

Received:
13 January 2016
Revised:
30 March 2016
Accepted:
20 April 2016

Heliyon 2 (2016) e00105



Individual motivation and threat indicators of collaboration readiness in scientific knowledge producing teams: a scoping review and domain analysis

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Abstract

This paper identifies a gap in the team science literature that considers intrapersonal indicators of collaboration as motivations and threats to participating in collaborative knowledge producing teams (KPTs). Through a scoping review process, over 150 resources were consulted to organize 6 domains of motivation and threat to collaboration in KPTs: Resource Acquisition, Advancing Science, Building Relationships, Knowledge Transfer, Recognition and Reward, and Maintenance of Beliefs. Findings show how domains vary in their presentation of depth and diversity of motivation and threat indicators as well as their relationship with each other within and across domains. The findings of 51 indicators resulting from the review provide a psychosocial framework for which

to establish a hierarchy of collaborative reasoning for individual engagement in KPTs thus allowing for further research into the mechanism of collaborative engagement. The indicators serve as a preliminary step in establishing a protocol for testing of the psychometric properties of intrapersonal measures of collaboration readiness.

Keywords: Social sciences, Education, Psychology

1. Introduction

There is a gap in the line of research inquiry in the team science literature in terms of individual, *intrapersonal* indicators for participation in team science despite this category of antecedents being equally important to others, such as *interpersonal* and technological aspects of scientific collaboration (National Academy of Science, 2015; Stokols et al., 2008a, b). We provide an assessment of the literature that addresses the *perceived* micro-level motivators and threats to scientific collaboration to address the issue of intrapersonal antecedent conditions that have the potential to impact individual participation in scientific knowledge-producing teams (KPTs) (Börner et al., 2010; Pohl et al., 2015; Stiener, 1972; Stokols et al., 2005; Vogel et al., 2012). Importantly, these individual motivators and threats can serve as measurable mediators to collaboration readiness. This effort draws from bodies of literature where interactive indicators of scientific team readiness are discussed and extrapolates indicators of motivation for KPT collaboration in other domains in the form of attitudes, beliefs, and experiences. There is less regard for causal relationships *than for* conformity to external expectations.

In an era when increased emphasis is being placed on the importance of collaborative efforts in science (National Institutes of Health, 2011), it has become a priority for behavioral and social scientists to understand better the underlying factors that support or deter individual engagement in collaborative research (Fiore, 2008). For academia and its knowledge-producing stakeholders, the demands for team science initiatives by external funding agencies are palpable, affecting eligibility and access to research funds. And understanding the most effective interventions (training, development, encouragement, etc.) for enhancing productive interdisciplinary collaboration and team science at all levels is growing in importance. The recent report of the National Research Council of the National Academies, “Enhancing the Effectiveness of Team Science” (2015) supports this recognition and is a charge to those that study teams that further “research is needed to enhance our basic understanding of team science processes as the foundation for developing new interventions” (p. 12). As those from the social sciences increase their contributions to advance this research agenda, they contribute to the growing recognition that social science efforts can expand and

increase the impact of scientific efforts across sectors that shape and change our national scientific agenda thus making our federal funding resources more effectual (Obama, 2015). This will require multilevel approaches by behavioral and social scientists with emphases on micro, meso, and macro level investigations who can contribute to the understanding of the unique operative dynamics within each of these levels to make recommendations about the relationship between one level and the others and thus increase our knowledge about collaborative efforts in science (Börner et al., 2010; Rousseau, 1985).

Teams of scientists working to solve complex problems actively employ a variety of skills and motivations in their collaborative efforts (Kraut et al., 1987; Mâsse et al., 2008). Collaboration is the cooperative effort between two or more entities striving towards a common goal (Andreas et al., 2006). Ensuring that teams maximize the effectiveness of scientific collaboration is key for these KPTs that strive to increase methodological diversity, engage in cross-disciplinary knowledge building, and leverage pools of resources so as to have greater impact on real-world problems (Bear and Woolley, 2011; Jones et al., 2008; Kyvik and Teigen, 1996). Individual motivations and threats to this type of collaborative activity affect the very ability of teams to assemble and sustain group activities that lead to the achievement of their goals. Much of the literature on individual readiness for scientific teams targets *interpersonal* skills, the interactive dynamics that support collaborative enterprises. Usually, this focus occurs in the context of environmental antecedents to teaming (Baron and Kenny, 1986; Cummings and Kiesler, 2008; Stokols et al., 2003). These environmental antecedents include infrastructures that support team science, cultures that support and reward team scholarship, preexisting conditions such as unique research challenges, strategic and large-scale collaborative opportunities, governmental incentives, scientific expectations, popular trends, and even national pride and global competition that may impede or encourage collaboration between scientific stakeholders (Greis et al., 1995; Hayton et al., 2013; Katila and Mang, 2003; Mowery et al., 1996; Ouchi and Bolton, 1988; Sakakibara, 1997; Stokols et al., 2008a).

Observing team science characteristics in terms of environmental antecedents has led researchers to focus on issues related to team size, organizational capacities, resource allocations, technologic preparedness, communication techniques and technologies, geographic proximity, and other attributes of the more structural moderators of motivation (Bayona et al., 2001; Fritsch and Lukas, 2001; Hayashi, 2003; Sakakibara, 2001; Santoro and Chakrabarti, 2002; Steensma et al., 2000). These inquiries have typically highlighted the necessary external supports that should lead researchers to want to participate in collaboration. Often addressing the problem of readiness from this meso (team) or macro (organizational) level of analysis (Börner et al., 2010), findings associated with these types of studies relate behavior and individual performance as a response to these environmental

mediators drawing attention to their causal effects on cognition, behaviors, and attitudes in individuals (Adler and Chen, 2011; Andreas et al., 2006).

Less effort has been made to understand the individual responses and challenges as individual researchers find themselves faced with making decisions about working within and across scientific teams. In response to this gap in understanding the full slate of antecedent conditions for team science (Stokols, 2006), we take an approach in our review that focuses on the *intrapersonal* conditions that impact collaboration readiness for team science, those that stem from individual perceptions that are ultimately connected to how an individual decides to interact with others in knowledge producing teams and within what capacity (Osterloh and Frey, 2000).

This work is the initial phase of a research agenda with the goal of developing an assessment tool for use by science teams and to measure pre-conscious and conscious collaboration readiness based on psychometric indicators, using a novel measurement (Lotrecchiano et al., 2014). The *intrapersonal* indicators identified from this review contribute to the development of a dynamic hierarchy of factors that serve as an important basis for the psychometric properties used in the instrument currently being validated (Lotrecchiano et al., 2015; Mallinson et al., 2016, under review). In this paper, we describe the first phase of mapping the terrain about motivation and threats in establishing the psychometric properties. We present therefore: 1) a discussion about collaboration readiness in scientific KPTs, 2) a method and findings from a scoping review of over 60 years of literature, and 3) concluding thoughts about the value of these indicators to psychometric measurement and measurement of individual collaboration readiness.

1.1. Collaboration readiness

Individual and community psychological readiness is discussed in a number of contexts and usually focuses on preparedness to respond to external stimuli (Skinnerian) (Lado and Wilson, 1994), internal urges (Freudian) (Engle and Arkowitz, 2006), learning abilities (Rogerian) (Ajzen, 1991; Ajzen and Fishbein, 1980; Bandura, 1991) and/or creativity (Jungian) (Oetting et al., 1995; 2001). Each of these schools of thought share the basic premise that individuals respond to needs that call them to adapt to a changing environment that will require cognitive, behavioral, and attitudinal adjustments (Miller and Tonigan, 1996). To measure these responses, output indicators and team interactive qualities have dominated the literature and have been used as evidence of individual readiness. Scholars and theorists have addressed concerns about this response in a number of ways. Contemporary issues associated with disparate groups (Olson and Olson, 2000), the ethics of collaboration (DuBois et al., 2012; Macrina et al., 1995), and the organizational antecedents necessary for productive scientific collaboration (Katz,

1982; Salazar et al., 2011) have received great attention. Popular methodological tools for studying these conditions have included bibliometrics (Hall et al., 2008a), networking analysis (Trochim et al., 2008; Wuchty et al., 2007), behavioral studies (Shuffler et al., 2011), social-cognitive framework analysis (Paletz and Schunn, 2010) and quality measures (Falk-Krzesinski et al., 2011; Mickan and Rodger, 2005).

Team and management scientists have worked to understand the motivational antecedents in several teaming environments less scientifically oriented in nature such as in sports, management teams, and service workforces (Ehrlinger et al., 2005; Hurtz and Williams, 2009). Some inquiries have focused on motivational antecedents specific to scientists and engineers using an expectancy model (Goodman et al., 1970), though with an emphasis on predictions of individual productivity and outputs. Approaches to individual motivations for collaborative science in similar sectors remain predominantly focused on measurement of organizational antecedents such as team process mediations to outcome, team work empowerment, and behavioral, affective, interpersonal, and intellectual processes rather than pre-conscious factors (Kennedy et al., 2008; Kirkman and Rosen, 1999; Weaver, 2008). Generally speaking, the problem of motivation and threat in KPTs are similar to those in other areas, in that, to understand readiness, one must understand the motivations and/or threats that are mediators of collaborative engagements. For KPTs the shifting context of science and its policies that deeply affect the decision-making processes of individuals as they navigate the knowledge-producing landscape throughout their careers.

1.2. Knowledge Producing Teams (KPTs)

KPTs are groups of collaborators that have shared and/or aligning mental models (Cannon-Bowers et al., 1993). Science teams represent an important type of KPTs that, though with similar features and processes to other types of teams, contain unique aspects because of expectations from the knowledge-generating environment in which they operate (National Academy of Science, 2015). KPTs primarily aim to create knowledge not ordinarily achieved outside of a collaborative environment. KPTs have task-oriented goals, share equipment and technologies, and develop professional and interpersonal relationships within their unique context and content situations (Mohammed and Dumville, 2001). These activities are embedded within the teaming process (DeChurch and Mesmer-Magnus, 2010) that grounds their purpose—the generation of new knowledge (Wuchty et al., 2007). KPT members are typified as collections of highly skilled, autonomous workers trained to use specific tools and theoretical concepts with goals that produce complex, intangible, and tangible results (Bisch-Sijtsema et al., 2011). Their involvement in teams is often the direct result of individual interests or enthusiasm rather than being assigned to a task. This said,

sustainability of projects and the alliances of these knowledge workers depend upon the continued successful collaborative motivations of individual contributors (Andreas et al., 2006), which is highly and continually influenced by individual readiness to enter into KPTs (Gajda, 2004).

Many who engage in KPTs do so in response to shifting individual and environmental opportunities for engagement over pre-constructed groupwork environments allowing for greater autonomy and free will when making decisions about engagement. This may be the main difference between many KPTs and other types of teams that are primarily charged with outputs that are gauged by market demands. Collaborative participation also plays a part in satisfying a variety of individual needs that range from basic intellectual creativity (Rhoten, 2003) to the need for being part of efforts beyond one's own creativity and skill boundaries (Adler and Chen, 2011). It can fulfill higher level needs that afford individuals the ability to participate in more complex thinking and problem solving with well-defined and shared goals (de Montjoye et al., 2014). It challenges collaborators to engage in knowledge sharing behaviors (Hung et al., 2010) and mollifies innate personal and social needs (Berg et al., 2011; Lakhani and Wolf, 2005) through human interactions (Melin, 2000). The mechanisms of how these desires affect decision-making and the move toward assembling in KPTs and more importantly how these influence career self-management (Quigley and Tymon, 2006) is critical to understanding how motivation and threat play a significant part in the decision-making processes of potential KPT participants and well worth exploration.

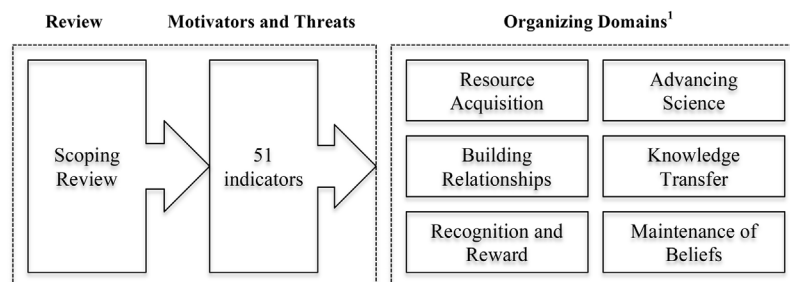
2. Method

A key set of literature served as the initial basis for extrapolating an *ad hoc* listing of search terms that were later expanded upon based on initial findings (Eigenbrode et al., 2007; Hagstrom, 1964; Salazar et al., 2011; Stokols et al., 2008b). A more comprehensive scoping review method (Arksey and O'Malley, 2005) was then employed to understand the breadth of the subject of individual motivations and threats to scientific collaboration across a large range of resources. This method was chosen over a systematic review method (Petticrew and Roberts, 2008), one that compiles literature associated with a bounded problem or research questions, as we felt it was more suited to the vast multidisciplinary and sometimes untethered literature that contributes to the discussion of scientific team collaboration. The review proceeded to search literature across discipline-specific domains: psychology, management, organizational science, leadership, social psychology, sociology, anthropology, and biomedicine, as well as interdisciplinary team and collaboration sciences. References highlighting interpretations of the mediating role of motivation for collaboration were sought and targeted. Search engines used included the public Science of Team Science (SciTS) Mendeley group (Falk-Krzesinski, 2015), Google Scholar, Scopus, and others that represent a

multidisciplinary array of literature (Academic Premier, Articles First, and ProQuest). Search criteria were designed that captured the meaning of specific indicators as uncovered in an iterative manner. Alterations to the criteria were made based on findings and terminology from the literature as domain clusters emerged.

An initial set of 56 indicators was later edited to 51 based on analysis of meaning found in the literature and the frequency of findings. One hundred and fifty (150) articles offering insight about scientific collaboration and KPTs were initially reviewed and analyzed for relevant content representing over 60 years of discourse and empirical research. These subsequently pointed to additional literature. In the end, 142 resources were included in this scoping review, mostly peer-reviewed (126) representing 81 journals along with 15 other items representing books, proceedings, and doctoral dissertations. Once compiled and sorted into indicator clusters, thematic coding identified overlaps in the literature at it pertained to each of the indicators. Based on themes found throughout the literature, indicators were grouped by emergent domains and named by the research team based on the general areas of focus: resource acquisition, recognition and reward, knowledge transfer, advancing science, building relationships, and maintenance of beliefs (Fig. 1). Indicators were related within and across domains through an intuitive process that matched frequency of authorship, keywords, and concepts leading to domain clustering of indicators (by volume) and visualization of dominating motivations and threats within and across domains. Ties within and across domains were decided based on the frequency of literature contributions to each indicator.

Once compiled, the indicators identified were organized by domains (Organizing Domains) and were related within and across domains using an interpretive methodology (Creswell, 2007) relating similar indicators based on meaning and key words. We also provide domain clustering of indicators (by volume); and an analysis of dominating motivations and threats by analyzing ties within and across



¹The Organizing Domains are further elucidated in Tables 1 through 6 below.

Fig. 1. Methodological Model.

domains. The conclusion focuses on the value of this compilation for further research (Fig. 2)

3. Results

3.1. Motivation and threat indicators

The depth of the available literature on individual motivators and threats varies by indicator, and there is no hierarchy to their order provided. While indicators are organized by motivators and threats, not all are so easily separated into dichotomous categories. This stated, our organization is based on dominant themes that emerged from our analysis (Table 1). For those that are both supporting *and* deterring by nature, two factors have been made to accommodate the duality found within the theme.

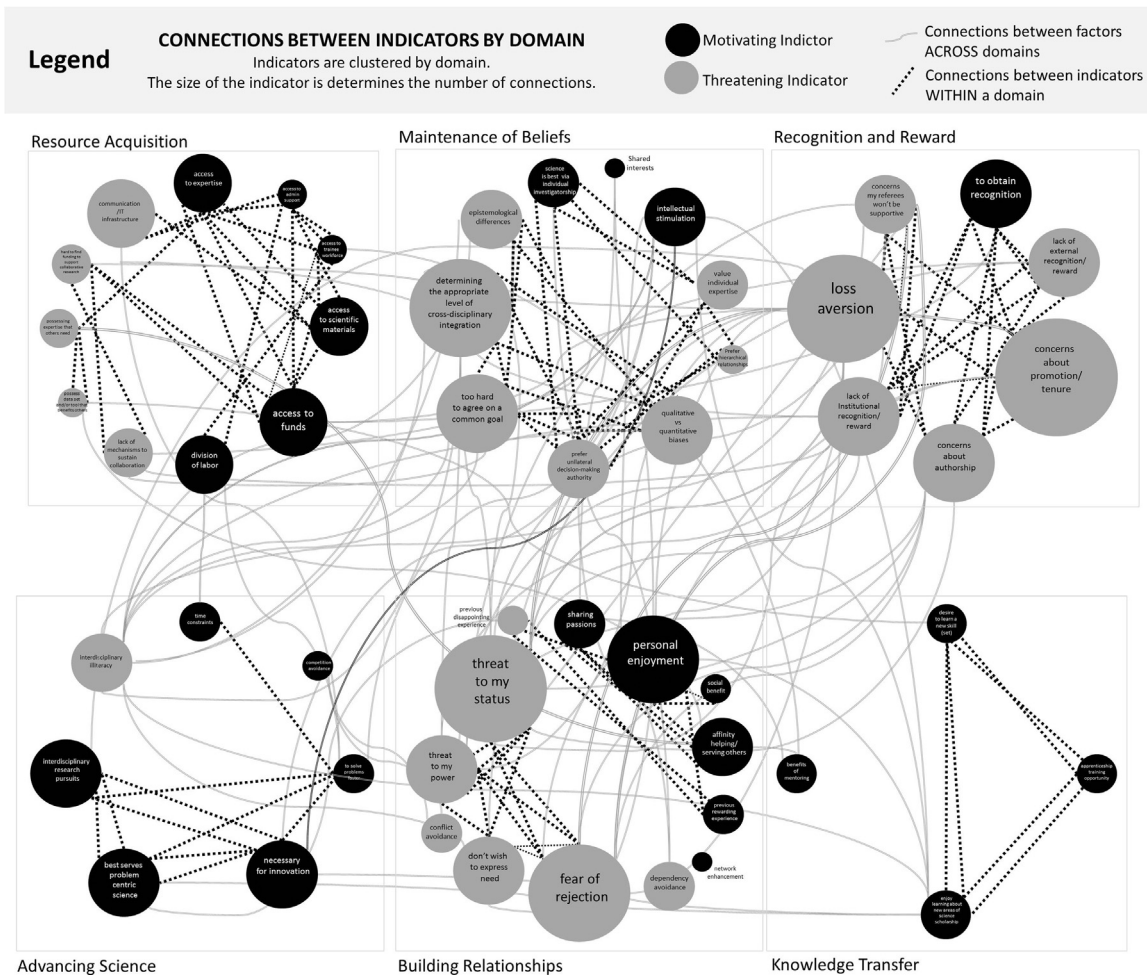


Fig. 2. Indicators grouped by Organizing Domain. Clustering the motivation and threat indicators by into domains by thematic coding.

Table 1. Resource Acquisition Organizing Domain.**Resource Acquisition: Accessing, acquiring, and deploying human and intellectual resources**

Motivation Indicators	Threat Indicators
<ul style="list-style-type: none"> • Access to expertise • Access to administrative support • Access to trainee workforce • Access to scientific materials • Access to funds • Need for division of labor 	<ul style="list-style-type: none"> • Communication/IT infrastructure • Possess data set and/or tool that benefits others • Possessing expertise that others need • Lack of available mechanisms to sustain a collaboration • Hard to find a funding mechanism to support collaborative research

3.2. Access to expertise

Complementarity of knowledge and skills between team members is an important component of research collaboration. Researchers who feel they lack expertise in certain areas will seek others that possess this needed knowledge or skill (Maglaughlin and Sonnenwald, 2005). This need has been evidenced throughout the evolution of research professionalism (Beaver, 2001; Beaver and Rosen, 1979) as research and writing tasks warranted increased strategic alliances (Fox and Faver, 1984) and benefits from other researchers' knowledge contributed to solving complex problems (Melin, 2000). Sharing expertise may be even more important in very specialized fields where expertise and skill are not so widely available (Birnholtz, 2006). Such motivation has also been reported in "bottom up" global collaborations that utilize national and regional facilities for big science and how these collaborations lead to growth in co-authorship (Georghiou, 1998; Wagner and Leydesdorff, 2005). Researchers motivated by skill complementarity have been described as 'tacticians' by Bozeman and Corley (2004) in their work on acquiring scientific and human capital. Hara, Solomon, Kim, and Sonnenwald (2003) argued that collaborations motivated by skill and knowledge complementarity are easier to establish than integrative collaborations and often require less compromise to differences amidst experts.

3.3. Access to administrative support

Access to resources, other than the intellectual capital found through complementarity, is also a well-established motivating factor for scientific collaboration. It is associated with other motivations across domains. However, few studies have cited administrative support acquisition as a reason to collaborate. In the case of international research centers, study participants have found management structures in these centers to be administratively burdensome (Turpin and Garrett-Jones, 2010). Collaboration between individuals and institutions creates more administrative and management needs, which may offset the benefits of

collaborating by the need to access shared administration. Though such complicating dynamics may shed a negative light on the role of administration as something that possesses a high level of maintenance, its availability generally supports collaborative efforts for KPTs (Katz and Martin, 1997).

3.4. Access to trainee workforce

Maglaughlin and Sonnenwald (2005) refer to trainees as a primarily human workforce resource. Katz and Martin's (1997) study revealed that some researchers did not consider students as collaborators at all and at times they did not even consider them co-authors or contributors to research, further suggesting that students may be seen as exploitable human resources in KPTs. Understood in this context, students become facilitators of collaboration and fill roles as laborers, especially those with higher degrees possessing their own motivations to work with senior knowledge workers (Beaver, 2001; Fox and Faver, 1984; Kraut et al., 1987). To work with collaborators who have access to these types of laborers is an attractive benefit regardless if considered collaborators or not. Garrett-Jones, Turpin, and Diment (2010) noted that access to PhD students and attracting students to their team were reasons often found amongst researchers motivated to participate in research centers.

3.5. Access to scientific materials

Closely related to the need to access scientific expertise is the need to access scientific resources like equipment, study populations, and other tangibles required to conduct research. Studies have reported that researchers will engage in collaborations because it provides access to equipment (Beaver and Rosen, 1979; Birnholtz, 2006; D'Este and Perkmann, 2011; Heinze and Kuhlmann, 2008), data (D'Este and Perkmann, 2011; Wagner and Leydesdorff, 2005), and facilities (Georghiou, 1998; Heinze and Kuhlmann, 2008). In certain fields, working within centralized science hubs provided researchers access to otherwise unavailable geographical regions and population groups (Georghiou, 1998; Sonnenwald, 2007).

3.6. Access to funds

Access to financial support of scientific effort is an oft-cited reason by which researchers are motivated to collaborate (Beaver, 2001; D'Este and Perkmann, 2011; Langford et al., 2006). Scientists engage in collaborations when they perceive that funding agencies and emerging science policies are favoring collaborative research efforts (Lewis et al., 2012; Maglaughlin and Sonnenwald, 2005). An emphasis by funding agencies for collaborative teams can be frustrating for some researchers who feel this type of work is less productive yet supportive of

their own specific research agendas (Nair et al., 2008). Researchers will look for collaborators in an effort to pool and leverage funds and share the cost of projects (Birnholtz, 2006; Fox and Faver, 1984; Georghiou, 1998; Katz and Martin, 1997; Kraut et al., 1987; Wagner and Leydesdorff, 2005). While some rank monetary gains as a primary motivator for collaboration (Langford et al., 2006; Lee, 2000), others place less importance on these financial benefits when compared to other intangibles (Turpin and Garrett-Jones, 2010). The need to access funds appears to be motivated by a desire to advance one's own research agenda rather than the potential for personal financial gains, even in industry-academia collaborations (D'Este and Perkmann, 2011; Lee, 2000).

3.7. Need for division of labor

The ability to divide research-related intellectual and task labor for time efficiency motivates researchers to collaborate (Beaver and Rosen, 1979). Scientific precision as well as productivity have been cited as reasons why researchers collaborate (Eaton, 1951). This need to divide work may be even more important in “more specialized or capital-intensive areas of science” (Katz and Martin, 1997, p. 16) that depend more sharply on time tables and pressures to develop outputs. However, division of labor is sometimes related to the size of the project rather than the level of specialization required (Sargent and Waters, 2004). In some KPTs, the disparity of skills might be quite low and collaboration might be more a pairing of suitable collaborative partnerships. Furthermore, the division of labor may be a more important motivator if researchers believe it will lead to more publications (Melin, 2000). Ultimately, this indicator favors the idea that collaboration is an opportunity to divide tasks rather than integrate and synthesize ideas, though it is not exclusive of it.

3.8. Communication/IT infrastructure

While communication technologies have as their goal more fluid collaboration, often the adoption of these technologies can be threatening in itself. The advent of sophisticated technological communications and the growing number of geographically dispersed teams have necessitated higher levels of literacy and acquisition with regards to IT infrastructures (Gray, 2008; Johnson et al., 2009). Literature reviews by Sonnenwald (2007) and Stokols et al. (2008a) on the topic of scientific collaboration have framed communication and IT infrastructure as enablers or facilitators of collaboration rather than motivators. While certain technologies have certainly afforded greater interactions amongst researchers, this is not always attractive to some within KPT communities. For example, Sonnenwald (2007) concluded that “information and communication technologies (ICTs) can facilitate scientific collaboration and give rise to new types of collaboration” (p. 660), the availability of which is key to the success of distance collaborations (Shrum et al.,

2008). Perhaps more relevant to the topic is that individuals who lack experience with these emerging technologies will be ill-prepared in situations other than those conducted face-to-face (Olson and Olson, 2000; Stokols et al., 2008a; Stokols et al., 2005). Sustained social communications (more face-to-face engagements) alongside task-related ones (technology-mediated interactions) can generate greater trust and social cohesion (Jarvenpaa and Leidner, 1999). The environment that is meant to facilitate more collaboration is often the one that creates the most barriers and frustrations for collaborators (Olson and Olson, 2000), which can affect one's motivations for knowledge sharing as a result (Hendriks, 1999).

3.9. Possess data set and/or tool that benefits others

Although access to scientific resources has been established as a motivating factor for collaboration, researcher's unconditional sharing of data and other resources is not an overt motivation. Rather, researchers collaborate to share *and* access resources and data (Wagner and Leydesdorff, 2005) suggesting that without a reciprocal process in place, researchers could be threatened by unidirectional sharing. Some authors highlight reasons by which researchers choose to collaborate in line with many of the supporting factors that have already been named in the acquisition of resources domain and others namely: 1) increase of visibility among peers and exploit complementary capabilities; 2) share the costs of projects that are large in scale or scope; 3) access or share expensive physical resources; 4) achieve greater leverage by sharing data; and 5) exchange ideas in order to encourage greater creativity. Melin (2000) concluded that researchers, on the surface, have a desire to share ideas and resources with others. This desire to expand, to find new ways of working and thinking, to share ideas and resources with other researchers and a general wish to collaborate are often met with challenges as to how to achieve this efficiently (Stokols et al., 2008a).

3.10. Possessing expertise that others need

While access to expertise has been established as a motivating factor for collaboration, similarly to data and resources, researcher expertise is not often shared in a unidirectional manner, rather collaborators are not motivated to overtly share their own expertise without some type of reward, recognition, or trade off. Melin (2000) provided such distinction when he concluded that researchers have a desire to share ideas and resources with others highlighting that "needs can be either of a material, knowledge-based or social kind...Somebody wants something, somebody else can perhaps provide it" (p. 38).

3.11. Lack of available mechanisms to sustain collaboration

Studies have found that trust, communication, and motivation (Rhoten and Parker, 2004) as well as productive outcomes, funding, relationships, and shared interests (Lewis et al., 2012) all impact sustainability of collaborations over time. Continuous evaluation can ensure that collaborations overcome the factors listed above (Sonnenwald, 2007). Additionally, providing appropriate rewards and incentives that compensate for the challenges met by scientific teams can sustain the motivation to collaborate. Some of the mechanisms that sustain long-term collaborations could dampen individual creativity and productivity (Rhoten, 2003; Rhoten and Parker, 2004; Stokols et al., 2008a). Participants were more satisfied and productive if they didn't feel locked into their collaborations. Yet evidence suggests that the number of affiliations with scientists outside of one's own field of inquiry are greater than most would imagine, and that "their relationships with other center members have 'positively' or 'very positively' influenced the development of their own research agendas. It is not surprising that, in the short-term, diversity will yield more creativity than productivity, but it is significant as one begins to measure the 'value' of interdisciplinary versus disciplinary science" (Rhoten and Parker, 2004, p. 8). Not surprisingly, a lack of motivation to enter into KPTs whose outputs are valued by peers are often due to the lack of systemic implementation, infrastructures, and reward systems in university centers thus deterring scientists from capitalizing on these relationships. Recommendations that institutions work to enable environments by establishing transdisciplinary research priorities, creating for joint appointments between departments, considering transdisciplinary work when evaluating for promotion, award, and recognition are emerging in the literature highlighting the importance of these structures for collaboration.

3.12. Hard to find a funding mechanism to support collaborative research

Lacking implementation infrastructure can lead to a lack in motivation to collaborate. However, even when these supports are available, a lack of funding to support collaborative endeavors, especially those with a high diversity of goals, can negatively impact motivation. Appropriate funding facilitates collaborative research, while lack of funding acts as a barrier (Eigenbrode et al., 2007; Lewis et al., 2012; Stokols et al., 2008a). Decreases in basic science funding and increases in the cost of conducting science motivate researchers to pool resources and collaborate (Harris et al., 2009; Heinze and Kuhlmann, 2008). In regard to funding directed at KPTs, some believe that funding agencies do not support or understand the need for such research that capitalizes on the benefits of collaborative engagements (Castán Broto et al., 2009), or that despite increases in interdisciplinary research funding, the funds are spread too thin (Laberge et al.,

2009). These trends, along with science policies that make funding for teams difficult by mere lack of abundance, can deter researchers from seeking to invest and risk other more viable funding options, (Table 2) regardless of their desires or interests to work collaboratively.

3.13. To obtain recognition

Scientists are motivated by the increased recognition and visibility that research collaborations provide (Beaver, 2001; Beaver and Rosen, 1979). Increased visibility is one reason why scientists participate in international collaborations (Wagner and Leydesdorff, 2005). In addition to personal recognition, collaboration can increase the visibility of the work produced through the multiple contacts and networks formed out of collaborations (Katz and Martin, 1997; Laberge et al., 2009). For students, participating in scientific collaborations is a sign of recognition and acceptance by the greater scientific community (Hara et al., 2003). Although Melin (2000) showed that increased visibility and recognition were only somewhat important, the author concluded that “a collaboration that is likely to bring less recognition to the participants will seldom occur” (p. 38).

3.14. Loss aversion

The idea of loss can be threatening no matter the context. Much of the literature speaks of specific risks or losses such as loss of funding, status, or recognition. In contrast, loss aversion is an environmental deterrent to collaboration, as Fox and Faver (1984), Georghiou (1998), and Sonnenwald (2007) have argued, representative of how sharing risk, or minimizing losses, can motivate stakeholders to choose collaborations over individual endeavors, especially when the risk of loss is diverted to shared rather than individual resources. Though collaboration may

Table 2. Recognition and Reward Organizing Domain.

Recognition and Reward: Mechanisms and methods by which human and intellectual resources are recognized

Motivation Indicator	Threat Indicators
<ul style="list-style-type: none"> To obtain recognition 	<ul style="list-style-type: none"> Loss aversion Lack of external recognition/reward Concerns about getting promoted/tenured Lack of institutional recognition/reward Concerns about authorship Concerns that my referees won't be supportive

minimize loss through shared risk, generally it remains a threat to open collaboration if a team member must calculate risk level. For this reason it is a threat to openly entering into collaborative activity. Loss aversion raises a number of questions, such as “How does a group establish an independent identity while remaining connected with its field of research?” and “How are consistency of focus and continuity of approach balanced against the freedom younger scientists need to develop as independent investigators?” (Hackett, 2005, p. 787).

3.15. Lack of external recognition/reward

Interdisciplinary research is often regarded as less rewarding than disciplinary work (van Rijnsouvera and Hessels, 2011) though it is embedded with a series of risks. Wray (2006) argues that scientists concerned with receiving adequate recognition for their work on collaborative projects may shy away from interdisciplinary, collaborative work. This deterrent requires management and investigation as to the sector-specific and cross-sector needs for reward and recognition (Parthaa and David, 1994; Turpin and Garrett-Jones, 2010). However, for some, collaboration provides more opportunities for reward and recognition otherwise unattainable in a strictly disciplinary environment (Turpin and Garrett-Jones, 2010). Though this may be the case, the opportunities for reward do not minimize the risks associated which may contribute to its threatening character.

3.16. Concerns about getting promoted/tenured

Promotion and tenure practices and policies appear to support individual and disciplinary achievements rather than interdisciplinary work. Therefore, interdisciplinary research can be considered risky in terms of career progression (Carayol and Thi, 2005; Coberly and Gray, 2010; Harris et al., 2009; Horlick-Jones and Sime, 2004; Maglaughlin and Sonnenwald, 2005; Rhoten and Parker, 2004; Zucker, 2012). Maglaughlin and Sonnenwald (2005) suggest that academic rank and status can affect the allocation of recognition in interdisciplinary projects. Much of the literature agrees that this risk is especially true for junior scientists, who must often delay collaborative work until tenure has been achieved (Boden et al., 2011; Carayol and Thi, 2005; Younglove-Webb et al., 1999). However, Birnholtz (2006) failed to show that tenure was “a significant predictor of collaboration propensity” (p. 2235). Additionally, it has been suggested that in some countries with tenure processes different than those in North America, collaboration can play an important role in the promotion process (Sargent and Waters, 2004).

3.17. Lack of institutional recognition/reward

Many of the existing reward systems in science do not provide adequate incentive for researchers to collaborate (Wray, 2006). Similarly, van Rijnsoever and Hessels (2011) found that reward systems favor disciplinary versus interdisciplinary work and therefore provide no incentive to collaborate across disciplines. In particular, departmental or institutional evaluation criteria for researchers often do not appear to support interdisciplinary work (Younglove-Webb et al., 1999), which leaves many scientists to work on collaborative projects “on the side,” in addition to their departmental projects (Boden et al., 2011). Some argue for the adoption of organizational incentives, changes in promotion structures, and long-term funding to sustain scientific collaborations (Ameij and Brown, 2004; Stokols et al., 2008a). The need for sweeping policy change in this sphere is also slowly gaining attention (American Psychological Association Board of Scientific Affairs, 2014; National Academy of Science, 2015). For some disciplines, participation in research centers may improve one's chances of promotion within their home department (Turpin and Garrett-Jones, 2010).

3.18. Concerns about authorship

Traditionally, the scientific environment has rewarded individual authorship (Stokols et al., 2008a) and therefore researchers have preferred to publish in a way that signifies individual credit, such as serving as the first or last author on an article (Barrett et al., 2005; Lewis et al., 2012). Pressure toward scientific collaboration, and thus an increase in co-authorship (Wuchty et al., 2007) and the risks associated shared acknowledgement, has created anxiety among researchers as they fear receiving inadequate credit for their work (Bennet et al., 2010; Conte et al., 2013; Wray, 2006). This, argues Wray (2006), affects researchers' motivation to work in scientific teams. Receiving less credit for one's work is likely to be more detrimental for junior scholars than for more established researchers (Fox and Faver, 1984).

3.19. Concerns that my referees won't be supportive

Concerns about how collaborative research is judged can impact scientists' decisions to engage in scientific collaboration and is often based on experience with reviewers' and evaluators' lack of skills to measure the validity of cross-disciplinary epistemics and methodologies (Öberg, 2009). One's reputation may be threatened if others perceive interdisciplinary or collaborative work as less credible or of lower status (Bracken and Oughton, 2009; Harris et al., 2009). Additionally, interdisciplinary publications may be more difficult to evaluate and reviewers may be more critical (Lamont et al., 2006; Rhoten and Pfirmman, 2007). Some have also reported that researchers are also concerned that the frameworks established to

evaluate interdisciplinary (Table 3) performance tend to force them back into their own disciplines for the purpose of evaluation (Lewis et al., 2012).

3.20. Desire to learn new skill (set)

While some researchers will engage in collaborations in an effort to tap into the expertise of their collaborators, others are motivated by the opportunity to learn new skills and gain experience (Beaver, 2001; Beaver and Rosen, 1979; Heinze and Kuhlmann, 2008; Melin, 2000). Over time, studies have consistently cited learning and gaining scientific experience as motivating indicators and benefits of scientific collaboration (Beaver, 2001; D'Este and Perkmann, 2011; Melin, 2000; Sonnenwald, 2007). As would be expected, young scientists have much to gain in terms of skills and experience by collaborating with more senior scientists (Hara et al., 2003; Nash, 2008; Wray, 2006) even amidst certain challenges associated with choosing inter- and transdisciplinary career paths (Nash et al., 2003). Other studies have framed learning as a process (Maglaughlin and Sonnenwald, 2005) or as an outcome (Kraut et al., 1987; Sargent and Waters, 2004) of collaboration rather than a motivator.

3.21. Apprenticeship/training opportunity

Learning opportunities that come from collaboration as bonuses rather than intended benefits of collaborations are not usually created for the purpose of learning only (Nair et al., 2008). It therefore seems logical that few studies have reported apprenticeship or formal training opportunities as primary reasons why researchers would be motivated to collaborate. The obvious exception in the literature is the trainee population. Collaborating with scientists provides students with apprenticeship opportunities that help them gain knowledge, skills, experience, and credibility within the scientific community (Hara et al., 2003;

Table 3. Knowledge Transfer Organizing Domain.

Knowledge Transfer: Organize, exchange, acquire, deploy knowledge

Motivation Indicators

- Desire to learn new skill (set)
- Apprenticeship/training opportunity
- Enjoy learning about new areas of science/ scholarship
- Benefits from mentoring

Threat Indicators

- *The scoping review found no significant literature that addressed threats in this domain.*

Maglaughlin and Sonnenwald, 2005; Meyers et al., 2012). An increase in global research collaborations has also provided new opportunities for trainees and fellows (Georghiou, 1998; O'Brien et al., 2013).

3.22. Enjoy learning about new areas of science/scholarship

In addition to wanting to learn specific skills and knowledge, researchers will seek to collaborate in an effort to learn about new areas of science (Beaver, 2001; D'Este and Perkmann, 2011; Maglaughlin and Sonnenwald, 2005; Nair et al., 2008). Turpin and Garrett-Jones (2010) found this to be true in the decision to collaborate with industry partners. Enjoyment in the learning process is not very widely discussed in the literature. It appears that scientists are motivated by the need or want to enter into “effortful cognitive endeavors” (Kearney et al., 2009, p. 581). When members have the freedom to engage in what truly is intellectually stimulating, “high performance is enjoyable and enhances innovation” (Nair et al., 2008, p. 151).

3.23. Benefits from mentoring

The opportunity to teach and mentor students and junior scientists is another motivator for collaboration (Beaver, 2001; Beaver and Rosen, 1979; Bozeman and Corley, 2004; Langford et al., 2006). There is evidence that this collaborative endeavor is beneficial to both mentors and trainees (Sampsel et al., 2013). In a study that identified collaboration strategies, Bozeman and Corley (2004) described the scientist motivated by this opportunity as ‘the mentor’. Lee (2000) also found that some scientists are motivated to collaborate with industry because of the opportunity to create jobs or internships for their trainees (Table 4).

Table 4. Advancing Science Organizing Domain.

Advancing Science: Contribute to an agenda or progression of science.

Motivation Indicators

- Individual time constraints
- To solve problems faster
- Competition avoidance
- Best serves problem-centric science
- Interdisciplinary research pursuits
- Necessary for innovation

Threat Indicators

- Interdisciplinary illiteracy

3.24. Individual time constraints

A more efficient use of time can be a motivating factor to collaborate (Beaver and Rosen, 1979). Indeed there have been times when pressures for rapid scientific discoveries have motivated scientists to collaborate (Sonnenwald, 2007). Additionally, collaborating may reduce the amount of time a scientist needs to learn new skills (Katz and Martin, 1997) and therefore collaborations assist in securing these assets quickly. This time saving relates to the division of labor and how this division translates into benefits for researchers in general (Becker and Murphy, 1992; Adams et al., 2005; Hagstrom, 1964; Heath and Staudenmayer, 2000; Kirkman and Rosen, 1999; Lee et al., 2015), though it is arguable whether these divisions support greater integration of knowledge versus rapid accomplishment of tasks. However, scientists continue to list the large time commitment required for collaboration as a deterrent, especially in the early stages of projects (Fox and Faver, 1984; Maglaughlin and Sonnenwald, 2005; Nair et al., 2008; Tress et al., 2009). Nevertheless, the added time spent early in collaboration appears worth it for some and may ultimately result in more time-efficient and satisfactory outcomes (McWilliam et al., 1997).

3.25. To solve problems faster

Beaver (2001) claimed that scientists are motivated to collaborate when pressured “to make progress more rapidly” (p. 373). Collaboration can help accelerate progress by combining scientific resources (Maglaughlin and Sonnenwald, 2005) and creating a sense of urgency and accountability among team members (Fox and Faver, 1984). Though similar to the consideration of motivation when faced with time constraints and the division of labor that both support more rapid results, rapid problem solving differs slightly in that it has been shown to be more dependent on interactional teaming factors like trust (Zand, 1972), organizational growth and decision-making (Greiner, 1998), and leadership skill development (Mumford et al., 2000).

3.26. Competition avoidance

Beaver and Rosen (1979) suggested that researchers collaborate to avoid competition. This highlights that scientists would rather collaborate than compete with others and risk loss to an opposing individual or team. Rhoten and Pfirmman (2007) described the disciplinary research environment as competitive and suggested that for some, especially marginalized groups such as women, interdisciplinary research is a less competitive research setting. However, collaboration can also increase competition by requiring that individuals share valuable information (Birnholtz, 2006; Fang and Casadevall, 2015) and receive criticism from others (Bracken and Oughton, 2009), which can leave individuals

vulnerable to a number of career damaging risks. [Birnholz \(2006\)](#) and [Petersen, Stanley, and Succi \(2011\)](#) concluded that the competitive risks associated with collaboration do not deter individuals from collaborating but rather influence their decision-making about with whom they collaborate.

3.27. Best serves problem-centric science

Researchers will collaborate to solve societally relevant and more complex problems ([Beaver, 2001](#); [Laberge et al., 2009](#); [Langford et al., 2006](#); [Rhoten and Pfirmman, 2007](#)). [Laberge et al. \(2009\)](#) found this to be especially true in interdisciplinary health research. Additionally, [Rhoten and Pfirmman \(2007\)](#) suggested that female researchers might be more motivated to collaborate because it enables them to solve problems that make an impact on society. Solving such problems will depend on the ability of interdisciplinary teams to adequately integrate their disciplines ([Eigenbrode et al., 2007](#)) and “share constructs across the different fields that study multidisciplinary collaboration and related issues, elaborate on specific similarities and differences in theory, data, and methods, classify gaps and important future directions in the state of the art of the study of multidisciplinary collaboration, and identify specific infrastructure changes and needs that would enable both the study and practice of multi- and interdisciplinary collaboration” ([Paletz and Schunn, 2010, p. 51](#)).

3.28. Network enhancement

[Beaver \(2001\)](#) argues that researchers seek collaborations in an effort to meet other researchers and expand their network. Some interpret the network building aspect of collaboration as a benefit of collaboration rather than a motivator in which to enter into collaborative environments ([Katz and Martin, 1997](#); [Lambiotte and Panzarasa, 2009](#); [Melin, 2000](#); [Turpin and Garrett-Jones, 2010](#)). Strong evidence of impact in some networks can be considered a motivating factor to join certain alliances ([Garner et al., 2012](#); [Ravid et al., 2013](#)) or maintain relationships with certain core disciplines to increase publication success and impact ([Bales et al., 2014](#)). Co-authoring, co-citation, and the development of project-generated articles seem to be major contributors to network building ([Garner et al., 2012](#); [Gazewood et al., 2006](#); [Geertz, 1973](#)). Networking appears to be an important element of collaboration since many alliances emerge from within one's own network ([Maglaughlin and Sonnenwald, 2005](#); [Sonnenwald, 2007](#)) though not exclusively ([Obeid et al., 2014](#)).

3.29. Interdisciplinary research pursuits

Pursuing collaborative work in an effort to address specific research problems, either close to one's own research interests or in line with one's wider agenda,

motivates researchers to work together (Melin, 2000; Rhoten and Parker, 2004; Wray, 2006). Inevitably this will require crossing disciplinary boundaries as one interacts with others (Klein, 2014). The type of cross-disciplinary research and the problems it hopes to solve (Sonnenwald, 2007), the size of the project (Fox and Faver, 1984), the complexity of the research topic (Eaton, 1951) and the types of skills required (Katz and Martin, 1997) are all elements that can play a part in the process of motivating an individual to seek out collaborative endeavors as one seeks to benefit from interfacing with cross-disciplinary partners.

3.30. Necessary for innovation

For some, collaboration is a necessity for innovation and advancing science (Beaver, 2001; Katz and Martin, 1997; Langford et al., 2006; Maglaughlin and Sonnenwald, 2005). The ability to innovate through collaboration appears to be associated with the pooling of expertise and resources (Uzzi et al., 2013) discussed earlier in this paper. In addition, in studies with Chinese R&D firms, “individual motivational states and team support for innovation climate uniquely promote individual innovative performance, and in turn, individual innovative performance linked team support for innovation climate to team innovative performance” (Chen et al., 2013, p. 1018), suggesting that needs directed toward innovation are both motivational antecedents as well as outcomes of collaborative interactions.

3.31. Interdisciplinary illiteracy

It is often under recognized that interdisciplinary skills are needed to collaborate. The lack of these skills can be a threatening component to collaboration. The nature of interdisciplinary research creates an environment where various languages, approaches, and beliefs must be integrated. Although this diversity is certainly a benefit of scientific collaborations, the integration and collaborative synthesis process can be difficult. The ability to navigate these, known as interdisciplinary literacy, can be lacking for some scientists, instilling confusion, frustration, and under-appreciation that can create conflict among team members (Bindler et al., 2012; Harris et al., 2009; Sonnenwald, 2007; Thompson, 2009; Younglove-Webb et al., 1999). Several studies have demonstrated that taking the time to address the language differences can help scientific teams overcome this barrier (Bracken and Oughton, 2009; Stokols et al., 2003; Thompson, 2009). Moreover, Maglaughlin and Sonnenwald (2005) have discussed the role of individuals as bridges to assist in interdisciplinary communication (Table 5). Differing languages can also impact publication in disciplinary journals and therefore developing a common language and interdisciplinary journals is important (Wear, 1999).

Table 5. Building Relationships Organizing Domain.**Building Relationships: Utilizing resources and knowledge to establish or expand connections**

Motivation Indicators	Threat Indicators
<ul style="list-style-type: none"> • A previous rewarding experience • Personal enjoyment • Social benefits • Sharing passions • Affinity toward helping/serving others 	<ul style="list-style-type: none"> • Fear of rejection • Don't wish to express need • Dependency avoidance • Conflict avoidance • Power threat • Status threat

3.32. A Previous rewarding experience

In examining literature on transdisciplinary scientific collaboration, [Stokols et al. 2008b](#) found that “a history of positive collaboration increases members’ readiness for effective teamwork” (p. S106) because of the members’ familiarity with each other and existing trust. Similarly, [Nair et al. \(2008\)](#) noted that participants repeatedly referred to the importance of previous relationships and past collaborations when deciding to engage in collaborative projects. Positive experiences had strong correlations with attitudes in favor of interdisciplinary science and productivity in trainees ([Stokols et al., 2008a](#)) and in more senior researchers ([Conn et al., 2015](#); [van Rijnsoever and Hessels, 2011](#)). [Birnholz \(2006\)](#), supported these findings and added that the quality of relationships was perhaps more important than the quality of the results or simply having worked together in the past. [Bozeman and Corley \(2004\)](#) characterized the researcher that is motivated by previous rewarding experiences as the ‘buddy’. It appears that socially rewarding experiences in collaboration have more influence on researchers’ decision to collaborate than scientifically/professionally rewarding experiences.

3.33. Personal enjoyment

Some studies have reported that researchers are motivated to collaborate with others because of the fun or enjoyment of collaborating ([Beaver, 2001](#); [Bozeman and Corley, 2004](#); [Kraut et al., 1987](#); [Maglaughlin and Sonnenwald, 2005](#)). [Sargent and Waters \(2004\)](#) points to the satisfying research ideas generated by others when in collaborative engagements. [Kearney et al. 2009](#) spoke of enjoyment involved with effortful cognitive endeavors; and ([Kraut et al., 1987](#)) spoke of the fun of

working with others. Alon (2010) equates the satisfaction and enjoyment of team members as having a strong effect on innovation.

3.34. Social benefits

Personal enjoyment and social satisfaction differ slightly. Scientific collaboration requires researchers to work with others and forces relationships. Personal chemistry between these individuals has been listed as a prerequisite for such collaborative efforts (Melin, 2000) and the enjoyment of collegiality has been reported as a benefit of collaborating (Isenberg, 1987). More importantly, studies have shown that the desire to work with others (Maglaughlin and Sonnenwald, 2005; Sargent and Waters, 2004), the perception that others are fun to work with (Bozeman and Corley, 2004), and that working with others is more enjoyable than working alone (Beaver, 2001; Beaver and Rosen, 1979; Fox and Faver, 1984; Katz and Martin, 1997; Kraut et al., 1987; Lotrecchiano, 2013) are reasons why researchers will opt to collaborate. Fox and Faver (1984) have also suggested that this may be particularly important for those within marginal groups such as women and academics with high teaching workloads.

3.35. Sharing passions

Researchers will collaborate because they want to share their passion with others (Beaver, 2001; Schneider et al., 1992). While this can be construed, as a type of social benefit, there is no real evidence that individuals need to benefit from this sort of sharing though but often both individuals and teams do. Individuals who promote a sharing culture contribute to transdisciplinary settings (Lotrecchiano, 2012). These tendencies in groups “affected individual level outcomes of job performance, psychological well-being, and withdrawal through their impact on organizational commitment and job satisfaction” (Carr et al., 2003, p. 605). In addition, project effectiveness can be measured based on “the intersection of talent, passion, and scientific objectives as motivating, because talent is related to competence, passion is an ingredient of autonomy, and shared objectives enhance social connectedness” (Alon, 2010, p. 152).

3.36. Affinity toward helping/serving others

Most of the literature focusing on helping and serving others is placed in the context of teaching and learning. Some unique literature focuses on workplace climate and rewards that highlight service being “a strategic imperative . . . revealing the routines and rewards most strongly related to service passion: responsiveness to consumers, hiring procedures (who and how), training (availability and content), and the way service is delivered” (Schneider et al., 1992, p. 705). These characteristics have become more commonly associated with

reward and recognition standards found in universities that value service above and beyond traditional faculty role requirements and include academic citizenship (Macfarlane, 2007), service-learning (Edmondson, 2003), and team teaching (Wildman and Bedwell, 2013) as venues in which faculty and researchers may apply their specific expertise to teaming venues and gain recognition and possible rewards.

3.37. Fear of rejection

As the prospect of loss can be a threatening proposition to a collaborator, fear can be a barrier that can equally challenge one from collaborating. There is no strong evidence that participating in scientific collaboration will lead to disciplinary rejection or that the fear of this rejection will deter scientists from collaborating. “It motivates individuals to prioritize detecting and managing potential rejection at a cost to other personal and interpersonal goals” (Berenson et al., 2009, p. 1064). However, academics feel that their interdisciplinary endeavors can negatively impact their credibility and reputation within their own discipline (Harris et al., 2009; Rhoten and Parker, 2004). The literature describes the fear of rejection in terms of career advancement, journal rejections, and funding rejections. Fear of rejection can be a strong indication of low levels of perceived social support, and related stress, as the reason for low performance (Langens and Schuler, 2005). Others have argued that within group interactions, member sensitivity to broad social cues, like their social network, can be reason for disengagement if one fears rejection from the network (Shapiro et al., 2011).

3.38. Don't wish to express need

A generally under-researched area, need expression can be a threat to actual collaboration, especially if the cause for those seeking collaborative partners is challenged by the interpersonal skills necessary to do so in a way that does not communicate vulnerability. These types of skills “includes behaviors generally aimed at communicating with others, in terms of asking questions, delivering presentations, influencing others, negotiating, persuading, and seeking information” (Kantrowitz, 2005, p. 97), which when lacking can serve as barriers to building relationships. “Findings suggest that persons deciding whether to seek help take into account not only their own costs and rewards, but also the cost-reward contingencies of their helper” (DePaulo and Fisher, 1980, p. 23). Proximity to non-collaborators who do similar work does appear to have an influence on the amount of help-seeking that takes place and the amount of discussions that take place that may lead to eventual collaborations (Boudreau et al., 2012; Hoegl and Proserpio, 2004; Kabo et al., 2014).

3.39. Dependency avoidance

For some, collaboration can create an undesired reliance on other team members. For example, delays due to slow-working collaborators were the most frequently cited complaints by Fox and Faver's (1984) study participants. Additionally, scientists, most notably junior scientists, who participate in scientific collaborations may become dependent on collaborative work if their own independent research suffers as a result (Sonnenwald, 2007). This type of social loafing which can be the result of a number of factors from reduced evaluation potential (Davis, 1969; Latane et al., 1979), 'free riding' (Kerr, 1983; Kerr and Bruun, 1983) and matching or minimizing efforts of a team (Jackson and Harkin, 1985) can serve as reasons why one might not care to engage in teaming for fear of such distractions. As early as Hagstrom (1964), the problem of pairing scientists with students and out of network stakeholders has highlighted the problem of dependency versus independence and its related stresses.

3.40. Conflict avoidance

The interdisciplinary research environment is one that is comprised of conflicting values, ideas, and scientific approaches and posit that scientific collaboration necessitating "a willingness to be questioned by others" (Bracken and Oughton, 2009, p. 392). This environment may therefore deter some from engaging in collaborations. Morse et al., 2007 found that a conflict avoidance attitude is a barrier to the interdisciplinary environment described by Bracken and Oughton (2009). However, the interdisciplinary research environment has been described as less competitive than working within one's own discipline, which can make it more attractive to some, especially researchers from marginalized groups such as women and underrepresented minorities (Rhoten and Pfirmman, 2007). The unknowns that can accompany collaborative engagement can also represent conflicts that researchers and scientists wish to avoid. Diversity and change can represent conflict for some, highlighting differences in work group norms of "gathering information, adapting to differing situations, issues, and needs, building social as well as task cohesion, and identifying clear mutual long term goals" (Bantz, 1993).

3.41. Power threat

Power is seemingly related to issues of status, and indeed the authors discuss also status in their studies. Power differential struggles are more competitive, combative, and ego-driven than debates of expertise (status) (Frodeman et al., 2010) and destroy interpersonal relationships within the team (Thompson, 2009). A threatening environment could deter some from collaborating, especially in the area of co-authorship (Conn et al., 2015; Milojević, 2013). Gender issues are also

considered by [Frodeman et al. \(2010\)](#) since it may be difficult to isolate the role of power and gender in scientific collaborations. Generally this aspect of power difference is reported as under-researched ([Mountz et al., 2003](#)).

3.42. Status threat

[Eaton \(1951\)](#) defined status as “the ranking of an individual by his society on the basis of socially acknowledged qualifications which are ascribed to him” (p.710). The literature on the role of status in scientific collaboration appears dichotomous. On the one hand, academic researchers, such as those interviewed by [Harris, Lyon, and Clarke \(2009\)](#), feel tension from their own communities when participating in collaborations and fear a loss of their status as a result. On the other hand, some have gained status within their organization for their participation in cooperative research centers ([Turpin and Garrett-Jones, 2010](#)). In the case of students and trainees, their inclusion in research collaborations by those with existing status (i.e., scientists, professors) has been considered a recognition of their status and credibility by the scientific field ([Hara et al., 2003](#)). Not surprisingly, the status of women and underrepresented minorities is well documented ([Bantz, 1993](#); [Benenson et al., 2014](#); [Bozeman and Boardman, 2014](#); [Kegen, 2013](#); [Maliniak et al., 2013](#); [Ridgeway, 1991](#); [Ridgeway, 2001](#)). Within interdisciplinary teams, status can result in team members debating expertise ([Table 6](#)), which has been found to be a barrier to effective teamwork ([Thompson, 2009](#)). However, some teams may be able to overcome this challenge without any impact on outcomes ([Younglove-Webb et al., 1999](#)).

3.43. Intellectual stimulation

The team environment in research allows for differing points of view, clarification of ideas, and constructive criticism ([Eaton, 1951](#)). [Beaver \(2001\)](#) noted that researchers are motivated by their curiosity and intellectual interests. Indeed, these

Table 6. Maintenance of Beliefs Organizing Domain.

Maintenance of Beliefs Domain: *Establishing, protecting, or building the value of science*

Motivation Indicators	Threat Indicators
<ul style="list-style-type: none"> • Intellectual stimulation • Share interests 	<ul style="list-style-type: none"> • Value individual expertise • Prefer hierarchical relationships • Prefer unilateral decision-making authority • Methodological biases • Too hard to agree on a common goal • Difficulty determining the appropriate level of cross-disciplinary integration • Epistemological differences

statements are supported in the literature. Studies have shown that scientists engage in research collaborations because they perceive a need for cross-fertilization and the generation of new ideas or knowledge (Beaver and Rosen, 1979; Katz and Martin, 1997; Sonnenwald, 2007; Tress et al., 2009; Turpin and Garrett-Jones, 2010). Additionally, for some, this intellectual curiosity is fueled by a desire to produce more practical and societally relevant (Fox and Faver, 1984; Rhoten and Parker, 2004; Tress et al., 2009).

3.44. Shared interests

Sonnenwald (2007) has found that shared interests, in the form of a research vision or goal, can motivate researchers to work together, and that these shared interests can help overcome barriers to collaboration. Furthermore, shared goals and interests can play an important role in sustaining collaborations (Lewis et al., 2012). Being interested in each other's work and placing similar priority on projects also impacts the willingness of scientists to collaborate (Hara et al., 2003). In fact, research centers are often built on the principle of shared research interests (Maglaughlin and Sonnenwald, 2005). A study of university-industry collaborations also showed that faculty members placed much importance on their research interests, in this case when compared to other factors such as business, learning, and teaching opportunities (Lee, 2000).

3.45. Value individual expertise

Unidisciplinary and knowledge specific perspectives can often be barriers in themselves that threaten collaboration. Early work on this topic suggested that multidisciplinary research may limit individual creativity (Eaton, 1951) and that researchers believe some disciplines may be more conducive to scientific collaboration than others (Fox and Faver, 1984). Recent studies have shown that researchers' decision to work individually, instead of collaboratively, is influenced by disciplinary traditions (Morse et al., 2007), the project at hand (Lewis et al., 2012), and the nature of the research question (Lewis et al., 2012; Nair et al., 2008).

3.46. Prefer hierarchical relationships

Hierarchical and collaborative teamwork is discussed as having two polar types of approaches or structures for collaboration (Eaton, 1951). The issue of preference for hierarchy within teams would seem in contrast to evidence that shows that individuals perform better when afforded the freedom to chart their own research agenda (Alon, 2010; Kearney et al., 2009). These findings are seemingly contrary to contemporary trends in collaborative teaming, especially based on its implications for contemporary leadership trends (Chen et al., 2007;

Gray, 2008; Keller, 2006; Zaccaro et al., 2001). “Preference for social dominance hierarchy is associated with neural functioning within brain regions that are associated with the ability to share and feel concern for the pain of others; this suggests a neurobiological basis for social and political attitudes” (Chiao et al., 2009, p. 174) and may in turn be a fundamental deterrent for some who challenge the benefits of working in environments where decision-making is the result of consensus building, compromise, or blended opinion. Evidence suggests that even within the most collaborative teams, where leadership is considered most receptive to mutual inclusion and decision-making, some members will be more comfortable with performing tasks related to their own discipline and are least stressed when instructed by the team or another leader in the group to do so (Lotrecchiano, 2012). Beliefs about the meaning of certain behavioral characteristics like introversion-extraversion, dominance, interpersonal sensitivity, masculinity-femininity, conservatism, intelligence, and adjustment may serve as indicators of the difference between hierarchical and more distributed decision-making environments and may deter some researchers from engaging collaboratively for fear of lack of stable scientific authority (Mann, 1959).

3.47. Prefer unilateral decision-making authority

Eaton (1951) debated the pros and cons of hierarchical and democratic teamwork in research collaborations early in the team science literature. Hierarchical teamwork can produce administrative efficiency although it can be detrimental to interpersonal relationships within the team. “In order to decide effectively, agents need the ability to (a) represent and maintain a model of their own mental attitudes, (b) reason about other agents’ mental attitudes, and (c) influence other agents’ mental attitudes. Social mental shaping has been advocated as a general mechanism for attempting to have an impact on agents’ mental states in order to increase their cooperativeness towards a joint decision” (Panzarasa et al., 2002). We might infer, however, that team decision-making protocols may be associated more with expectations of behaviors and characteristics that point to scientific authority, as represented through hierarchical structures over group-decision techniques: intelligence, masculinity–femininity, and dominance (Lord et al., 1986). Democratic teamwork, on the other hand, can support creativity within the team, but the lack of structure may hamper long-term sustainability. Although related to this indicator, Eaton's debate does not provide insight into personal preferences for one system over the other. Fox and Faver (1984) have touched on scientists' preference to work alone due to collaborative decision-making being more time consuming. However, Fox and Faver (1984), and other studies (Lewis et al., 2012; Morse et al., 2007) suggest that scientists will opt to work alone for reasons related to the research at hand rather than because of the decision-making structure.

3.48. Methodological biases

Disparities in scientific methods, tools, routines, and scales between collaborators create challenges for scientific collaborations and can often create conflict within teams (Eigenbrode et al., 2007; Fox and Faver, 1984; Hara et al., 2003; Heinze and Kuhlmann, 2008; Younglove-Webb et al., 1999). For example, Stokols et al. (2005) demonstrated that scientific teams with members who had prior history of working together were better able to launch projects than newly formed teams that first needed to negotiate disparities in their scientific approaches. For others with less experience with opposing and/or complementary methodological worldviews, coordination and mutual adjustment based in reflexive and theoretical sensitivity is necessary (Eigenbrode et al., 2007; Hall et al., 2005). Studies have also shown that compatibility of research methods may depend on the disciplines involved (Birnholtz, 2006; Heinze and Kuhlmann, 2008; Laberge et al., 2009), and that in many technologically-driven sectors, biases for quantitative methodologies can lead to ‘pecking order’ dynamics favoring certain types of researchers and their methodologies (Chubin et al., 1979; Mountz et al., 2003).

3.49. Too hard to agree on a common goal

Agreeing on research goals in a scientific collaboration can be difficult (Harris et al., 2009) and failure to do so can lead to unsuccessful projects (Rhoten and Parker, 2004; Sargent and Waters, 2004). Some authors note that alignment of individual and team goals must be a priority (Winter and Berente, 2012). Spending more time early in collaborative projects to negotiate goals is therefore an important step for teams (Benishek et al., 2014; Katz, 1982; Stokols et al., 2005; Wong-Parodi and Strauss, 2014) although some researchers may be unwilling to commit this time (Fox and Faver, 1984).

3.50. Difficulty determining the appropriate level of cross-disciplinary integration

Transdisciplinary integration has been described as a long and difficult process that scientific teams must overcome to achieve expected outcomes (Laberge et al., 2009; Stokols et al., 2003). Difficulties with definition and the characteristics of different levels of cross-disciplinarity often serve as conceptual barriers in teams hoping to collaborate on a certain level of disciplinary integration (Klein, 2014; Lotrecchiano, 2010). Hara et al. (2003) describes integrative collaborations as less frequent but more participative endeavors than complementary collaborations. The difficulty in determining the appropriate level of integration appears to be affected by issues of personal and disciplinary status and hierarchy (Eaton, 1951; Harris et al., 2009). Furthermore, the requirement of management of teams greatly affects their ability to understand differing constructs and mental models within the team

(Jeffrey, 2003; Pennington et al., 2013), which may in turn affect one's ability and motivation to participate in multi-perspective teams due to frustration and lack of ability to adjust to integration expectations.

3.51. Epistemological differences

Epistemological differences between collaborators can hinder the collaborative process (Eigenbrode et al., 2007; Laberge et al., 2009; Maglaughlin and Sonnenwald, 2005). Hara et al. (2003) provide an example of an unsuccessful collaboration due to “different working styles and approaches to science” (p. 960) resulting in “frustration, unresolved conflicts, and, in the worst case scenario, discontinued work...Some of these differences are incommensurably rooted in different epistemologies while other differences are more a question of culture” (Öberg, 2009, p. 405). Mountz et al. (2003) have studied the process of “methodological becoming” in a team of geographers with transnational connections and argued “there is an under-theorized relationship between the politics of academic research projects and the broader political movements with which they engage” (p. 29) suggesting that collaboration differences transcend mere plurality of techniques but represent core differences in the interpretation of knowledge. Overcoming these root differences in perspective is a matter of “overcoming internal monologism or monodisciplinarity, attaining provisional integration, and questioning the integration as necessarily partial” (Nikitina, 2005, p. 389). Other studies have reported that biases against other disciplines (Chubin et al., 1979; Maglaughlin and Sonnenwald, 2005) and the belief that there exists a hierarchy among disciplines (Harris et al., 2009) also negatively affect collaboration and interpersonal relationships within teams. Some researchers felt that “genuine integration of various disciplines” (Laberge et al., 2009, p. 800) was never reached during scientific collaborations.

4. Discussion

4.1. Domain clustering (volume)

In clustering the motivation and threat indicators, we found inequity in the literature between both the number of indicators once clustered into thematic domains and an imbalance between motivators and threats within domains. The domains of Resource Acquisition, Building Relationships, and the Maintenance of Beliefs dominated as domains with the most number of unique indicators. The Resource Acquisition and Building Relationship domains showed the greatest balance between number of motivators and threats in general, while the Maintenance of Beliefs domain showed a greater range of threats associated with it than actual motivators. In visualizing this we show motivator and threat indicators organized into differing domains. Through thematic analysis of literature

content across and within domains we have adopted a means of ties based on the relevance of literature to each indicator. Literature contributing to more than one indicator is tied together either within a domain or across more than one. The size of indicator is defined by the amount of literature that contributes to its definition within the review (Fig. 2, above).

This stated, the representative numbers of motivations and threats should not be interpreted as polarizing within a domain. In addition, each motivation does not necessarily have an antithetical threat. Rather, these indicators represent dynamics within a domain that may illustrate (according to published literature) emphases found in a particular area of inquiry with more productive outputs. The reason for this could be multifold based on wavering and waning interests over time. It would seem that these three domains (Resource Acquisition, Building Relationships, and the Maintenance of Beliefs) dominate in the literature as those with the most nuanced conversations on motivations and threats, which precipitates the high diversity of evidence.

With regards to the remaining domains (Advancing Science, Recognition and Reward, and Knowledge Transfer), it is clear that although the discourses around these clusters are less nuanced (described in fewer unique indicators), the literature documents less divergent thought on the subject of collaboration and its motivating and threatening factors. In other words, we have found that in these domains there is a higher degree of convergent thought found in the literature reviewed. The Advancing Science domain is clearly dominated by motivating factors. This is to say that most discourse about the advancement of science would seem to represent the advancement of science as evidence of a strong reason why individuals should be motivated to collaborate. In the reverse, Recognition and Reward would seem to be dominated by threats about why individuals might not choose to collaborate especially if the right environmental structures were not in place. In addition, though the Advancement of Science and Resource Acquisition domains could be broadly associated within the Knowledge Transfer domain, this domain in comparison is relatively low in diversity of indicators and highly developed with a strong degree of discourse though the indicators associated with the domain would seem to be highly unique. In general, even with low diversity, Knowledge Transfer would seem to be a motivating factor overall to collaboration for individuals.

4.2. Dominating motivators and threats

As this inquiry does not measure indicators by a weighted measure other than their appearance in the literature, it is not possible to comment on the indicators that show significant value by their relational characteristics. By focusing on strength and weakness within and across domains, several inferences can be made. First, with an emphasis on within-domain relationships, some indicators are strongly tied

to each other in the literature. For example, in the Building Relationships domain, motivators are more strongly tied to motivators and threats to threats (See Fig. 2 dotted line associations) suggesting greater affinity on the discourse associated with each indicator. This is similarly the case in the Maintenance of Belief, Advancing Science, and Knowledge Transfer domains. In comparison, the Resource Acquisition and Recognition and Reward domains show more cross indicator ties suggesting that more discourse in these areas is open to debate, nuances between what constitutes a motivator and a threat, and/or conflicting interpretations. For example, interdisciplinary illiteracy is defined through a literature that also contributes to several other indicators across multiple domains. This topic is more solidly part of a more complex discussion. In comparison, those indicators that contribute to the knowledge transfer domain are more highly bound to other learning indicators suggesting that their appearance in the literature may be more localized and specific with less relational evidence to other domains and indicators. Second, by looking at ties across domains, some are more heterogeneous in their relationships with others. For example, Advancing Science as a domain has more ties with all of the other domains than any other. This domain is also dominated by motivating indicators as a cluster. However, the Knowledge Transfer domain, also dominated by motivating indicators has relatively few cross-domain ties. Relationship Building and Maintenance of Beliefs are clearly most critical to secondary ties between the other clusters even though both of these have highly divergent motivator and threat in-group ties. Resource Acquisition and Recognition and Reward seem to be subsets of these two other domains by relationship suggesting that social domains like relationships and resource inquiries is somehow bound to more tangible attributes to collaboration like resources, recognition, and rewards.

5. Conclusions

This study elucidates the breadth of individual, *intrapersonal* indicators that serve as important antecedents in team science. Our assessment of the literature focused on *perceived* micro-level motivators and threats (indicators) to collaboration to uncover conditions that have the potential to impact individual participation in scientific knowledge-producing teams (KPTs). We started by considering the interrelated dynamics of motivation and goals-setting that are endemic to KPTs (Locke and Latham, 2004; Osterloh and Frey, 2000; Rousseau, 1985). This initial work contributes to foundational definitions and a map to the discourse on individual motivations and threats to collaboration across sectors. As such, it is a preliminary effort to organize the literature into domains of individual motivation and threat indicators and provides a map that guides further investigation in this area of team science (research, measurement, and theory) on the micro level.

As Locke and Latham (2004) have emphasize there is an ongoing need to generate metatheory with the goal of building understanding about motivation that emphasize the need to develop more complete and practical theories. Our interdisciplinary review goes beyond any one motivation theory or disciplinary body of knowledge and strives to recognize the benefits of integration of theories across knowledge boundaries and literatures. Its ultimate ability to contribute to theory about motivation in KPTs is measured by the emphasis on the primacy of the individual's role in self-actualizing the meaning of collaborative efforts as an extension of satisfaction and need as related to perceived environment threats. This is a key addition to the discourse on micro-level inquiry into motivations and threats for individuals in teams. In addition, there is value of these indicators to psychometric measurement and measurement of individual collaboration readiness.

Intrapersonal factors and perceptions about environmental and structural elements likely share the same—if not more—impact on participant decision-making about KPT engagement (Stokols, 2006) and can lead to useful structures in which to measure readiness. We see value in factor analyses on the individual level similarly to 'hard' and 'soft' organizational factor analyses to items like competency fitness and technological readiness and organization character, willingness to collaborate, and empathy for relationships but more isolated to the individual level of analysis (Rosas and Camarinha-Matos, 2009). We differ in our approach to using factors to measure readiness based on interactive measures and team values to address team readiness for cross-disciplinary collaboration (Hall et al., 2008b; Misra et al., 2015). Thus, with proper psychometric testing it may be possible to contribute to a new line of theories of motivation and threat that may be useful in the measurement of collaboration readiness on the individual level. In addition, by isolating the level of analysis to the individual level, the discourse on individual level decision-making and motivations about collaborative engagement may be possible considering both *inter-* and *intrapersonal* factors in the same theoretical framework (Rousseau, 1985).

In testing such assumptions, certain special matters must be considered about the compilation of indicators. While no hierarchical framework based on frequency of evidence found in the literature has been presented in this review, it is possible to attempt to design a hierarchy that might suggest higher and lower level motivations to science collaborations in KPTs. This requires research and testing with KPT members and those entering into such teams. In doing so, care would need to be taken to consider the life-course variables that impact individual's motivations and what in their environment is most threatening at any particular time in their development scientists. Variables of rank, gender, age, disciplinary tradition, etc. all conspire to affect what in fact motivates one to participate in team research. A hierarchy of motivations might be less static and unilateral and transferable amongst different KPTs but rather more dynamical suggesting that different

motivations and threats may be in combination measurable in only like-oriented team members and not all, even though mixed populations of individuals work within KPTs. This would be in concert with our initial findings in this the testing of this hierarchy that seems to suggest that hierarchies differ based on age, gender, developmental phases of professionals, etc. (Mallinson et al., 2016, under review). This is not hard to imagine and research has shown that this is a common social dynamic in KPTs (Lotrecchiano, 2013). In testing any such framework that would attempt to organize these indicators one would have to triangulate individual context against degrees of individual satisfaction and intensity of collaboration. For this research, the intent is to test these indicators in this very way attempting to create a dynamical hierarchy of motivations and threats against a hierarchy of need (Maslow, 1943) and degrees of engagement in teams (Bailey and Koney, 2000) to understand better how participating in teams satisfied individual need for self-actualization and if this process actually correlates with higher levels of collaborative activity.

A final benefit to this work is its contribution to the development of learning opportunities for KPT members that can assist them in assessing their own readiness for collaborative engagement from an *intrapersonal* perspective. At the core of Mezirow's transformative learning theory is the concept of critical reflection which involves a critique of one's *intrapersonal* assumptions implicit in one's beliefs and a challenge to the validity of presuppositions made in prior learning situations (Mezirow, 1990; 1998). This process of reflection triggers one to correct erroneous interpretations resulting over time in a changed perspective which could influence future decisions and actions (Dirkx, 1998; Mezirow, 1990). Mezirow (1990) emphasized perspective transformation as a key outcome of the transformative learning process for adults; that through the process of making sense of and reflecting on one's own perspective about the subject matter under study, changes to meaning structures can occur that could involve refinement or elaboration of existing meaning schemes and/or creation of new schemes and perspectives. This process of sense-making can be thought of as the continual exploration, integration, and judgment of an emerging perspective much like a drafting process (Weick et al., 2005). Such opportunities that target individuals and their perceived understanding about KPTs drawn from their own reflections on what motivates and threatens them in this process of engagement can be better served with psychometric evidence of how these indicators support and deter sustainability in teams.

Declarations

Author contribution statement

Gaetano R. Lotrecchiano: Conceived and designed the experiments.

Trudy R. Mallinson, Lisa S. Schwartz, Holly J. Falk-Krzesinski: Analyzed and interpreted the data; Wrote the paper.

Tommy Leblanc-Beaudoin: Contributed reagents, materials, analysis tool or data.

Danielle Lazar: Performed the experiments.

Funding statement

This work was supported by a 2014 Emerging Scholars Grant awarded by the George Washington University School of Medicine and Health Sciences, Washington, DC.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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