads

- Leaders should ensure high levels of transactive memory (i.e., knowing who knows what on the team)

- Little modification needed, leaders can rotate tasks in virtual science teams such as agenda creation, meeting facilitation, knowledge management activities, leading electronic discussions, keeping track of schedules, and making external presentations

- Little modification needed; leaders can use such dyadic structures and rotation to achieve high levels of cohesion and trust among members

- Little modification needed although with members with very high (and different) levels of expertise, more time will have to spent establishing transactive memory

**Communication**

**Norms, protocols, and roles**

- Leaders build trust through the establishing of communication norms, protocols, and roles; questions that need answering include:
  - How will members work together both in and out of team meetings?
  - Who will be responsible for capturing and sharing knowledge?
  - When will knowledge be gathered?
  - How will decisions get made and by whom?
  - What are the generally accepted norms of behavior in the team?

- Leaders establish team charters to formalize and answer the important questions above.

- Little modification needed

- Little modification needed

**Technology use**

- Leaders ensure that the right technology is used for the right tasks (rule of thumb: the more complex the message, the richer the media needed)

- Leaders should encourage the use of electronic discussion boards and virtual meeting spaces, rather than relying on email, for virtual team communication

- Because virtual science team tasks are oftentimes complex, ambiguous, and require innovation, leaders will need to make sure their teams have sufficient face-to-face, video-, and audio-conferencing available; this is particularly true for highly diverse (i.e., inter-disciplinary teams)

- While email can be used effectively for one-to-one member communication, it is less efficient for complex, team-oriented discussions

**Distance meetings**

Leaders should engage in healthy meeting management behavior before, at the beginning of, during, after, and between meetings by:

- Before meetings, making sure agenda items are assigned, conflicts are surfaced, and timelines are very visible

- At the beginning of meetings, leaders should take 5-10 minutes to re-create the team feeling by discussing more personal events or significant accomplishments

- During the meeting, leaders should ensure inclusiveness using innovative techniques such as electronic voting tools

- At the end of meetings, leaders should make sure there is a clear allocation of action items and meeting minutes are posted rapidly in knowledge repositories

- Little modification needed
- Between meetings, leaders should initiate and facilitate electronic discussion threads, track progress on a timeline, and follow up with one-on-one discussions with team members.

| **Virtuality** | - Leaders should encourage the use of richer communication tools such as high definition video-conferencing (e.g., Cisco Systems’s Telepresence); in lieu of email, electronic discussion threads should be encouraged for team-based communication; getting members together periodically face-to-face should also benefit. | - Little modification needed |