# Team Training for Team Science: Improving Interdisciplinary Collaboration

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## Introduction

*"The myth of the solitary scientist in search of truth is a romantic notion whose continued existence serves as the major barrier to progress in bringing the collective weight of the sciences to bear on the problems of human kind. And the idea that all scientific progress takes place within the boundaries of current disciplines in historically invalid and currently counter-productive"*

-Kahn & Prager, 1994, p. 12

Interdisciplinary research teams (IRT) have been prevalent for years, and many of the great science contributions were due to team science. For example, the discovery of DNA structure was completed by individuals from the genetics, biology, physics and biophysics department. These scientists all played vital roles based on their field specialty; however, there was no set role allocation. The team worked interdependently to reach the end goal: discovery. The Manhattan Project is another prominent breakthrough by an IRT. This science team comprised of over 10 key members spanned across 19 different locations. The contributors had diverse science backgrounds including physics, mathematics, and chemistry. Although these science teams were successful in achieving an innovative concept, they were not free of problems. Rosalind Franklin, a great contributor to the discovery of the DNA structure was not a Nobel Prize recipient like the other three scientists involved, and there is an ongoing debate on who should officially receive credit for this remarkable discovery. In addition, the Manhattan Project scientists had multiple decision-making disagreements and communication issues, and espionage problems. Science teams will most likely encounter challenges during their course of action, just as the aforementioned science teams, and overcoming these issues is necessary for success. Because the salience of science teams continues to increase amongst contemporary

societies, it is important for science teams to address any barriers, and to ultimately be successful in their projects. Therefore, it is important to provide science teams with information and training on how to address and prevent certain team-based challenges. The purpose of this essay is to identify what strategies and concepts within the team training science can be leveraged to science teams to help with this goal.

As previously mentioned, interdisciplinary science teams are needed (Börner et al., 2010; Borrego & Newswander, 2010; Vogel et al., 2012). The problems faced by science and society are too complex for individual scientists, and even smaller research groups to solve (NIH, 2006; NSF, 2006). Critical challenges such as climate change, sustainability, public health and energy require collaboration amongst multiple scientists with expertise in various domains (Borrego & Newswander, 2010; Fiore, 2008). Without such collaboration, these issues will not be successfully addressed. In many cases, the theories and methods from some disciplines are not adequate to solve certain problems. As such, pressing issues in domains such as biology and public health require the conceptual and methodological capacity that can arise from an interdisciplinary approach (Kessel, Rosenfield & Anderson, 2008). Furthermore, the need for interdisciplinary teams also stems from technologic advancements (Nash, 2008). Specifically, some disciplines are more experienced than others (i.e., computer engineering, biotechnology) in understanding and fully utilizing cutting edge technologies and this expertise is essential in order to address current critical issues.

It is apparent that cross-collaboration is not only needed, but required (Kessel, Rosenfield, Anderson, 2008), to solve these prominent scientific issues. The question then becomes, why has the art of interdisciplinary research not been perfected? Interdisciplinary research is still in its “prolonged developmental period,” (Kessel, Rosenfield, Anderson, 2008).

How do we advance it? What theories, methods, and tools are needed for greater success and a long-term movement towards IRT? It is clear that interdisciplinary teams face challenges relating to antecedent, process, and outcome factors (Kessel, Rosenfield, Anderson, 2008), and although some of the specifics for these issues are unique to interdisciplinary teams, similar challenges are present within teams in other domains. Furthermore, prominent team challenges and the necessary teamwork competencies have been studied in the teams literature (e.g., Salas and Cannon-Bowers, 2000), and the training of these concepts is subsumed within the science of team training (e.g., Kozlowski & Salas, 2009). The science of team training is composed of integration between the science of training effectiveness and the science of teams. In other words, it blends evidence-based training techniques with teamwork competencies rooted in the science of teams. Our argument is that interdisciplinary teams can utilize this scientific base in order to understand how to increase their teamwork and team effectiveness. In this paper, we describe the science behind team training and how it can be leveraged to advance IRT. The ultimate goal of this paper is to translate the science of team training into principles for successful implementation of science team training and to identify the factors that need to be considered when providing team training to interdisciplinary teams.

## Team Training

Because of the emphasis placed on high performing teams within organizations and the influence of teams on the global economy, the attention towards team training has drastically increased over the past few decades (Campbell & Kuncel, 2001). Before we describe how to implement team training, we first define team training and its goals. Team training is a theoretically grounded and systematic practice comprised of strategies and tools targeted to enhance teamwork competencies and processes (Salas, Cooke & Rosen, 2008; Tannenbaum,

Salas, & Cannon-Bowers, 1996). It is designed to improve teamwork and it has a strong empirical base supporting its effectiveness in enhancing team performance (see Salas, DiazGrandados, Klein, Burke, Stagl, Goodwin & Halpin, 2008 for meta-analysis). Team training programs have been utilized by teams spanning across a variety of diverse domains such as medicine, aviation, and education. For example, in the 1970s, it was noted by the National Transportation Safety Board (NTSB) that teamwork breakdowns were a significant factor in aviation accidents. These factors led to the development of Crew Resource Management (CRM) as a form of training in the aviation industry (Wiener, Kanki & Helmreich, 1993). CRM was designed for flight crews and a large number of studies have provided evidence for its effectiveness in enhancing team performance (e.g., Salas et al., 2006). This is but one of many examples of how team training research has developed methods and approaches for addressing many complex teamwork challenges. We turn now to a more specific discussion of "what" needs to be trained for team effectiveness.

Teamwork is comprised of three competency categories: attitudes, behaviors and cognitions, (Salas, Rosen, Burke, & Goodwin, 2008) which are referred to as the ABC's of teamwork (Salas & Cannon-Bowers, 2000). Attitudes, in essence, are the motivational drivers of teamwork in that they influence behavioral action and include constructs such as cohesion, collective efficacy, and trust (Salas & Cannon-Bowers, 2001). Behaviors include processes such as information exchange, monitoring team process, leadership behaviors and they are the processes necessary for teamwork (Salas & Cannon-Bowers, 2001). Cognitions refer to the knowledge and shared understanding among team members and include team mental models, situation awareness, and transactive memory systems (Salas & Cannon-Bowers, 2001). In other words, the ABCs define how team members feel, do, and think, respectively (Salas & Cannon-

Bowers, 2001), and reflect the emergent states and processes that are the drivers of team learning, performance, viability, and overall team effectiveness. We have briefly summarized and defined core teamwork competencies that have been repeatedly supported in the literature as being effective in enhancing team performance in Table 1.

-- Table 1 --

Research supporting the notion that team training interventions improve team effectiveness is extensive. Salas and colleagues (2008) conducted a meta-analysis on team training effectiveness and found a primary effect size of .34 ($k$=52, $n$=1.563) (Salas et al., 2008). A more recent meta-analytic study of team training on team outcomes found there to be a direct, positive effect ($d$ =.85, $n$ = 1,413) in relation to affective, cognitive, subjective task-based skill, objective task-based skill, and teamwork skill outcomes (Delise, Gorman, Brooks, Rentsch & Steele-Johnson , 2010). A number of reviews of the team training literature have summarized the effectiveness of research in domains as diverse as aviation (Salas, Burke, Bowers, & Wilson, 2001), medical (Weaver, Rosen, Salas, Baum, & King, 2010), and the military (Stout, Salas, & Fowlkes, 1997). In short, a strong body of evidence shows the effectiveness of team training. As the relevance of teams within organizations increases so does the need for team training. The need for teamwork skills in the job market continues to grow (Alsop, 2004; Kozlowski & Illgen, 2006; O'Conner & Yballe, 2007; Vance et al., 2007) and team training is becoming a necessity for organizations and educational institutions. While many may have some understanding of what teamwork is, not everyone has been properly trained on how to engage in appropriate teamwork processes. As such, teamwork training within educational institutions is increasingly recognized as necessary in preparing students for their professional career (Vance et al., 2007).

A university setting is the ideal environment for a teamwork training program because it allows students to develop their teamwork abilities before embarking out in the work force. In addition, it is during an individual's university and postgraduate career where their intellectual orientation emerges (Stokols, in press). Introducing team work concepts and training basic team work skills within secondary education will directly help students and employers, but will also improve the quality of team interaction universally. Although not many exist, there are a few programs which have been designed to increase team effectiveness amongst students. The Comprehensive Assessment of Team Member Effectiveness (CATME) (www.CATME.org) is one such tool that enables students to rate themselves and their team members on their teamwork abilities, and then generates feedback on suggested team behaviors. The system is also designed for instructors to use in order to provide instruction and feedback to their students on teamwork competencies. Some graduate programs also offer courses designed to increase collaboration and teamwork skills (e.g. the Seminar in Social Ecology, and Strategies of Theory Development offered at the University of California, Irvine) (Stokols, in press). The importance of introducing team training during the undergraduate and graduate years of education, and specifically IRT in education, is also evident in the rise of science funding initiatives aimed at increasing the amount of research collaboration across disciplines within these institutions. Examples include the NIH's Common Fund Interdisciplinary Research Program and the Integrated NSF Support Promoting Interdisciplinary Research and Education (INSPIRE) initiative.

In sum, we see a number of important developments converging on a need for team training. First, is the rise of complex scientific research, addressing multifaceted issues and the shift from individual science to team science (Jones, Wuchty & Uzzi, 2008). Second is the recognition that interdisciplinary research is the key to innovation and success for solving future

problems. Third, funding agencies and science programs have initiated more movement towards IRT. Nonetheless, the question remains, why have graduate and research institutions not increased their attention to better training of interdisciplinary collaboration? Current interdisciplinary teams experience challenges due to individual, institutional and contextual factors (Kessel, Rosenfield & Anderson, 2008; Nash, 2008; Stokols, Mirsa, Moser, Hall, & Taylor, 2008) all of which team training interventions have been shown to improve. Organizations also seem to, in the nascent stages of project development, operate well across disciplines, but as the timeline gets deeper, their interdisciplinary collaboration dwindles (Stokols, in press). Given this, it is important for IRT to be exposed to teamwork training to increase long-term collaboration and the success of these teams. Furthermore, the earlier in the educational pipeline training interventions are implemented (e.g., in graduate institutions) will increase the capacity for IRT in upcoming generations. In short, interdisciplinary research is research conducted by a team (Fiore, 2008) and we must better understand how to apply the science of training to IRTs. Towards this end, in the remainder of this paper we detail a set of established training principles in order to facilitate the application of training interventions to IRT.

## Principles for Team Training

As noted, a robust body of knowledge has demonstrated that team training is effective. Nonetheless, the ways in which it is delivered and developed is essential to its effectiveness (Shuffler, DiazGranados, & Salas, 2011). First and foremost, when developing a training program, it is important to think of it systematically. Training design is a methodical process developed to foster learning and convey essential knowledge, skills, and attitudes (KSAs ) (Salas & Cannon-Bowers, 1997). Successful training design requires adequate planning and

preparation, and training developers need to implement theoretically-based and scientifically-supported instructional principles throughout the training program (Salas & Cannon-Bowers, 1997). It is important to note that the system of training development follows that of a before, during, and after training organizational timeline. That is, when implementing a training program, it is necessary to complete certain steps within each training stage. The goal of this next section is to identify evidence-based principles that when completed before, during, and after team training will maximize program success. The presented principles have been empirically supported within the training literature as well as in the *team* training literature. We leveraged general training research in order to derive our team training recommendations; therefore, although we present these principles in a way that is specific to team training programs, they are also compatible with any other training program. We would also like to note that some of these principles may overlap between phases; however, for organizational purposes, they are presented in their best fit phase. Within each of these principles we highlight how these may, or may not, be able to uniquely contribute to training IRT.

**Before Team Training**

The bulk of the work for a team training programs happens before training occurs. It is essential for an organization to set the stage for their training program; otherwise it will not be a success. The processes necessary before training are described in detail throughout this sub-section.

**Principle 1. Conduct a Team Needs Analysis.** In order to identify the specific teamwork KSAs that are needed for an organization, a team needs analysis should be executed (Salas & Cannon-Bowers, 2000). Moreover, an organization must ask what, how, and who should the training include, and these questions will be answered upon completion of a team

needs analysis. This step is crucial to team training success, and because of its significance, some researchers suggest it to be conducted as the first step when designing a training program. We suggest, however, that it happens *after* creating a supportive learning environment and after receiving buy-in from trainees and supervisors. This is because a team needs analysis requires information from trainees and supervisors. If trainees do not value or completely understand the training's purpose, then they are unlikely to provide useful information during the team needs analysis (Gregory et al., 2012). The needs analysis process consists of assessing the organizational, task and person needs (Arthur, Bennett, Edens, & Bell, 2003). This process is also congruent with Baldwin and Ford's (1988) training input model consisting of work environment (i.e. organizational analysis), training design (i.e. task analysis), and trainee characteristics (i.e. person analysis). All training programs require a needs analysis, unlike other training programs, team training programs need to consider the team as an "individual unit" (Shuffler, Pavlas, & Salas, 2012) and consider not only the team task itself, but also the teamwork requirements (i.e., knowledge, skills, abilities, and attitude requirements) of the team. Therefore, a *team* needs analysis includes all necessary components of a training needs analysis, but its focal point is the team and not its individual members (McGhee & Thayer, 1961). The steps include: (1) an organizational analysis, (2) a team task analysis, and (3) a person analysis, as described below:

*Organizational analysis*: An organizational analysis outlines the degree to which the organization supports the training. The focus of this analysis is to identify the degree in which the organization provides a supportive climate and facilitates team training effectiveness. Questions to ask include: Has the organization communicated the value of this training? Are

there incentives from the organizations for training participants? Will the organization reward trainees who utilize the teamwork concepts taught on the job?

*Team task analysis*: The goal of a team task analysis is to determine the specific tasks the team will be executing and the team competencies needed to successfully execute these tasks. It is also important to conclude if there are any teamwork competencies that the team lacks. Identifying frequent and difficult team tasks is essential in the process as well as deciphering team members' responsibilities and the interdependencies amongst team members. Successful strategies for identifying this information include: interviewing subject matter experts (SMEs), reviewing relevant organizational documentation, reviewing scientific literature related to the job/task, and reviewing organizational performance standards.

*Person analysis*: It is important to consider the fact that not all trainees equally benefit from training opportunities (Sims, Burke, Metcalf, & Salas, 2008). Moreover, the goal of a person analysis is to identify who should attend training. That is, do certain team members display negative teamwork behaviors or specific attributes that may impact training needs? It is important to understand trainee characteristics because they will impact the effectiveness of the training program. For example, Towler and Dipboye (2001) found that when trainees scoring high in mastery goal orientation were coupled with organized training lectures and inexpressive trainers, their problem solving skills decreased. Furthermore, we suggest the measurement of team aptitude, age, self-efficacy, and personality as these factors have all been shown to influence training performance and motivation (Cannon-Bowers, Salas, & Milham, 2000; Colquitt et al., 2000).

When it comes to science teams, this form of needs analysis will be particularly important. It will help to clarify what the science teams need to do collaboratively. In particular,

by making explicit factors such as interdependencies and aptitudes, the team training can be better tailored for the scientific research at hand. Similarly, understanding the particular attitudinal requirements will help team leaders better manage the group dynamics that will emerge when training attitudes alone will not suffice. During this phase of the training development process, it may also be beneficial for research institutions to measure their current level of collaboration readiness; thus, if the organization, team, or individuals are lacking collaboration readiness this issue can be addressed during training. Hall and colleagues (2008) recently developed and validated a collaboration readiness measure, and we recommend utilizing it before, during and after training.

**Principle 2. Consider the Characteristics of the Trainees.** Organizations need to be aware that individual trainee characteristics can impact the overall effectiveness of a team training program. Specifically, trainees' skill ability as well as certain personality traits can impact their performance within the training (Salas, Tannenbaum, Kraiger, & Smith-Jentsch, 2012). Before placing individuals in a team training program, it is important to assess their relevant skill ability as this is a predictor of individual and team task performance. A team training program is designed to improve teamwork skills, and not task skills. Therefore, it is important that team members demonstrate the ability or potential ability to perform the team task before they are trained to operate within the team.

Individual personality traits should also be considered when developing a training program. Research suggests that certain personality variables predict team performance (cf Bell, 2007; Driskell, Goodwin, Salas & O'Shea, 2006; Driskell, Hogan, & Salas, 1988; Neuman & Wright, 1999). Specifically, agreeableness and conscientiousness have repeatedly been shown to have a positive relationship with performance on a team (Bell, 2007; Driskell, Goodwin, Salas &

O'Shea, 2006; Neuman & Wright, 1999; Driskell, Hogan, & Salas, 1988). Team members scoring high on agreeableness tend to be more cooperative and display social skills needed for successful teamwork, and agreeableness has also been related to conflict resolution and open communication skills (Neuman & Wright, 1999). Conscientious individuals tend to be better at accomplishing goals as well as with order and organization (Neuman & Wright, 1999).When developing a team training program, the organization should assess these personality traits in order to delineate if there are certain teamwork competencies on which the training should focus. For example, if an organization's employees score low on conscientiousness, the organization should make sure to incorporate tools for successful goal-setting in their training.

Other individual traits influencing training outcomes include self-efficacy, goal orientation, and motivation to learn. Self-efficacy, whether acquired before or during training, increases motivation to learn as well improves learning outcomes (Chen, Gully, Whiteman, & Kilcullen, 2000; Mathieu, Tannenbaum, & Salas, 1992; Quiñones, 1995). Trainees expressing high self-efficacy levels are also more likely to participate in learning (Bandura, 1997; Phan, 2011); self-efficacy can be promoted by reminding trainees of past successes, and by ensuring positive learning experiences early on in the training. An individual's goal-orientation (mental framework used to shape behaviors within a learning-environment) may also influence training success (Salas et al., 2012). Goal-orientation can either be mastery (learning) or performance oriented (Dweck, 1986). Research suggests that trainees with a strong leaning orientation express a higher desire to acquire new skills, effort to learn (Fisher & Ford, 1998), and display an increase in learning outcomes (Phillips & Gully, 1997). In contrast, those with performance orientation are less likely to engage in tasks that require risks and are more concerned with seeming adept which may cause a decrease in learning during training (Salas et al., 2012).

Therefore, training program goals and objectives should be framed such that they foster learning-oriented behavior. Also, trainees displaying performance-oriented behavior should be provided with greater structure while those exerting learning-oriented behavior should be given more freedom and responsibility for their own learning process. Motivation to learn is another trait that contributes to training effectiveness; however, this concept will be discussed in later sections.

In the context of training for IRT, it is likely that scientists will vary in the aforementioned personality dimensions. As such, to the degree that research organizations recognize the importance individualized assessment programs, training interventions might be more effective. Conversely, scientists might be more homogenous on the attitudinal characteristics such as efficacy and learning orientation. As such, training designed to support IRT might be able to more directly apply interventions tailored toward those who have a strong learning orientation. In conclusion, it is important for an organization to consider the characteristics displayed by trainees. Certain individuals may display qualities which are more desirable for teamwork situations as well as training performance. The organization should be aware of such trainees that don't express these traits, and ensure a training environment which will increase the onset of these characteristics.

**Principle 3. Create a Team Training Environment Conducive to Training Goals.** To ensure successful development within the team training program and amongst trainees, it is necessary for the organizational climate to reflect the goals of the training. The perception of an organization's procedures, norms, and practices constitutes the organizational climate (Denison, 1990), and this climate should align with the training program focus and goals. In order to do so, it is recommended that the organization involves the trainees in the decision process to begin training, actively supports learning, and that the organization stresses the importance of the

training (Quiñones, 1997). After incorporating all of the suggested actions, the organizational climate will be set for training to occur.

When framing attendance policies for the training, it is important to seek a balance between voluntary and mandatory attendance (Salas et al., 2012). Mandatory training may signal that the program is critical for employees and Tannenbaum and Yukl (1992) have concluded that if an organization expresses the value of training programs, mandatory training may be viewed more positively than voluntary training. However, one should be cautious when making training mandatory if it is framed in a way that highlights employee deficiencies. Research suggests that advance notification of training and opportunity framed training increases learning (Ford, Eleanor, Weissbein, Gully & Salas, 1998) and ameliorates trainee anxiety (Martocchio, 1992). The organization should communicate to its employees why they are attending the training and the benefits that it offers (Salas et al., 2012). It is also important for the organization to communicate to employees what to expect from the training. Research suggests that if trainees' expectations are unfulfilled, they exhibit lower post training commitment, self-efficacy, motivation, (Sitzmann, Bell, Kraiger & Kanar, 2009; Tannenbaum, Mathieu, Salas, Cannon-Bowers, 1991) and reduced performance (Hoiberg & Berry, 1978). Trainees' motivation towards training also has a positive relationship with knowledge acquisition and retention, transfer of training and onset of positive attitudinal change (Salas & Cannon-Bowers, 2001).

Considering this principle in the context of science teams, this is an important issue given that many scientists typically are not trained as members of a team. Given this, one could highlight the increasing role of collaboration in the scientific process. Additionally, the value, more generally, of improving interpersonal skills for scientists could be communicated. At a more specific level, the efficiencies that arise when teams work well, could be explained to

potential trainees in scientific organizations. In short, an understanding of the potential resistance scientists might have to training would inform how this could be overcome.

**Principle 4. Create a Supportive Learning Environment.** Ensuring the organization exhibits an environment that supports learning is crucial in preparing the climate for successful training to occur as it enhances trainees' motivation to learn and helps promote transfer of training (Salas & Cannon-Bowers, 2001). Demonstrating the value of learning and team training early on increases trainees' intrinsic (internal drive or interest in the current task) and extrinsic (derivative of situational factors) motivation to actively participate in training and to utilize the information learned during the training (Colquitt, LePine, & Noe, 2000). Trainees' motivation towards training is also influence by the organization's presentation of the training to employees. The way in which the training is framed effects trainees' self-efficacy and motivation, which in turn affects their reactions, learning, and transfer of training motivation (Burke, Salas, Wilson-Donnelly, & Priest, 2004; Quiñones, 1995; Tai, 2006). Specifically, Quiñones (1995) found that when a training intervention was coined "advanced", the motivation, self-efficacy, and learning outcomes were perceived more favorably and were more apparent than when the same training program was labeled "remedial."

Although training programs should aim to enhance both intrinsic (e.g. goals, needs, attitudes) and extrinsic (e.g. incentives) motivation of trainees, interventions aimed at increasing intrinsic motivation are of higher value (Ryan and Deci, 2000). Conceivably the most empirically-supported and beneficial strategy for improving intrinsic motivation, and therefore team performance, is goal setting (Locke & Latham, 1990). Goal setting increases trainees' attention, effort, and persistence, and indirectly increases acquisition of newly trained knowledge and strategies (Locke & Latham, 2002). Research suggests goals to be specific, difficult to obtain

(Kleingeld, van Mierlo & Arends, 2011; Locke & Latham, 2002) and both proximal (short-term) and distal (long-term) (Taylor, Russ-Eft, & Chan, 2005). In support of this, Kleingeld and colleagues (2011) found specific goals made at the team level to have a substantial effect on group performance ($d$ = .80). Although we have stressed the importance of only intrinsic motivation, it is also essential for organizations to support high extrinsic motivation in trainees. This can be done by offering trainees incentives for actively participating in the training and for utilizing trained concepts on the job. For most teams, these rewards can either be on the individual or team level and do not need to be grandiose; a quick acknowledgement from a supervisor is sufficed. However, a simple "pat on the back" for scientists will most likely not be adequate, and incentives appropriate for science teams should be implemented. For example, it may be reasonable to publically acknowledge scientists who complete a team training program and refer to them as qualified candidates for IRT. Another incentive may be to offer continuing education credits in exchange for completion of a team training program. Klein (2010) also suggests granting a joint appointment or adjunct position for those who collaborate across disciplines or have cross-disciplinary connections.

The final recommendation for establishing a positive learning climate for trainees is to stress the necessity of the team training program. As previously stated, trainees do not learn from the training if the program is perceived as invaluable for the organization. Organizations should positively speak of the program, and communicate to trainees why the training is being implemented and what concepts will be trained (Cannon-Bowers, Rhodenizer, Salas & Bowers, 1998). Although most scientists value educating themselves on new topics and learning new skills, they may not be willing to sacrifice their time to complete a team training program. If this occurs, we recommended the organization to advertize and incentivize team training attendance

to professors, senior researchers, and the like. In addition to stressing the significance and utility of the training content, organizations should communicate the specific program content. Doing so will enhance trainees' value of and learning from the training. Advance organizers, outlines of preliminary training information and prepractice briefs, are tools that can be distributed to trainees and supervisors in order to increase their conceptualization of the training purpose (Salas et al., 2012). Preparing the organization and its employees for a team training program is a key factor in the success of a training program. The identified actions, when implemented before training and reinforced throughout, will provide the foundation for learning to occur. It is important to note that the previous principal and the current principal display substantial overlap such that the recommended actions are similar. The distinction between the two principals rests in the purpose of the conducted steps; an organization should create a climate that reflects the training goals (Principle 3), and fosters learning (Principle 4).

When considering this principle in the context of science teams, we can, again, identify what factors might be particularly important. First, as with our prior principle, scientists would benefit from understanding how the training can improve their research programs. For example, by making explicit the value of goal-setting in scientific research, and how the training will improve the likelihood of better scientific outcomes, is one way to promote training. Related to this, the particular rewards or incentives would need to be clearly established. For example, given that scientists are motivated in ways unique to other personnel, one could explore how participating in training programs could count towards tenure review (e.g., as a service component). Finally, given the learning orientation scientists already hold, the complexity of the pre-practice materials could be more thoroughly developed. Specifically, given that scientists are predisposed to learning, they may take the added time to understand the training content prior to

the training session. Pedagogically, this opens up the opportunity for more intense group work during the training.

**Principle 5. Create Teamwork Conditions that Support Transfer of Team Training.** The main objective of team training is to increase team effectiveness for the long term –promote transfer of training. It may seem as if learning and transfer are one in the same, but they are theoretically distinct concepts. Learning includes the basic understanding of the principles, facts, and concepts presented during training and is measured either during or immediately upon termination of training; whereas, transfer is the continual application of these concepts on the job (Kirkpatrick, 1979). In essence, the goal of transfer is for trainees to generalize and maintain trained skills in a real-world setting. In order to foster transfer, the organization's policies and procedures should reflect the desired attitudes and behaviors taught in the training program. In addition, the leadership team should be trained on how to foster continued utilization of the trained competencies. Organizations should also obtain initial buy-in from trainees and supervisors and train realistic and relevant KSAs to prevent trainee skill decay.

Policies and procedures are a main part of the organizational system, and should be taught to trainees during training and reinforced on the job (Salas et al., 2006). An organization should develop policies that emphasize teamwork and identify procedures that ensure effective team performance prior to training. Adherence to the policies and procedures relies not only on proper training, but also team leadership modeling behaviors and fostering transfer of the concepts. Thus, leadership should be trained on how to demonstrate proper behavior and assist transfer. For example, team leadership may generate a check list of essential teamwork processes, incorporate this into training, and encourage the use of the checklist on the job.

Utilizing a checklist may not be realistic for science teams; however, the organization could post teamwork policies and procedures in a high traffic area of the department.

As with our other principles, trainees' motivation plays an important role in whether transfer of training occurs (Colquitt et al., 2000; Facteau, Dobbins, Russell, Ladd, & Kudisch , 1995; Mathieu et al., 1992; Noe and Wilk, 1993; Tai, 2006). Trainees are more likely to transfer the concepts learned from training to their organization if their motivation to learn and to transfer is high (Burke & Hutchins, 2007). Furthermore, when trainees' motivation is high and they perceive the training to be valuable or helpful in achieving valued outcomes, they are more likely to transfer trained concepts to the job (Blume, Ford, Baldwin & Huang., 2010; Chiaburu & Marinova, 2005; Tziner, Fisher, Senior & Weisberg, 2007). Although it is important for trainees to display learning motivation, transfer motivation may actually be a greater need because it is directly related to their utility of the trained concepts during teamwork (Chiaburu & Lindsay, 2008). Transfer motivation and transfer of training has been shown to increase when trainees display value and perceived utility of teamwork concepts (Burke & Hutchins, 2007; Chiaburu & Lindsay, 2008; Velada, Caetano, Michel, Lyons, & Kavanagh, 2007). Trainees should understand how the team training program will help them achieve their career and team goals, and understand the training relevance. It is recommended that organizations continuously communicate training value to trainees. In doing so, the organization will obtain buy-in from its employees; thus, increasing the likelihood of transfer.

Trainee skill decay is a major threat to organization, and precautionary measures should be taken to avoid the problem. In a meta-analysis conducted by Arthur, Bennett, Stanush, and McNelly (1998), it was found that little to no skill decay is found in trainees 1 day after training; however, reports done 1 year after training, show a loss of over 90% of the trained concepts.

Known factors affecting skill decay are the nature of the task; greater decay occurs in cognitive vs. physical tasks and increased retention in tasks with discrete answers (closed-loop) vs. tasks with an indefinite answer such as a problem solving task (open-loop) (Arthur et al., 1998). More importantly, Arthur et al. (1998) found dramatic decreases in retention after periods of nonuse of practice. Organizations should plan training programs close to the period where trainees will most need to utilize the skills trained. This decreases the time between training and performance, and helps in reducing the onset of skill decay. The teamwork concepts trained within a team training program should also be relevant to the organization as the training of skills usually takes a "use it or lose it" approach. As such, it is not recommended to provide training for infrequent or unnecessary KSAs.

When considering training transfer for science teams, it is clear that the concepts to be trained are those that will be utilized. For example, if a team of scientists recently received a collaborative grant, it is clear that they will quickly be able to make use of teamwork training. As such, this would reduce the likelihood of decay. Similarly, if a new research center is being developed (e.g., funding for a large scale collaborative project like the National Science Foundation "Science and Technology Center"), training programs should be part of the planning. This, too, will increase the acceptance as well as enhance the probability of training transfer.

**During Team Training**

There are several principles that need to be followed during training that will ensure training effectiveness. This includes the delivery method utilized for concepts trained as well as proper team development practices. The following principles are rooted within the sciences of learning, motivation and training and are outlined below.

**Principle 6. Develop Content of Team Training.** The overarching goal of a team training program is to further develop trainees' teamwork, or the "behavioral, cognitive, and attitude skills needed to communicate, interact, and coordinate tasks effectively with other team members" (Salas et al., 2002, p. 240). Furthermore, team training programs are not designed to enhance task-based KSAs, and it is important to note that training participants should display task proficiency before attending team training. It is not advised to teach teamwork before teaching task work (i.e., the skills necessary for task completion; Salas et al., 2001). This ensures complete efficiency for team training programs as the trainees will already be familiar with the tasks they need to complete. Based on the information obtained from the team needs analysis, the organization should have a general idea of what to include in the team training program, and the organization should refer back to the team needs analysis to conclude which competencies should be the focal point of the training. For example, if SMEs suggested that the most difficult tasks involved heavy communication between team members, the team training program should focus on identifying effective communication skills. We recommend drawing from the teamwork competencies previously identified in order to get a general idea of what to include for a team training program. Specific teamwork skills pertinent to IRT and potential training strategies for these skills are outlined in Table 2.

--Table 2--

**Principle 7. Utilize Appropriate Instructional Delivery Methods.** The content within a team training program is not all that should be considered when designing; selecting the appropriate delivery method for this information is of importance, as well. The team training delivery method is the media which team training is presented, and consists of information-based, demonstration-based and practice-based modes (Salas & Cannon-Bowers, 2000). Most

successful team training programs incorporate all methods as certain strategies are more efficacious in presenting different levels of information and knowledge to trainees. In fact, in a qualitative review, it was reported that 59% of the studies included (n=26) indicated using a mix method approach to content delivery (Salas, DiazGranados, Weaver, King, 2008). Most programs began with an information-based method and/or demonstration-based method and concluded with a practice-based method. The results of the team needs analysis will provide better insight as to which method may be more beneficial or feasible based on organizational resources and what teamwork skills are most needed for the organization. In the following sub-sections, we will briefly describe each method.

*Information*: Information-based methods include information packets, slide presentations, advance organizers, and lectures and are normally presented during the initial phase of team training. Information on teammate roles and responsibilities, expectations of the team, team goals, and task interdependencies are the bulk of the information that should be presented using this medium. Moreover, this delivery method should be utilized only to present declarative information to trainees, and research suggests that information-based delivery has a minor impact on team training effectiveness when it is the sole method used in a training program (Davis et al., 1999; Weaver et al., 2010). Although information-based delivery does have a number of positive elements, such as ease of delivery, low cost for implementation, and ease of content delivery, it should be coupled with other delivery methods.

*Demonstration*: Demonstration-based delivery provides trainees with direct examples of teamwork competencies and the opportunity to observe targeted teamwork behaviors. This delivery method includes in person demonstrations and demonstrations through technological mediums, such as video or simulation. Demonstration-based delivery is effective in fostering

transfer of training (Taylor, Russ-Eft, & Chan, 2005), and is theoretically grounded in the social learning theory (Bandura, 1977) and behavior modeling training (Sorcher & Goldstein, 1972). This delivery mode is cost effective, flexible and easy to integrate with other team training delivery methods. When utilizing this method, it is important to demonstrate both positive and negative examples of the identified teamwork KSAs. Relevant literature should be scrutinized in order to determine proper and improper examples of team competencies. Furthermore, following receipt of demonstrations, trainees should be able to properly identify how to, and how not to implement teamwork behaviors.

*Practice*: When describing this team training delivery method, it is difficult to not restate the age old adage, "practice makes perfect." However, not all practice methods increase learning or expertise (Ericsson, 2008). Research suggests *deliberate* practice improves performance and its success in producing learning outcomes within a team training program have also been supported (Ericsson, 2008; Goettl et al., 1996; Satish and Streufert, 2002; Shute and Gawlick, 1995). This method provides trainees the chance to exercise targeted teamwork competencies; thus, increasing their conceptualization of the material. Practice should be guided by the trainer in order to ensure the competencies are properly interpreted and practiced (Salas, Burke & Cannon-Bowers, 2002). Specific practice-based methods that ensure a safe and secure learning environment for trainees include role-play and simulations (Smith-Jentsch, Salas & Baker, 1996). Within role-play activities, trainees are assigned specific roles by the instructor or script and are instructed to utilize the trained concepts in order to successfully complete their role. Simulations are designed to mirror a real-world environment and provide trainees the opportunity to execute tasks similar to what they would experience on the job.

Each of these teamwork training delivery methods has pros and cons, and each are well-suited for certain types of knowledge. It is recommended that a team training program incorporate all delivery methods; however, it is understood that this may not be possible due to an organization's resources and logistics. The organization's overarching goal for the team training programs should be kept in mind when choosing delivery methods. Information-based delivery is well-equipped when providing the foundation for learning basic teamwork processes while demonstration-and practice-based approaches provide a better opportunity for trainees to conceptualize and integrate hot to utilize teamwork KSAs.

When it comes to training for science teams, it is likely that information delivery will likely be better suited for this context. While demonstration based methods will also be helpful, the kind of behavioral coordination typically trained with such methods, occurs less frequently in science teams. As such, knowledge of teamwork competencies might be better trained through less labor intensive methods.

**Principle 8. Provide Team Development Aids.** Team training programs are, in general, designed to enhance team development and the onset of teamwork competencies. However, not all team training programs do this successfully. For example, in 2008, a sales' team supervisor decided his team was not performing to the best of their ability. He created a team training intervention which included him simulating drowning a team member in front of the team. He then proceeded to shout to the observers, "You saw how hard Chad fought for air right there. I want you to fight that hard to make sales" (Vick, 2008). Clearly, this intervention did not increase team development or performance, and eventually resulted in a tremendous law suit. In comparison, numerous team training programs have been validated by researchers within various domains (e.g. TeamSTEPPS in the medical field and Crew Resource Management in the aviation

industry) (King, Battles & Baker, 2008; Salas, Burke, Bowers, & Wilson, 2001). The bottom line is that not all team training programs are created equal (Shuffler, DiazGrandados, Salas, 2011). In order to aid longitudinal team development certain job-aids or tools should be presented during training; including feedback, debriefs (after-action reviews), and coaching.

Feedback is a vital component of demonstration- and practice-based delivery methods of team training. Providing trainees with proper feedback throughout training helps to ensure the proper training and development of teamwork competencies and promotes increased comprehension of what trainees are doing well and where they need improvement. Feedback can be formally implemented using debriefs or after-action review tools or informally by exchanging messages from leadership to trainees. Regardless of feedback presentation, it is vital that it is accurate, delivered in a timely manner, is focused on team processes vs. outcomes, is appropriate, and is both positive and negative (Smith-Jentsch, Zeisig Acton & McPherson, 1998; Smith-Jentsch, Cannon-Bowers, Tannenbaum & Salas, 2008). Feedback should also be clear, concise and constructive (Salas et al., 2002).

Debriefs reinforce learning and can be conducted during training (after an exercise or simulation), or upon termination of training in the post-training work environment (Salas et al., 2012). Debriefs are an effective tool for improving team performance, and military teams and leaders that conducted effective debriefs were said to outperform other teams by up to 40% (Smith-Jentsch et al., 2008; Tannenbaum, Smith-Jentsch, & Behson, 1998). During a team debrief, the team reviews a prior experience, identifies successes and failures, and where improvement can be made. A successful training program should not only implement debriefs within the training, but also provide trainees with the knowledge necessary to conduct debriefs after training to reflect on real-world experiences (Salas et al., 2012).

It is important to note that just because a team completes a team training program, this does not mean their learning is complete. Further, it is important for trainees to continue, even after training, to learn on the job (Tannenbaum, Beard, McNall, & Salas, 2010). This experience has to be guided, and coaches or team leaders may serve as facilitators (Buckingham & Coffman, 1999). Therefore, it is important that during training, team leaders are provided with tools, training, and support to increase their coaching skills. A team training program's main objective is to foster team development and providing trainees with tools and job-aids will increase their retention of training thereby increasing the use of trained teamwork concepts. Training is a systematic process that technically ends after the training occurs; however, a successful training program will provide trainees with tools so that they can continue to learn and excel on the job.

Each of the above can be realistically implemented for science teams. Perhaps most important, though, to emphasize who on the team would be responsible for feedback, debriefing, or coaching. It is reasonable to expect that the Principal Investigator or science team leader should manage these roles. Nonetheless, ensuring that all science team members are well versed in, and accepting of, feedback, debriefing practices, and coaching, will help to ensure the effectiveness of the training program.

**After Team Training**

Logically speaking, it would seem as if the termination of the training program denoted the end of the organization's "to-do list" list in terms of ensuring team training success. However, this notion is completely inaccurate. It is essential for the organization to partake in several steps after training occurs in order to ensure complete effectiveness of the training. These critical elements include conducting a training evaluation and continuing to promote training transfer; each element is briefly discussed below.

**Principle 9. Evaluate Team Training.** To evaluate training effectiveness, Kirpatrick's (1979) evaluation procedure should be implemented. These evaluation levels include reactions, learning, behavior and results and are grounded within one another such that the former levels are precursors to the latter. However, positive outcomes within one level do not imply positive outcomes in subsequent levels. *Reactions* are normally assessed immediately after training occurs and include trainees' attitudes towards the training. This evaluative process consists mostly of self-report questionnaires and such questions should focus if they found the training useful, enjoyable and valuable. *Learning* is assessed by accounting for the maximum performance change by trainees during the training, and is referred to what trainees "can do" following training (Klehe & Anderson, 2007). Learning focuses on the declarative knowledge acquired by trainees and should be assessed pre- and post- training in order to identify the change score. Keep in mind that there may be a delayed effect on learning, and behavior transfer may still be effective even if learning improvements are insignificant (Keith & Frese, 2008). *Behavior* outcomes, in comparison to learning, are not what the trainee "can do," but signify what the trainee "will do" (Klehe & Anderson, 2007). Behaviors are assessed by investigating whether trainees utilize the KSAs taught during training (e.g. communication, leadership skills, etc.) in the actual on the job environment. *Results* are outcome-oriented variables and assess the overall effectiveness of a training program. Results are assessed following all previous training evaluation levels and consider external variables that feed into utility, such as the ratio of cost to cost benefit, of team training.

In addition to following Kirkpatrick's (1979) training evaluation process, team training programs should also assess certain team-based elements such as leadership, team performance, and training content. Several recommendations specific to team training evaluation have also

been identified: (1) develop team process and outcome assessment tools, (2) record team-level and individual-level data, and (3) assess performance during multiple time periods (Salas, Burgess, & Cannon-Bowers, 1995; Salas & Cannon-Bowers, 2000; Salas & Cannon-Bowers, 2001). Evaluation is a crucial step in determining the effectiveness of a training program as well as indicating whether the program needs to be altered before another implementation or whether trainees need remediation training.

While there are many challenges associated with evaluating science (e.g., Stokols et al. 2008), much of the above can be leveraged for evaluating science teams. For example, at a more micro level, evaluation of team process can be done when it comes to scientific tasks such as designing and executing experimentation. Similarly, evaluation of scientific products such as collaborative papers, provide opportunities for assessing teamwork in science teams.

**Principle 10. Promote Transfer of Team Training.** Unfortunately, just because trainees may learn the trained concepts following training, there is no guarantee that they will actually utilize and transfer this information to the work environment. Therefore, several steps, on the organizational front, should be taken in order to increase the application of teamwork concepts on the job (Goldstein & Ford, 2002). Before training occurs, the organization has been instructed to foster the transfer of training (see Principle 5), but the organization also needs to complete follow up measures in order to completely support transfer of training. Specifically, organizations need to provide practice, support, and real-time opportunities for trainees to utilize newly trained teamwork concepts upon completion of the training program.

Ideally, an organization will implement a team training program focused on competencies identified as critical, relevant, and needed within the organization. However, this is not always the case, and sometimes the use of the newly trained concepts may not be immediately apparent

following training. As previously stated, the lack of practice of trained teamwork concepts leads to skill decay. Therefore, it is imperative for an organization to make sure that they create an environment conducive to the use of the trained teamwork competencies. For example, following training, the organization may want to quickly assign a team-based assignment. It is also recommended for the organization to suggest the utilization of the trained teamwork competencies amongst trainees.

Another way to reinforce transfer of training is to have buy-in from supervisors regarding the team training program. Supervisors play a critical role in warranting the use of teamwork concepts trained are actually used on the job (Colquitt, et al., 2000; Smith-Jentsch, Salas & Brannick, 2001). Including supervisors throughout training may also increase transfer of training as supportive leadership is linked to the establishment of a supportive organizational climate (Taylor et al., 2005). Research has also shown that in a team task, supportive leaders increased the application of learned skills under typical performance (Smith-Jentsch et al., 2001). Specifically, supervisors can model the application of trained behaviors, provide trainees with the time and materials needed for accurate performance, and encourage, recognize and reward the use of trained teamwork competencies (Salas & Stagl, 2009). Peers are also key players in support of training transfer (Blume et al., 2010). Observing other team members using trained skills and the coaching of one another to use trained concepts aids in training transfer immensely (Gilpin-Jackson & Bushe, 2007). Encouraging networking between employees regarding how to utilize trained concepts and sharing ideas about the training is recommended.

Several other factors have been linked to successful transfer of training such as cognitive ability, self-efficacy, motivation, perceived utility of training, behavioral modeling, error management, realistic training environments, transfer climate, support, opportunity to perform,

and follow-up (Grossman & Salas, 2011). Therefore, we continue to stress the importance of establishing and *maintaining* a supportive and transfer climate. Organizations should make sure the importance of utilizing these key teamwork competencies is ingrained within the organizational climate; otherwise, trainees will sense a lack of importance regarding the material and will abandon utility completely. It is also important for the organization to continue to follow-up with trainees and supervisors regarding training. This can be achieved by offering refresher training, if needed, or simply by continuing to communicate the value of the trained concepts.

As stated earlier, training transfer for science teams is critical to long-term success. To reiterate, the concepts to be trained need to also be encouraged by the organization. This includes not only specific support for teams of scientists (e.g., those working on collaborative projects), but also for the organization as a whole. For example, university departments can be encouraged to be more collaborative both internally (within disciplines) but also externally (across disciplines). When Chairs, and Deans, or Center Directors, foster this kind of interaction, the opportunities for transfer will be greatly enhanced.

**Summary**

In summation, these principles are designed to increase the effectiveness of a team training program. Although some of these principles may overlap between the different stages of training (before, during, and after), it is suggested that they are implemented in the presented order. It is also important to restate that team training programs do not hold a one-size-fits-all approach; therefore, it is important to model the organization's team training program after the core goals and objectives of the organization and also the results of the team needs analysis. We recommend the use of these principles in order to successfully implement a team training

program for interdisciplinary teams. However, we have noted that there are several critical challenges of interdisciplinary teams, and therefore, any team training program designed for interdisciplinary teams should take these issues into account. In the following sections we will identify barriers within interdisciplinary teams, and provide recommendations for the implementation of team training principles specifically in IRT.

-- Table 3 --

**Challenges Faced by Interdisciplinary Research Teams**

Interdisciplinary research is the cultivation of several disciplines which come together to solve an interrelated issue. Furthermore, IRT are comprised of several individuals who display a multitude of knowledge backgrounds. IRT are inherently diverse, and therefore, exhibit challenges due to the different nature of how different disciplines address science and practice. As noted by Fiore (2008), team science is sometimes criticized by those who think that scientists are collaborating with one another on projects where they may actually be more successful if they worked individually. However, this is just not the case as IRT bring together a multitude of perspectives on a problem and diverse backgrounds which in turn increase the ability to solve a complex issue (Bennett & Gadlin, 2012; Fiore, 2008). As identified earlier, scientific issues are increasingly becoming more complex and science teams are required in order to solve these issues. Perhaps some science teams are more successful than others, and this may be due to the fact that they operate more efficiently as a team than others. We propose that this issue isn't that these scientists would perform better as individuals, but that they would perform better if they received a proper team training program. IRT face antecedent, process and outcome issues, most of which, we believe, can be ameliorated by providing these teams with a formal team training program. In this section we will first identify antecedent issues, then process issues and follow

with outcome issues. We will then provide specific recommendations as to how to implement a team training program in these teams, keeping in mind their specific challenges

Interdisciplinary teams face multiple challenges even during the nascent stages of formation. Such antecedent factors include: collaborative-readiness, preparation and planning, and institutional support. Collaboration readiness refers to the degree to which a team or institution displays evidence of preparedness for collaboration (Romero, Galeano, & Molina, 2009). This is reflected in an array of factors including the display of organizational support for collaboration (e.g. amount of departments within an educational institution), the presence of technologies allowing for effective communication, and the degree to which team members have previously enacted in collaborative activities across organizational boundaries (Stokols et al., 2008). These factors play a large role in whether an interdisciplinary team succeeds, and poses one of the facilitating factors of interdisciplinary team success (Fuqua, Stokols, Gress, Phillips, Harvey, 2004; Kessel, Rosenfield, & Anderson, 2008; Morgan et al., 2003; Olson & Olson, 2000; Stokols et al., 2003; Stokols, 2006). Interdisciplinary collaboration requires strategic preparation amongst team members, and most interdisciplinary teams display a lack of planning (Stokols, 2006; Stokols et al., 2008). Few team members have received training specific to how to succeed within an interdisciplinary team, or a team in general (Stokols et al., 2008). This leads to ambiguity of team goals, lack of a shared timeline of achievement, and unrealistic expectations for group harmony. Institutions should provide interdisciplinary teams with necessary training as well as more support for collaboration across disciplines. Educational institutions continue to heavily reward scientists for individual achievements such as a sole authored paper published in a top-tier journal or a patented product. Furthermore, scientists are less likely to collaborate across disciplines because they are unsure if their work will be

incentivized. There is also a lack of funding support from institutions for interdisciplinary collaboration. For example, most departments provide funding to narrow-focused projects extending a short time period (Kessel, Rosenfield, & Anderson, 2008). Furthermore, interdisciplinary projects are just the opposite: broad focused projects with a heightened goal and longer timeline requirement.

IRT also display numerous process oriented challenges. These issues are related to different disciplinary perspectives, leadership, ineffective communication, and interpersonal factors. Due to the fact that interdisciplinary teams are just that: teams consisting of members with different backgrounds, conflicts tend to arise. This is because of the lack of consistency between various disciplines regarding language, methodology, and theory (Stokols et al., 2008). Challenges are also likely to arise regarding leadership amongst interdisciplinary teams. This is because most leaders within these teams lack collaborative skill and management experience (Stokols et al., 2008). Communication barriers are possibly one of the most common issues amongst interdisciplinary teams. First, many interdisciplinary teams are distributed across departments or universities. The lack of collocated spaces for interdisciplinary teams to meet face-to-face is also a main contributor to ineffective communication (Stokols et al., 2008). Second, distinct languages across disciplines can also hinder communication. Related to this, interdisciplinary teams also face many interpersonal discrepancies due to conflicting scientific theories and the immense amount of work involved in collaborative projects (Fiore, 2008; Morse, Nielson-Pincus, Force, & Wulfhorst, 2007; Pickett, Burch, & Grove, 1999).

Although antecedent and process challenges are more prominent, interdisciplinary teams also face outcome challenges. Mainly, conflicts arise from career development issues. As previously stated, most interdisciplinary teams lack preparation and planning before embarking

on a project. This lack of planning is directly related to outcome issues because team members involved may not get the most out of the collaboration because objectives regarding outcomes were not well-established. For example, in the nascent stages, team members should outline a publication plan. Outcome issues also arise because of the lack of support from funding agencies. Interdisciplinary teams may not work as hard on collaborative projects because the guarantee of future funding is not present. An assurance of long-term support by funding agencies would increase the collaboration period; perhaps increasing trust amongst team members, strong relationships, and outcomes. Scientists may also see other scientists as a posing a threat to their career advancement because, traditionally, researchers are rewarded for individual work such as a single-authored publication in their fields' top-tier journal (Fiore, 2008). In addition to these career development issues, some scientists may feel their identity is at risk because they are bridging to a new area of research than their area of expertise (Borner et al., 2010; Nash, 2008).

From this brief review above, we turn next to a set of observations that need to be considered for IRT. We suggest that these need to be addressed to develop and foster team training programs within IRT.

**1. What are the necessary KSAs for interdisciplinary research teams?** In order to determine the specific teamwork concepts to incorporate within a team training program, it is first necessary to define the KSAs needed for team task. Currently, the core competencies and teamwork processes that are critical to obtain success within interdisciplinary teams are not solidified. The current focus of IRT research seems to be identifying the specific challenges faced by IRT (e.g. Bennett and Gadlin, 2012). Yes, research has determined IRT challenges and characteristics of successful IRT, but is this research all-encompassing? What is the desired skill level for these competencies? Also, how do failing teams adjust their current performance to

become effective? It can be inferred that a main issue amongst IRT is conflict; however, the specific problems involving conflict are not delineated. How exactly does conflict affect these teams? Where in the process are these challenges occurring? What are the necessary skills interdisciplinary teams need to manage conflict? Research also suggests communication as one of the main issues IRT face, but an exemplar model of communication and attainment method is still in question. The most recognized thesis is the notion that interdisciplinary communication is the amalgamation of two or more disciplinary languages with the goal of developing a collective agreement (Holbrook, 2013; Klein, 2005); however, some disagree with and pose differing conceptualizations of the ID communication process (Holbrook, 2013). Further, in order to develop an IRT team training program we need to understand not only what teamwork competencies are needed, but also how these processes are identified and attained. Exhaustive research efforts on specific competencies thought necessary for IRT should be conducted, such as the recent longitudinal study on heterogeneous research groups conducted by Cummings and colleagues (2013). Studies resembling the work of Cummings et al. (2013) are needed to identify the necessary KSAs for IRT, and for developing IRT training programs.

**2. What is the nature of task interdependency amongst interdisciplinary research teams?** Researchers utilize the term team and group interchangeably (Kozlowski & Bell, 2003); however, it is important to note that they do bode differences. A group can be defined as two or more individuals who "share information, perspectives, and insights; to make decisions that help each person do his or her job better; and to reinforce individual performance standards" (Katzenbach & Smith, 1992, p. 3) while a team is defined as a "distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have been assigned specific roles or functions to perform,

and who have a limited life-span of membership" (Salas, Dickinson, Converse, & Tannenbaum, 1992, p. 4).

Perhaps the most unique characteristic of a team is its high level of interdependency amongst members. Researchers have identified four categories of team task interdependence: pooled, sequential, reciprocal, and team (Saavedra, Early, & Van Dyne, 1993). Pooled interdependence is when contributions to the team output are made by each individual and team member interactions are not required. Sequential interdependence refers to when one group member must act before another can perform. Reciprocal interdependent tasks require coordination amongst team members and temporally lagged, two-way interactions are present. Team interdependence refers to the highest level of task interdependence and it requires team members to collaborate simultaneously in order to complete the task. What is the level of task interdependency for IRT tasks? Currently, this answer is unknown. This distinction matters because, as discussed in Fiore (2008), criticisms of the effectiveness of interdependent teams are present. Specifically, some think tasks completed by interdependent teams could be done as, or more, effectively by individuals. Are these teams actually groups in that they don't necessarily need one another to complete the team task? We argue that they have been correctly identified as teams; however, this may not be the case. It is necessary to further investigate the nature of interdependency within interdisciplinary teams in order to comprehensively answer this question.

**3. Is collaboration readiness present?** As previously stated, collaboration readiness is the degree to which an organization fosters and supports interdisciplinary interactions amongst its personnel. In order for interdisciplinary teams to operate efficiently, collaboration readiness must be present on an individual, team and institutional level (Stokols et al., 2008). While many educational institutions promote the importance of collaborating across disciplines, they do not

actively promote an environment that makes this possible. This is partly due to the stress put on tenure seeking faculty members as well as the lack of funding for long term, multidisciplinary projects. The question that still needs to be addressed is whether these institutions are in fact ready to foster interdisciplinary research. Researchers should investigate the nature of collaboration readiness amongst institutions in order to determine the necessary degree of improvement.

**4. How do you evaluate interdisciplinary relationships?** As stated earlier, a formal training evaluation is completed upon termination of the training program. A main component of an evaluation is to measure trainees' KSAs pre and post training. In order to do so, the teamwork competencies essential to the organization need to be established as well as their competency level. So the question becomes, what constitutes good interdisciplinary teamwork? Is it the level of collaboration the team displayed? Is it whether they achieved their individual goals, or the team goals? Does team viability determine good interdisciplinary teamwork? The answers to these questions and other similar questions need to be addressed in order to determine a set measurement plan for interdisciplinary team effectiveness. Necessary teamwork skills within other domains have been established by looking at said high-performing teams within the real-world. Unfortunately, the data on high-performing interdisciplinary teams within the science domain is sparse (Borrego & Newswander, 2010), and the current assessment methods for collaboration effectiveness fluctuates (Stokols et al., 2008). Researchers have begun to investigate these teams (i.e. Cummings & Kiesler, 2005; 2013); however, much work remains, and researchers should continue to study science teams in a more comprehensive manner.

In conclusion, because interdisciplinary teamwork research is a relatively modern topic, there are unknown elements related to team training effectiveness that we suggest being

addressed. We have also identified specific antecedent, process and outcome factors which influence interdisciplinary team success. These factors should be taken into consideration when implementing a team training program. Although interdisciplinary research is inherently team research, interdisciplinary teams face specific challenges that should be considered when implementing a team training program (Fiore, 2008). Nonetheless, the team training principles previously identified provide a good starting point for developing a team training program for interdisciplinary teams. We conclude with a list of tips for establishing a team training program for IRT which takes into consideration the particular issues faced by IRT.

-- Table 4 --

**Leveraging the Current Body of Knowledge to Support Interdisciplinary Research Teams**

Although current research regarding the training of interdisciplinary teams is not yet all-encompassing, we can leverage information from related fields to advance our conceptualizations. A large body of knowledge regarding the specific KSAs needed for successful teamwork presently exists. Teams, in general, display certain challenges that can be overcome by the training of these KSA processes, such as cooperation, coordination, effective communication, and conflict management. In addition, evidence-based training design and delivery methods have also been distinguished and these have been identified in the previous sections. To this end, our paper now takes a more practical approach. We will now review what we can actively do to advance interdisciplinary team science by leveraging the present literature from related domains. In the subsequent section, we outline specific actions to take as they relate to training, education, and performance for IRT.

**Training**

A critical step in developing a team training program is outlining the necessary teamwork competencies for the organization (see Principle 6). In order to do so, it is important that the organization draws on existing research on what KSAs are required to successfully execute the future team tasks. Unfortunately, this research knowledge is lacking within interdisciplinary team research (Fiore, 2008). However, research on transdisciplinary teams, although still limited, is more abundant than interdisciplinary team research (e.g. Nash et al., 2003; Vogel et al., 2012). Transdisciplinary scientists build on findings in different domains, and then tackle issues by integrating these individual perspectives to create new theoretical frameworks and methodological tools (Rosenfeld, 1992). Whereas interdisciplinary teams are a conglomerate of expert scientists from various fields who collaborate freely with one another to address issues, but do not necessarily integrate conceptual and methodological approaches in their work (Pellmar & Eisenberg, 2000). Furthermore, these two collaborative techniques, although they are disparate, do display very similar qualities, and it is beneficial for the interdisciplinary team research to draw information from the transdisciplinary field.

In addition to looking to related fields to leverage information, researchers should thoroughly investigate present and past science teams in order to identify critical elements for team effectiveness. For example, Bennett and Gadlin (2012) recently held in-depth interviews with team members of successful and unsuccessful science research teams ($n$=5) and identified several reoccurring themes for success, including: self-awareness and team-awareness, establishing trust, creating a shared vision, sharing recognition and credit, communication, and enjoying the science (Bennett and Gadlin, 2012). In addition, Cummings and colleagues (2013) investigated the effect of heterogeneity on research groups ($n$=549), and found larger groups to

be more productive than smaller groups, but this productivity declined as heterogeneity increased. This current research on the performance of science teams contributes immensely to the field; thus, researchers should continue similar work in order to determine key elements for success and to increase the generalizability of the findings. We recommend *identifying the teamwork competencies needed for successful IRTs by incorporating the knowledge gained from related fields and continuing to investigate "Teams in the Wild."*

Identifying critical KSAs for science teams may pose as a daunting task because of their unique nature. Science teams are not only distinct in terms of team member characteristics and the issues they face, but also in relation to their current tasks. This is important to denote because the type of task the team needs to accomplish affects the required competencies, and in turn dictates training characteristics. In other words, situational and task characteristics impinging on a team influences required competencies as well as training design and delivery methods (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995). Task and environmental factors which impact the nature of required competencies and training strategies include task interdependence, task/environmental stability, team member turnover, membership in multiple teams, and the variety of tasks performed by the team (Cannon-Bowers, et al., 1995). Because these characteristic play a role in team training effectiveness for other types of teams, it is highly possible that they will affect team training for IRT. In addition to identifying the key competencies for IRT, we recommend researchers identify task and situational factors, and to use this knowledge to *build a taxonomy of science teams* in order to organize the kinds of science teams. In turn, a taxonomy will aid in the identification of: 1) influencing factors (e.g. the nature of interdependency), 2) key KSAs, and 3) successful training strategies.

Another key influencing element to the success of a team training program is the presence of team leaders and mentors (see Principle 8). Research within the transdisciplinary field has also outline the importance of mentors on these teams' success in that they model collaborative research and cultivate young scientists to explore other domains (Nash et al., 2003). Although critical factors in interdisciplinary team success, experienced leaders seem to be lacking (Stokols et al., 2008). Therefore, an immediate step in progressing interdisciplinary team science is to train leaders on teamwork competencies and how to guide interdisciplinary teams to success. Such topics that should be covered may include: communication between team members, team goal-setting , and assigning roles and responsibilities. It is also important for these leaders to be aware of how to lead distributed teams because many interdisciplinary teams are geographically dispersed. Although current technology may facilitate communication and interaction between distributed teams, geographically dispersed teams are more likely to fail or underperform (Cummings and Kiesler, 2005; Olson and Olson, 2000), thus increasing the importance of training distributed team leaders on how to facilitate proper teamwork. Their major challenge is coordinating the team insofar individual scientists can utilize each other's ideas and expertise even with the lack of face-to-face contact (Communication and tech book). Furthermore, such topics that should be covered with a distributed team leader may include how to successfully incorporate virtuality (e.g. discussion boards, chat rooms, video conferencing), and specific strategies for addressing the challenges face by these teams (e.g. miscommunication due to emails, lack of face-to-face contact). Thus, we recommend *providing IRT team leaders with training on how to successfully guide their team.*

**Education**

In terms of education, it is important that graduate institutions foster a collaboration ready environment. As we have repeatedly denoted, interdisciplinary teams need organizational support in order to succeed (Fiore, 2008; Lavin et al., 2001). Presently, institutions can do so by outwardly applauding interdisciplinary behavior (Fiore, 2008). A greater merit should be awarded to scientists who successfully complete collaborative research projects, especially since this action is sometimes considered a negative towards earning tenure. Furthermore, many institutions issue statements and initiate programs in support of interdisciplinary collaboration; however, the institutions policies and norms seem to communicate the opposite, in turn sending contradictory messages to its employees (Bennett & Gadlin, in press). For example, when investigating research teams and collaborations at NIH, Bennett and colleagues (2012; 2010), found that despite formal institutional pronouncements of support for research collaborations, most scientists felt they were "going against the grain" of the organization (Bennett & Gadlin, 2012; Bennett, Gadlin, & Levine-Finley, 2010). Furthermore, interdisciplinary research needs to be rewarded not only by educational institutions, but by professional and funding communities alike (Fiore, 2008). 360 degree support is needed, especially since these teams require much more resources in comparison to individual research projects. Julie Klein (2010), a leading researcher of interdisciplinary studies, identifies facilitating strategies for introducing interdisciplinarity within an institution. Although her mechanisms were developed for educational institutions creating an interdisciplinary department or track, the mechanisms described will foster collaboration readiness for IRT, as well.

Educational institutions can also support collaboration on an interpersonal level. Trust is a major contributor to team success and establishing trust amongst team members and

organizational trust provides the base for critical teamwork processes (e.g. communication, shared cognition, conflict management) and enables effective collaboration (Costa, Roe, & Taillieu, 2001; Shrun, Genuth, & Chompalov, 2007). Trust develops through relationships amongst team members, and through relationships between team members and the organization (Costa, Roe, & Taillieu, 2001). An organization can help the onset of trust amongst its members by ensuring accurate information is presented to scientists. For example, if an organization states that it values IRT and collaboration, it is important that this message is also conveyed by actions (policies, procedures, rewards for collaboration). An organization may also foster trust amongst its employees. Because individuals within an interdisciplinary team display unique characteristics in terms of their background, it may pose a challenge to establish trust amongst team members. This may be offset if educational institutions developed more opportunities for interpersonal relationships to emerge before embarking on collaborative projects. Also, providing faculty and students with the ability to build rapport with one another will most likely increase their willingness to collaborate amongst departments. The organizational environment serves as a backbone of collaboration, and it is necessary for scientists to feel they will receive support from their organization in regards to embarking on a collaborative journey. Thus, we recommend *educational institutions to establish collaboration readiness.*

Educational institutions can also foster collaboration by incorporating teamwork concepts within present courses. For example, within a graduate course, review the ABC's of teamwork, and outline specific teamwork competencies and how to improve upon them; this could easily be done in the first semester of a doctoral or master's program. Providing students with this information would not only foster collaboration but would also be beneficial for any future teamwork projects. Few institutions have actually begun to incorporate teamwork training within

their curriculum. Within the BA, MA, and PhD Programs in Social Ecology at the University of California, Irvine, interdisciplinary collaboration concepts are introduced through required courses, such as a doctorate Seminar in Social Ecology and a graduate seminar on Strategies of Theory Development (Stokols, in press). Furthermore, the use of a teamwork training curriculum is present in other domains as well. For example, TeamSTEPPS (teamstepps.ahrq.gov/) is a teamwork training curriculum that is heavily utilized by the medical community. TeamSTEPPS was developed to improve patient safety through the enhancement of communication and other critical teamwork skills among health care professionals (Henriksen et al., 2008). Since its inception, TeamSTEPPS has been successful in improving team effectiveness, and has since been altered to meet the needs of other types of teams and implemented within K-12, law enforcement, and other various domains (Deering et al., 2011; Mayer et al., 2011). Consequently, we recommend *adapting current team training curriculum*, and *developing a formal team training curriculum for IRT*.

In addition to designing a formal team training curriculum for scientists, students and other personnel involved in IRT, graduate and research institutions should informally educate these members on collaboration. Institutions should provide more cross-disciplinary collaborative opportunities to students and faculty. For example, a university could develop an interdisciplinary research showcase where student teams working across disciplines could present their work. Providing this type of experience within a school setting may not be as intimidating as promoting grant funded interdisciplinary work. When students think of interdisciplinary teams, the first thing that comes to mind are, most likely, complex research questions and projects, such as unmanned spacecraft, or the cure for cancer. It is important to inform students that collaborative work does not have to be immensely complex, or large-scale.

Another example would be to conduct a workshop on collaboration; specifically outlining its importance and suggestions for successful participation. Informal information presentations are important because they foster collaboration and ultimately provide advice on how to create conditions for successful collaboration. Thus, we recommend *informally presenting collaborative techniques.*

**Performance**

In order to promote and ensure that interdisciplinary teams are successful, they must be provided with tools that foster longitudinal collaboration. Presently, there are certain tools designed to help IRT, such as the Toolbox for Philosophical Dialogue and Collaboration & Team Science: A Field Guide. The Toolbox for Philosophical Dialogue (Eigenbrode, et al., 2007) is an apparatus that was designed to address the need for "philosophically informed communication," and consists of discussion questions which draw out scientists' perspectives on philosophical features of their work (Eigenbrode, et al., 2007). The toolbox should be utilized in the beginning stages of interdisciplinary team formation, and when tested ($n$=4) it was shown to open lines of communication between team members and help identify potential barriers and facilitators to cross-disciplinary collaboration (Eigenbrode, et al., 2007). Bennett, Gadlin, and Levine-Finley (2010) developed Collaboration & Team Science: A Field Guide based on the results of a qualitative study of 5 self-assembled science teams (30 individuals) and a review of relevant team and group literature. The field guide provides scientists with background information on collaborative science and tools and strategies that can foster their success. Although these resources are helpful in increasing collaborative success, one common problem is that they are usually implemented on a project-specific, short-term basis (Stokols, in press). Moreover, the issue within interdisciplinary teams is not that they aren't successful in the beginning, but they

are lacking long-term collaborative success. Furthermore, tools or job-aids that will increase longitudinal success should be utilized. We suggest the training and use of debriefs (after-action reviews) and coaches (team leaders). Research has shown the effectiveness of said job-aids (identified in Principle 8) in increasing teamwork skills (Tannenbaum & Cerasoli, 2013), and leveraging these tools for IRT would most likely be beneficial in increasing long-term success.

Teams often develop issues overtime, and, as previously stated, within IRT, as time progresses, the amount of collaboration between parties will most likely decrease. In addition to providing teams with job-aids and tools to help boost collaboration and team effectiveness, it would be beneficial for these teams to have some type of "live" tool they can utilize at anytime from anywhere, such as a "Collaborative Dr." The "Collaborative Dr." would provide evidence-based advice of what to do before, during, and after the collaboration period. Specifically, the Dr. would provide information identifying how to conduct a debrief, self-correct, resolve conflict, behave as a leader, and perform other necessary teamwork processes. The Dr. could also be further developed to help diagnose and fix issues faced by science teams in real-time. For example, the Dr. could provide feedback to a team on their performance and provide reminders for deadlines, reoccurring meetings and check-ins. In addition to existing outside of departments, many science team members are distributed geographically; therefore, it may be hard for them to communicate effectively. The Dr. may be able to increase communication between these team members by providing them with needed reminders to update the others. Researchers at the University of California, Irvine and University of Texas Health Science Center at San Antonio have collaborated on the development of such tool, The Collaboration Success Wizard (CSW) (Bietz et al., 2012). The CSW is an evaluative instrument designed to further improve the quality of team reflection following performance (Bietz, 2012). Team members answer a set of

questions before, during, and after their collaboration period, and the CSW generates immediate feedback based on their answers. Currently, the CSW has been implemented within 12 projects (149 individuals), and its validation is still in progress (Bietz, 2012). The CSW, and other such job-aids will be useful in enhancing collaboration effectiveness because they focus not only on one individual team members, but all parties involved (leadership, team members, organization).Thus, our final recommendation is to *provide IRT with job-aids that nurture long-term collaboration*.

## Conclusion & Future Needs

There has recently been an increasing amount of support and interest for the development and training of graduate students to operate within IRT. The increase of the complexity of scientific issues has also contributed to the significance of training the next generation of scientists how to efficiently operate within interdisciplinary teams. Point blank, team training interventions should be implemented within graduate institutions. Because this type of training, in this setting, would be in its purely nascent stage, it is recommended to offer a training to graduate students in such a way that bridges mandatory and voluntary attendance. In other words, the training itself should not be graded or required; however, the institution should stress how crucial it is for graduate students attend. The value of a team training program within graduate institutions is extensive. Teams are everywhere, in organizations, in research, in sport; however, skilled team members are few and far between. Attending a team training program as a graduate student will only increase their placement on the “to hire” list. Currently, interdisciplinary collaboration and training is also lacking amongst the science and engineering fields (Borrego & Newswander, 2008). The lack of collaborative research amongst these scientists may contribute to why, when collaboration does exist, it is not wholly effective. These

researchers are not accustomed to working across domains, and therefore, conflicts arise. Interdisciplinary teams need further training in order to increase their performance, and we suggest the implementation of a team training program. Team training programs offer individuals, teams and organizations significant advantages. These programs are scientifically grounded, and research regarding their positive influence on team performance is exceedingly robust (cf. Salas et al., 2008). The research in support of team training is overwhelmingly present and borrowing and adapting this literature for science teams is a must. Although, work still needs to be done in regards to developing the exact prescription for how to do so, we know enough to begin.

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**References**

Alsop, R. J. (2004). Corporate reputation: anything but superficial–the deep but fragile nature of corporate reputation. *Journal of Business Strategy, 25*(6), 21-29.

Arthur, W., Bennett, W., Edens, P. S., & Bell, S. T. (2003). Effectiveness of training in organizations: A meta-analysis of design and evaluation features. *Journal of Applied psychology, 88*(2), 234-244.

Arthur, W., Bennett, W., Stanush, P.L., & McNelly, L.T. (1998) Factors that influence skill decay and retention: a quantitative review and analysis. *Human Performance, 11*(1), 57-101.

Baldwin, T. T., & Ford, J. (1988). Transfer of training: A review and directions for future research. *Personnel Psychology, 41*(1), 63-105.

Bandow, D. (2001). Time to create sound teamwork. *Journal for Quality and Participation, 24*(2), 41-47.

Bandura, A. (1977). Social learning theory.

Bandura, A. (1997). Self-efficacy: The exercise of control. New York: W.H. Freeman

Beal, D. J., Cohen, R. R., Burke, M. J., & McLendon, C. L. (2003). Cohesion and performance in groups: A meta-analytic clarification of construct relations. *Journal of Applied Psychology, 88*(6), 989-1004.

Bell, S. (2007). Deep-level composition variables as predictors of team performance: A meta-analysis. *Journal of Applied Psychology, 92*(3), 595-615. doi: 10.1037/0021-9010.92.3.595

Bennett, L. M., & Gadlin, H. (2012). Collaboration and team science: from theory to practice. *Journal of investigative medicine: the official publication of the American Federation for Clinical Research, 60*(5), 768.

Bennett, L. M., & Gadlin, H. (in press). Supporting interdisciplinary collaboration: The Role of the institution. In O'Rourke, Crowley, Eigenbrode, and Wulfhorst (Eds.), *Enhancing Communication and Collaboration in Interdisciplinary Research.*

Bennett, L. M., Gadlin, H., & Levine-Finley, S. (2010). *Collaboration & Team Science: A Field Guide.* NIH Office of the Ombudsman, Center for Cooperative Resolution.

Bietz, M.J., Abrams, S., Cooper, D.M., Stevens, K.R., Puga, F., Patel, D., Olson, G.M., & Olson, J.S. (2012). Improving the odds through the Collaboration Success Wizard. *Translational Behavioral Medicine, 2*(4), 480–486.

Blume, B. D., Ford, J. K., Baldwin, T. T. and Huang, J. L. (2010), 'Transfer of training: a meta-analytic review', Journal of Management, 39, 1065–105.

Börner, K., Contractor, N., Falk-Krzesinski, H. J., Fiore, S. M., Hall, K. L., Keyton, J., & Uzzi, B. (2010). A multi-level systems perspective for the science of team science. *Science Translational Medicine, 2*(49), 49cm24.

Borrego, M., & Newswander, L. K. (2008). Characteristics of successful crossdisciplinary engineering education collaborations. *Journal of Engineering Education, 97*(2), 123–134.

Borrego, M., & Newswander, L. K. (2010). Definitions of interdisciplinary research: Toward graduate-level interdisciplinary learning outcomes. The *Review of Higher Education, 34*(1), 61-84.

Bradley, B. H., Postlethwaite, B. E., Klotz, A. C., Hamdani, M. R., & Brown, K.G. (2011). Reaping the benefits of task conflict in teams: The critical role of team psychological safety climate. *Journal of Applied Psychology, 97*(1), 151-158.

Buckingham, M., & Coffman, C. (1999). *First, break all the rules: What the worlds greatest managers do differently*. Simon and Schuster.

Bunderson, J. S., & Sutcliffe, K. M. (2003). Management team learning orientation and business unit performance. *Journal of Applied Psychology, 88*(3), 552-560.

Burke, C. S., Salas, E., Wilson-Donnelly, K., & Priest, H. (2004). How to turn a team of experts into an expert medical team: guidance from the aviation and military communities. *Quality and Safety in Health Care, 13*(suppl 1), i96-i104.

Burke, L.A., & Hutchins, H.M. (2007) Identifying trainers' knowledge of training transfer research findings-closing the gap between research and practice. *International Journal of Training and Development, 11*(4), 236-264.

Campbell, J. P., & Kuncel, N. R. (2001). Individual and team training. In N. Anderson, D. S. Ones, H. Sinangil, & C. Viswes-varan, (Eds.), *Handbook of industrial, work, and organizational psychology: 287*. London, UK: Sage

Cannon-Bowers, J., Salas, E., & Milham, L. M. (2000). The transfer of team training: Propositions and preliminary guidance. *Advances in developing human resources*, 63-74.

Cannon-Bowers, J. A., Tannenbaum, S. I., Salas, E., & Volpe, C. E. (1995). Defining competencies and establishing team training requirements. *Team effectiveness and decision making in organizations, 333*, 380.

Chen, G., Gully, S. M., Whiteman, J. A., & Kilcullen, R. N. (2000). Examination of relationships among trait-like individual differences, state-like individual differences, and learning performance. *Journal of Applied Psychology, 85*(6), 835.

Chiaburu, D. S. & Marinova, S. V. (2005). What predicts skill transfer? An exploratory study of goal orientation, training self-efficacy and organizational supports. *International Journal of Training and Development, 9*, 110–23.

Chiaburu, D. S. & Lindsay, D. R. (2008). Can do or will do? The importance of self-efficacy and instrumentality for training transfer. *Human Resource Development International, 11*, 199–206.

Colquitt, LePine, & Noe, R. A. (2000). Toward an integrative theory of training motivation: A meta-analytic path analysis of 20 years of research. *Journal of applied psychology, 85*(5), 678-707.

Connaughton, S. L., & Daly, J. A. (2004). Identification with leader: A comparison of perceptions of identification among geographically dispersed and co-located teams. *Corporate Communication: An International Journal, 9*(2), 89-103.

Costa, A. C., Roe, R. A., & Taillieu, T. (2001). Trust within teams: The relation with performance effectiveness. *European journal of work and organizational psychology, 10*(3), 225-244.

Cummings, J. N., & Kiesler, S. (2005). Collaborative research across disciplinary and organizational boundaries. *Social Studies of Science, 35*(5), 703-722.

Cummings, J. N., Kiesler, S., Zadeh, R. B., & Balakrishnan, A. D. (2013). Group Heterogeneity Increases the Risks of Large Group Size A Longitudinal Study of Productivity in Research Groups. *Psychological science, 24*(6), 880-890.

Davis, D., O'Brien, M. A. T., Freemantle, N., Wolf, F. M., Mazmanian, P., & Taylor-Vaisey, A. (1999). Impact of formal continuing medical education. *JAMA: the journal of the American Medical Association, 282*(9), 867-874.

De Dreu, C. K., & Weingart, L.R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A meta-analysis. *Journal of Applied Psychology, 88*(4), 741-749.

Deering, S., Rosen, M. A., Ludi, V., Munroe, M., Pocrnich, A., Laky, C., & Napolitano, P. G. (2011). On the front lines of patient safety: implementation and evaluation of team training in Iraq. *Joint Commission Journal on Quality and Patient Safety, 37*(8), 350-1AP.

Delise, L. A., Allen Gorman, C., Brooks, A. M., Rentsch, J. R., & Steele-Johnson, D. (2010). The effects of team training on team outcomes: A meta-analysis. *Performance Improvement Quarterly, 22*(4), 53-80.

Denison, D. R. (1990). *Corporate culture and organizational effectiveness*. John Wiley & Sons.

Driskell, J. E., Goodwin, G. F., Salas, E., & O Shea, P. G. (2006). What makes a good team player? Personality and team effectiveness. *Group dynamics, 10*(4), 249.

Driskell, J. E., Hogan, R., & Salas, E. (1988). Personality and group performance. *Review of Personality and Social Psychology, 14*, 91-112.

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist, 41*(10), 1040-1048.

Eigenbrode, S. D., O'Rourke, M., Wulfhorst, J. D., Althoff, D. M., Goldberg, C. S., Merrill, K., Morse, W., Nielsen-Pincus, M., Stephens, J., Winowiecki, L., & Bosque-Perez, N. A.

(2007). Employing philosophical dialogue in collaborative science. *BioScience, 57*(1), 55-64.

Endsley, M. R., & Garland, D. J. (Eds.). (2000). *Situation awareness analysis and measurement*. CRC Press.

Ericsson, K. A. (2008). Deliberate practice and acquisition of expert performance: a general overview. *Academic Emergency Medicine, 15*(11), 988-994.

Facteau, J. D., Dobbins, G. H., Russell, J. E., Ladd, R. T., & Kudisch, J. D. (1995). The influence of general perceptions of the training environment on pretraining motivation and perceived training transfer. *Journal of Management, 21*(1), 1-25.

Fiore, S. M. (2008). Interdisciplinarity as teamwork how the science of teams can inform team science. *Small Group Research, 39*(3), 251-277.

Fisher, S. L., & Ford, J. K. (1998). Differential effects of learner effort and goal orientation on two learning outcomes. *Personnel Psychology, 51*(2), 397-420.

Ford, K., Eleanor M., S., Weissbein A., D., Gully, M. S., & Salas, E. (1998) Relationships of goal orientation, metacognitive activity, and practice strategies with learning outcomes and transfer. *Journal of applied psychology, 83*(2), 218. doi: 10.1037/0021-9010.83.2.218

Fuqua, J., Stokols, D., Gress, J., Phillips, K., & Harvey, R. (2004). Transdisciplinary collaboration as a basis for enhancing the science and prevention of Substance use and "Abuse". *Substance use & misuse, 39*(10-12), 1457-1514.

Gilpin-Jackson, Y. and Bushe, G. R. (2007). Leadership development training transfer: a case study of post-training determinants. *Journal of Management Development, 26*, 980–1004.

Goldstein, I. L. & Ford, J. K. (2002). *Training in Organizations, 4th ed*. Belmont, CA: Wadsworth Thompson Learning.

Goettl, B. P., Yadrick, R. M.. Comolly-Gomez, C., Regian, W. I., & Shebilske, W. L. (1996). Alternating task modules in isochronal distributed training of complex tasks. *Human Factors, 38*, 330-346.

Gregory, M. E., Feitosa, J., Driskell, T., Salas, E., & Vessey, W. B. (2012). Designing, delivering, and evaluating team training in organizations: Principles that work. In E. Salas, S. I.

Tannenbaum, D. Cohen, & G. Latham (Eds.), Developing and enhancing high-performance teams: Evidence-based practices and advice. San Francisco, CA: Jossey-Bass.

Grossman, R., & Salas, E. (2011). The transfer of training: what really matters. *International Journal Of Training & Development, 15*(2), 103-120. doi:10.1111/j.1468-2419.2011.00373.x

Gully, S. M., Devine, D. J., & Whitney, D. J. (1995). A meta-analysis of cohesion and performance: Effects of levels of analysis and task interdependence. *Small Group Research, 26*(4), 497-520.

Hackman, J. R. & Wageman, R. (2005). A theory of team coaching. *Academy of Management Review, 30*(2), 269-287.

Hall, K. L., Stokols, D., Moser, R. P., Taylor, B. K., Thornquist, M. D., Nebeling, L. C., Ehret. C.C., Barnett, M.J., McTiernan, A., Berger, N.A., Goran, M.I., & Jeffery, R. W. (2008). The collaboration readiness of transdisciplinary research teams and centers: findings from the National Cancer Institute's TREC Year-One evaluation study. *American journal of preventive medicine, 35*(2), S161-S172.

Henriksen, K., Battles, J. B., Keyes, M. A., Grady, M. L., King, H. B., Battles, J., Baker, D.P., Alonso, A., Salas, E., Webster, J., Toomey, L., & Salisbury, M. (2008). TeamSTEPPS: Team strategies and tools to enhance performance and patient safety.

Hoiberg, A., & Berry, N. H. (1978). Expectations and perceptions of Navy life. *Organizational Behavior and Human Performance, 21*(2), 130-145.

Holbrook, J. B. (2013). What is interdisciplinary communication? Reflections on the very idea of disciplinary integration. *Synthese*, 1-15.

Jehn, K. A. (1995). A multimethod examination of the benefits and detriments of intragroup conflict. *Administrative Science Quarterly, 40*(2), 256-282.

Jehn, K. A. (1997). A qualitative analysis of conflict types and dimension in organizational groups. *Administrative Science Quarterly, 42*(3), 530-557.

Jones, B. F., Wuchty, S., & Uzzi, B. (2008). Multi-university research teams: shifting impact, geography, and stratification in science. *Science, 322*(5905), 1259-1262.

Kahn, R. L. and Prager, D. J. (1994). Opinion: interdisciplinary collaborations are a scientific and social imperative. *The Scientist, 8*(14), 12-13.

Katzenbach, J. R., & Smith, D. K. (1992). *The wisdom of teams: Creating the high-performance organization*. Harvard Business Press.

Katz-Navon, T. Y., & Erez, M. (2005). When collective- and self-efficacy affect team performance. *Small Group Research, 36*, 437-465.

Keith, N., & Frese, M. (2008). Effectiveness of error management training: a meta-analysis. *Journal of Applied Psychology, 93*(1), 59.

Klehe, U. C., & Anderson, N. (2007). Working hard and working smart: motivation and ability during typical and maximum performance. *Journal of Applied Psychology, 92*(4), 978.

Kirkpatrick, D. L. (1979). Techniques for evaluating training programs. *Classic writings on instructional technology, 1*, 231-241.

Kessel , Rosenfield, & Anderson. (2008). *Interdisciplinary research [electronic resource]: case studies from health and social science*. Oxford: Oxford University Press. 478

King, H. B., Battles, J., & Baker, D. P. (2008). Team STEPPS: Team Strategies and Tools to Enhance Performance and Patient Safety (Performance and Tools).

Klein, J. T. (2005). The discourse on transdisciplinarity: An expanding global field. In J. T. Klein, W. Grossenbacher-Mansuy, R. Haberli, A. Bill, R. W. Scholz, & M. Welti (Eds.), Transdisciplinarity: Joint problem solving among science, technology, and society—An effective way for managing complexity (pp. 35–44). Basel, Switzerland: Birkhauser Verlag.

Klein, J. T. (2010). Creating interdisciplinary campus cultures: A model for strength and sustainability. San Francisco: Jossey-Bass.

Klein, C., DiazGranados, D., Salas, E., Le, H., Burke, C. S., Lyons, R., & Goodwin, G. F. (2009). Does team building work?. *Small Group Research*,*40*(2), 181-222.

Kozlowski, S. W., & Bell, B. S. (2003). Work groups and teams in organizations. *Handbook of Psychology, Second Edition*.

Kozlowski, S. W., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. *Psychological science in the public interest, 7*(3), 77-124.

Kozlowski, S. W., & Salas, E. (Eds.). (2009). Learning, training, and development in organizations. Taylor & Francis.

Lavin, M. A., Ruebling, I., Banks, R., Block, L., Counte, M., Furman, G., ... & Holt, J. (2001). Interdisciplinary health professional education: a historical review. *Advances in Health Sciences Education, 6*(1), 25-47.

LePine, J. A., Piccolo, R. F., Jackson, C. L., Mathieu, J. E., & Saul, J. R. (2008). A meta-analysis of teamwork processes: Tests of a multidimensional model and relationships with team effectiveness criteria. *Personnel Psychology, 61*(2), 273-307.

Lewis, K. (2004). Knowledge and performance in knowledge-worker teams: A longitudinal study of transactive memory systems. *Management science,50*(11), 1519-1533.

Lewis, K., Lange, D., & Gillis, L. (2005). Transactive memory systems, learning, and learning transfer. *Organization Science, 16*(6), 581-598.

Locke, E.A. and Latham, G.P. (1990). A theory of goal setting and task performance. Englewood Cliffs, NJ: Prentice-Hall.

Locke E.A. and Latham G.P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist, 57*,705–717.

Marks, M. A., Mathieu, J. E., & Zaccaro, S.J. (2001). A temporally based framework and taxonomy of team processes. *Academy of Management Review, 26*(3), 356-376.

Marks, M. A., Sabella, M. J., Burke, C. S., & Zaccaro, S. J. (2002). The impact of cross-training on team effectiveness. *Journal of Applied Psychology*, *87*(1), 3.

Marks, M. A., Zaccaro, S. J. & Mathieu, J. E. (2000). Performance implications of leader briefings and team interaction training for team adaptation to novel environments. *Journal of Applied Psychology*, 85(6), 971–986.

Martocchio, J. J. (1992). Microcomputer usage as an opportunity: The influence of context in employee training. *Personnel Psychology, 45*(3), 529-552.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of applied psychology*, 85(2), 273-283.

Mathieu, J. E., Tannenbaum, S. I., & Salas, E. (1992). Influences of individual and situational characteristics on measures of training effectiveness. Academy of Management Journal, 35(4), 828-847.

Mayer, C. M., Cluff, L., Lin, W. T., Willis, T. S., Stafford, R. E., Williams, C., Saunders, R., Short, K.A., Lenfestey, N., Kane, H.L., & Amoozegar, J. B. (2011). Evaluating efforts to optimize TeamSTEPPS implementation in surgical and pediatric intensive care units. *Joint Commission Journal on Quality and Patient Safety, 37*(8), 365-3AP.

Morgan, G. D., Kobus, K., Gerlach, K. K., Neighbors, C., Lerman, C., Abrams, D. B., & Rimer, B. K. (2003). Facilitating transdisciplinary research: the experience of the transdisciplinary tobacco use research centers. *Nicotine & Tobacco Research, 5*(Suppl 1), S11-S19.

Morgeson, F. P., DeRue, D. S., Karam, E. P. (2010). Leadership in Teams: A Functional Approach to Understanding Leadership Structures and Processes. *Journal of Management, 36*(1), 5-39.

Morse, W., Nielson-Pincus, M., Force, J., & Wulfhorst, J. 2007. Bridges and barriers to developing and conducting interdisciplinary graduate-student team research. *Ecology and Society, 12*(2), 8.

Nash, J. M. (2008). Transdisciplinary Training. *American journal of preventive medicine, 35*(2), S133.

Nash, J. M., Collins, B. N., Loughlin, S. E., Solbrig, M., Harvey, R., Krishnan-Sarin, S., ... & Spirito, A. (2003). Training the transdisciplinary scientist: A general framework applied to tobacco use behavior. *Nicotine & tobacco research, 5*(Suppl 1), S41-S53.

Neuman, G. A., & Wright, J. (1999). Team effectiveness: beyond skills and cognitive ability. *Journal of Applied Psychology*, 84(3), 376.

NIH. National Institutes of Health. (2006). NIH roadmap for medical research. Bethesda, MD: Author.

Noe, R. A., & Wilk, S. L. (1993). Investigation of the factors that influence employees' participation in development activities. *Journal of applied psychology*, 78(2), 291.

NSF. National Science Foundation. (2006). National Science Foundation investing in America's future strategic plan FY 2006–2011 (No. NSF 06-48). Arlington,VA: Author.

Olson, G. M., & Olson, J. S. (2000). Distance matters. *Human-computer interaction, 15*(2), 139-178.

Pellmar, T. C., & Eisenberg, L. (Eds.). (2000). *Bridging disciplines in the brain, behavioral, and clinical sciences*. National Academies Press.

Phan, H. (2011). Interrelations between self-efficacy and learning approaches: a developmental approach. *Educational Psychology, 31*(2), 225-246.

Phillips, J. M., & Gully, S. M. (1997). Role of goal orientation, ability, need for achievement, and locus of control in the self-efficacy and goal--setting process. *Journal of Applied Psychology*, 82(5), 792.

Pickett, S. T. A., Burch Jr, W. R., & Grove, J. M. (1999). Interdisciplinary research: maintaining the constructive impulse in a culture of criticism. *Ecosystems, 2*(4), 302-307.

Propositions and preliminary guidance. *Advances in developing human resources*, 63-74.

Quiñones, M. A. (1995). Pretraining context effects: Training assignment as feedback. *Journal of applied psychology*, 80(2), 226.

Quiñones, M. A. (1997). Contextual influences on training effectiveness. Training for a rapidly changing workplace: *Applications of psychological research*, 177-199.

Rico, R., Sánchez-Manazanares, M., Gil, F. & Gibson, C. (2008). Team implicit coordination processes: A team knowledge-based approach. *Academy of Management Review, 33*(1), 163-184.

Romero, D., Galeano, N., & Molina, A. (2009). Mechanisms for assessing and enhancing organisations' readiness for collaboration in collaborative networks. *International Journal of Production Research, 47*(17), 4691-4710.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary educational psychology, 25*(1), 54-67.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist, 55*(1), 68-78.

Saavedra, R., Earley, P., & Van Dyne, L. (1993). Complex interdependence in task-performing groups. *Journal Of Applied Psychology*, 78(1), 61-72. doi:10.1037/0021-9010.78.1.61

Salas, E., Burgess, K. A., & Cannon-Bowers, J. A. (1995). Training effectiveness techniques. Research techniques in human engineering, 439-471.

Salas, E., Burke, C. S., Bowers, C. A., & Wilson, K. A. (2001). Team training in the skies: does crew resource management (CRM) training work? Human Factors: The Journal of the Human Factors and Ergonomics Society, 43(4), 641-674.

Salas, E., Burke, C. S., & Cannon-Bowers, J. A. (2002). What we know about designing and delivering team training: tips and guidelines. Creating, implementing, and managing effective training and development: State-of-the-art lessons for practice, 234-261.

Salas, E., & Cannon-Bowers, J. A. (1997). Methods, tools, and strategies for team training.

Salas, E. & Cannon-Bowers, J.A. (2000). The anatomy of team training. In S. Tobias & J.D. Fletcher (Eds.), Training & retraining: A handbook for business, industry, government, and the military (pp. 312-335). New York: Macmillan.

Salas, E., & Cannon-Bowers, J. A. (2001). The science of training: A decade of progress. *Annual review of psychology, 52*(1), 471-499.

Salas, E., DiazGranados, D., Klein, C., Burke, C. S., Stagl, K. C., Goodwin, G. F., & Halpin, S. M. (2008). Does team training improve team performance? A meta-analysis. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50*(6), 903-933.

Salas, E., DiazGranados, D., Weaver, S. J., & King, H. (2008). Does team training work? Principles for health care. Academic Emergency Medicine, 15(11), 1002-1009.

Salas, E., Dickinson, T. L., Converse, S. A., & Tannenbaum, S. I. (1992). Toward an understanding of team performance and training.

Salas, E., Prince, C., Baker, D. P., & Shrestha, L. (1995). Situation awareness in team performance: Implications for measurement and training. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 37*(1), 123-136.

Salas, E., Rosen M., Burke, S., & Goodwin, G. (2008). The wisdom of collectives in organizations: An update of the teamwork competencies. In E. Salas, M. A. Rosen, S. C. Burke, G. F. Gooodwin (Eds.), Team effectiveness in complex organizations: cross-disciplinary perspectives and approaches (39-82). New York, NY: Psychology Press.

Salas, E., Rozell, D., Mullen, B., & Driskell, J. E. (1999). The Effect of Team Building on Performance An Integration. *Small Group Research, 30*(3), 309-329.

Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a "Big Five" in Teamwork? *Small Group Research, 36*(5), 555-599.

Salas, E. & Stagl, K. C. ( Eds.). (2009). Design training systematically and follow the science of training. in E. Locke *Handbook of Principles of Organizational Behavior: Indispensible Knowledge for Evidence-Based Management, 2nd ed.* Chichester: John Wiley & Sons, 59–84.

Salas, E., Wilson, K. A., Priest, H. A., & Guthrie, J. W. (2006). Design, delivery, and evaluation of training systems. *Handbook of Human Factors and Ergonomics, Third Edition*, 472-512.

Salas, E., Tannenbaum, S. I., Kraiger, K., & Smith-Jentsch, K. A. (2012). The science of training and development in organizations: What matters in practice. *Psychological Science in the Public Interest, 13,* 74-101.

Satish, U. & Streufert, S. (2002). Value of a cognitive simulation in medicine: Towards optimizing decision making performance of healthcare personnel. *Quality and Safety in Health Care, 11*, 163- 167.

Shuffler, M. L., DiazGranados, D., & Salas, E. (2011). There's a science for that: team development interventions in organizations. *Current Directions in Psychological Science, 20*(6), 365-372.

Shuffler, M. L., Pavlas, D., & Salas, E. (2012). Teams in the military: A review and emerging challenges. In J. H. Laurence, M. D. Matthews (Eds.), *The Oxford handbook of military*

*psychology*(pp. 282-310). New York, NY US: Oxford University Press. doi:10.1093/oxfordhb/9780195399325.013.0106

Shute, V. J., & Gawlick, L. A. (1995). Practice effects on skill acquisition, learning outcome, retention, and sensitivity to relearning. *Human Factors, 37*, 781-803.

Sims, D. E., Burke, C. S., Metcalf, D. S., & Salas, E. (2008). Research-based guidelines for designing blended learning. *Ergonomics in Design: The Quarterly of Human Factors Applications, 16*(1), 23-29.

Sitzmann, T., Bell, B. S., Kraiger, K., & Kanar, A. M. (2009). A multilevel analysis of the effect of prompting self-regulation in technology-delivered instruction. *Personnel Psychology, 62*(4), 697-734.

Smith-Jentsch, K. A., Cannon-Bowers, J. A., Tannenbaum, S. I., & Salas, E. (2008). Guided team self-correction impacts on team mental models, processes, and effectiveness. Small Group Research, 39(3), 303-327.

Smith-Jentsch, K.. Salas, E., and Baker, D. P. (1996b). Training team performance-related assertiveness. *Personnel Psychology, 49*, 909-936.

Smith-Jentsch, K. A., Salas, E., & Brannick, M. T. (2001). To transfer or not to transfer? Investigating the combined effects of trainee characteristics, team leader support, and team climate. Journal of Applied Psychology, 86(2), 279.

Smith-Jentsch, K. A., Zeisig, R. L., Acton, B., & McPherson, J. A. (1998). Team dimensional training: A strategy for guided team self-correction.

Sorcher, M., & Goldstein, A. P. (1972). A behavior modeling approach in training. *Personnel Administration, 35*(2), 35-41.

Stewart, G. L. (2006). A meta-analytic review of relationships between team design features and team performance. *Journal of Management, 32*(1), 29-55.

Stokols, D. (2006). Toward a science of transdisciplinary action research. American journal of community psychology, 38(1-2), 63-77.

Stokols, D. (2014). Training the next generation of transdisciplinarians. Enhancing Communication & Collaboration in Interdisciplinary Research. O'Rourke, M., Crowley, S., Eigenbrode, SD and Wulfhorst, JD London, Sage Publications..

Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., Unger, J., Palmer, P., Clark, M.A., Colby, S.M., Morgan, G., & Trochim, W. (2003). Evaluating transdisciplinary science. *Nicotine & Tobacco Research, 5*(Suppl 1), S21-S39.

Stokols, D., Misra, S., Moser, R. P., Hall, K. L., & Taylor, B. K. (2008). The ecology of team science: understanding contextual influences on transdisciplinary collaboration. *American journal of preventive medicine, 35*(2).

Stout, R. J., Salas, E., & Fowlkes, J. E. (1997). Enhancing teamwork in complex environments through team training. *Group Dynamics: Theory, research, and practice, 1*(2), 169.

Tai, W. (2006) Effects of training framing, general self-efficacy and training motivation on trainees' training effectiveness. *Personnel Review, 35*(1), 51-65.

Tannenbaum, S. I., Beard, R. L., McNall, L. A., & Salas, E. (2010). Informal learning and development in organizations. Learning, training, and development in organizations, 303-332.

Tannenbaum, S. I., & Cerasoli, C. P. (2013). Do team and individual debriefs enhance performance? A meta-analysis. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 55*(1), 231-245.

Tannenbaum, S., Mathieu, J., Salas, E., Cannon-Bowers, J. (1991). Meeting trainees' expectations: The influence of training fulfillment on the development of commitment, self-efficacy, and motivation. Journal of Applied Psychology, 76, 759-769.

Tannenbaum, S. I., Salas, E., & Cannon-Bowers, J. A. (1996). Promoting team effectiveness. *Handbook of work group psychology*, 503-529.

Tannenbaum, S. I., Smith-Jentsch, K. A., & Behson, S. J. (1998). Training team leaders to facilitate team learning and performance.

Tannenbaum, S. I., & Yukl, G. (1992). Training and development in work organizations. Annual review of psychology, 43(1), 399-441

Taylor, P. J., Russ-Eft, D. F., & Chan, D. W. (2005). A meta-analytic review of behavior modeling training. *Journal of applied psychology*, *90*(4), 692.

Towler, A.J., & Dipboye, R.L. (2001) Effects of trainer expressiveness, organization, and trainee goal orientation on training outcomes. *Journal of Applied Psychology, 86*(4), 664-673.

Tziner, A., Fisher, M., Senior, T. and Weisberg, J. (2007). Effects of trainee characteristics on training effectiveness. *International Journal of Selection & Assessment, 15*(2), 167–74.

Vance, D., Dawson, J., Wadley, V., Edwards, J., Roenker, D., Rizzo, M., & Ball, K. (2007). The accelerate study: The longitudinal effect of speed of processing training on cognitive performance of older adults. *Rehabilitation Psychology, 52*(1), 89.

Velada, R., Caetano, A., Michel, J.W., Lyons, B.D., Kavanagh, M.J. (2007) The effects of training design, individual characteristics and work environment on transfer of training. *International Journal of Training and Development, 11*(4), 282-294.

Vick, K. (2008). Team-building or torture? Court will decide. Washington Post. Available from www.washingtonpost.com

Vogel, A. Feng, A., Oh, A., Hall, K.L., Stipelman, B.A., Stokols, D., Okamoto, J., Perna, F.M., Moser, R., and Nebeling, L. (2012). Influence of a National Cancer Institute transdisciplinary research and training initiative on trainees' transdisciplinary research competencies and scholarly productivity. *Translational Behavioral Medicine, 2*(4), 459-468.

Weaver, S. J., Rosen, M. A., Salas, E., Baum, K. D., & King, H. B. (2010). Integrating the science of team training: guidelines for continuing education. *Journal of Continuing Education in the Health Professions, 30*(4), 208-220.

Webster, J. S., King, H. B., Toomey, L. M., Salisbury, M. L., Powell, S. M., Craft, B., ... & Salas, E. (2008). Understanding quality and safety problems in the ambulatory environment: seeking improvement with promising teamwork tools and strategies. *Rockville, MD: Agency for Healthcare Research and Quality*.

Wiener, E. L., Kanki, B. G., & Helmreich, R. L. (Eds.). (1993). Cockpit resource management. Access Online via Elsevier.

Zaccaro, S. J., Blair, V., Peterson, C., & Zazanis, M. (1995). Collective efficacy Self-efficacy, adaptation, and adjustment: Theory, research, and application (pp. 305-328). New York, NY, US: Plenum Press.

Zaccaro, S. J., Rittman, A. L., & Marks M. A. (2001). Team leadership. *Leadership Quarterly, 12*(4), 451-483.

**Table 1 Teamwork Competencies.**

| Category | Competency | Definition | Sources |
|---|---|---|---|
| **Behavior Competencies** | | | |
| | Communication | A shared process of sending and receiving information between team members which enforces the team's attitudes, behaviors and cognitions | Connaughton & Daly, 2004; LePine, et al., 2008 |
| | Coordination | Utilizing behavioral and cognitive processes to execute a task and transform team resources into outcomes | Marks, et al., 2001; Rico, et al., 2008; Stewart, 2006 |
| | Conflict | The perceived discrepancies in beliefs, views, or interests of one or more team members | Bradley, et al., 2011; DeDreu & Weingart, 2003; Jehn, 1995, 1997 |
| | Leadership (coaching) | Providing guidance to the team and acting as a leader; establishing goals and a pathway to team success | Hackman & Wageman, 2005; Morgeson, et al., 2010; Zaccaro, et al., 2001 |
| **Attitude Competencies** | | | |
| | Trust | Shared belief that all team members will be beneficial to the team and perform as required by their responsibilities | Bandow, 2001; Salas, Sims, & Burke, 2005 |
| | Collective Efficacy | Certainty that the team displays the ability to achieve its goals and accomplish its tasks. | Katz-Navon & Erez, 2005; Zaccaro, Blair, Peterson, & Zazanis, 1995 |
| | Psychological safety | Shared belief of security within the team which allows for interpersonal risk-taking. | Edmonson, 1999 |
| | Cohesion | Collective dedication and commitment for the team, its goals, and tasks. | Beal, Cohen, Burke & McLendon,2003; Gully, Devine, & Whitney, 1995 |
| | Team learning orientation | The degree to which team goals are driven by learning. | Bunderson & Sutcliffe, 2003 |
| | | | |

| **Cognition Competencies** | | | |
|---|---|---|---|
| | Team Mental Models | A shared understanding of the team task and applicable knowledge that each team member can contribute | Marks, Zaccaro & Mathieu, 2000 |
| | Transactive Memory Systems | A joint system for processing, storing, and recalling information where each team members is responsible for a part of the total amount of information | Lewis, 2004; Lewis, Lange & Gillis, 2005 |
| | Situation Awareness | The acuity of surrounding elements in regards to time and/or space, the understanding of their meaning, and the projection of their status following a change in something else (e.g. time, predetermined event) | Endsley & Garland, 2000; Salas, Prince, Baker, Shrestha, 1995 |

**Table 2 Teamwork Processes for Interdisciplinary Research Teams.**

| Skill | Behavioral Markers | Potential Team Training Strategy |
|---|---|---|
| Communication (Marks, Mathieu, & Zaccaro, 2001) | • Sharing of information<br>• Use of information protocols<br>• Quality of communication<br>• Quantity of information | Guided team self-correction (Smith-Jentsch, Cannon-Bowers, Tannenbaum, & Salas, 2008) |
| Leadership (Salas, Sims, & Klein, 2004) | • Clarify team member roles and responsibilities<br>• Engage team in regular meetings<br>• Motivate team members<br>• Synchronize individual task work<br>• Provide situation updates<br>• Self-correct | Guided team self-correction (Smith-Jentsch, Cannon-Bowers, Tannenbaum, & Salas, 2008); Team-leader training (Tannenbaum, Smith-Jentsch, & Behson, 1998) |
| Interpersonal relationship development in the book, p. 99 | • Share information amongst team members<br>• Admit mistakes and accept feedback<br>• Establish rapport with team members | Team building (Klein, 2009) |
| Goal specification (Marks, Mathieu, & Zaccaro, 2001) | • Identify team's goals and performance objectives<br>• Prioritize goals and sub-goals | Team building (Klein, 2009); Team-leader training (Tannenbaum, Smith-Jentsch, & Behson, 1998) |
| Monitoring progress towards goals (Marks, Mathieu, & Zaccaro, 2001) | • Track progress toward team goals and tasks<br>• State what needs to be done for goal attainment<br>• Share progress with all team members | Team huddle (Webster et al., 2008) |
| Team monitoring (Marks, Mathieu, & Zaccaro, 2001) | • Provide backup behavior<br>• Anticipate team member's needs<br>• Understand team member's roles and responsibilities<br>• Shift workload during high periods of stress or workload | Guided team self-correction (Smith-Jentsch, Cannon-Bowers, Tannenbaum, & Salas, 2008) |
| Conflict management (Marks, Mathieu, & Zaccaro, 2001) | • Before conflict occurs, establish conditions amongst the team which prevent, control, or guide team conflict<br>• Work through task and | Team debriefs (Tannenbaum & Cerasoli, 2013); Team building (Klein, 2009) |

| | | |
|---|---|---|
| | interpersonal disagreements | |
| Adaptability (Salas, Sims, & Klein, 2004) | • Anticipate team member actions<br>• Alter course of action if needed<br>• Integrate new team members | Cross-training (Marks, Sabella, Burke, & Zaccaro, 2002) |
| Shared mental models (Salas, Sims, & Klein, 2004) | • Coordinate without overtly communicating<br>• Anticipate other team members | Guided team self-correction (Smith-Jentsch, Cannon-Bowers, Tannenbaum, & Salas, 2008); Cross-training (Marks, Sabella, Burke, & Zaccaro, 2002) |
| Team/ collective orientation (Salas, Sims, & Klein, 2004) | • Ensure teamwork is valued<br>• Ensure a strong collective efficacy | Cross-training (Marks, Sabella, Burke, & Zaccaro, 2002) |

**Table 3 Team Training Principles and Tips.**

| **1. Conduct a Team Needs Analysis*** |
|---|
| *Tips:*<br>• Obtain buy-in from trainees and supervisors first<br>• Conduct an organizational, team task, and person analysis<br>• Think of the team as one unit when determining necessary KSAs |
| **2. Consider the Characteristics of the Trainees*** |
| *Tips:*<br>• Assess trainees' skill level<br>• Consider personality and other individual characteristics<br>• Design program to enhance self-efficacy<br>• Style training to cater towards trainees' goal-orientation |
| **3. Create a Team Training Environment Conducive to Training Goals** |
| *Tips:*<br>• Involve trainees in the decision-making process to attend training<br>• Present training as an opportunity for advancement |
| **4. Create a Supportive Learning Environment** |
| *Tips:*<br>• Stress the value of the training to trainees<br>• Set distal and proximal goals for the training program with trainees<br>• Make sure the goals are specific and challenging<br>• Offer incentives for active participation during training and for training transfer |
| **5. Create Teamwork Conditions that Support Transfer of Team Training*** |
| *Tips:*<br>• Develop organizational policies and procedures on team performance<br>• Ensure trainees' motivation to transfer is high<br>• Implement training near the time trainees will need the trained skills<br>• Do not provide training for infrequently used or unnecessary KSAs |
| **6. Develop Content of Team Training*** |
| *Tips:*<br>• Build training content from the critical KSAs determined from the team needs analysis<br>• Draw content from empirically-supported teamwork competencies |

**7. Utilize Appropriate Information Delivery Methods**

*Tips:*

- Utilize more than one delivery method
- Information-based methods are more helpful for displaying declarative knowledge; demonstration-based for procedural; practice-based for conceptual
- Demonstrate positive and negative examples when using a demonstration-based approach

**8. Team Development Tools***

*Tips:*

- Utilize evidence-based team development aids
- Provide feedback throughout training
- Feedback should be clear, concise, and constructive
- Foster the use of debriefs on the job
- Train leaders to be successful coaches

**9. Evaluate Team Training**

*Tips:*

- Measure reactions, learning, behavior, and results
- Record team level and individual data
- Assess performance during multiple time periods

**10. Promote Transfer of Team Training***

*Tips:*

- Provide opportunities to use teamwork skills on the job
- Continue to stress the importance of the trained concepts
- Encourage networking amongst employees
- If needed, offer refresher training

*Although we recommend the use of all identified principles, these principles, at the discretion of the authors, are most relevant for science teams producing knowledge.

**Table 4 Implications and Considerations for Interdisciplinary Research Teams.**

| Principle | Implications for IRT | Considerations for IRT |
|---|---|---|
| **1. Conduct a Team Needs Analysis** | • Determines KSAs necessary for successful interdisciplinary teams | • Lack of experience within interdisciplinary teams amongst team members |
| **2. Consider the Characteristics of the Trainees** | • Enables the exchange of ideas between team members and encourages the development of interpersonal relationships<br>• Ensures all team members are aware of each other's talents | • Team members possess a high skill ability in their discipline and little to none in others<br>• Contrasting interpersonal styles |
| **3. Create a Team Training Environment Conducive to Training Goals** | • Involves trainees in the attendance process<br>• Identifies value of training | • Senior scientists may feel training is unnecessary |
| **4. Create a Supportive Learning Environment** | • Increases collaboration readiness within an organization | • Many organizations lack collaboration readiness<br>• Lack of shared vision about high-priority goals |
| **5. Create Teamwork Conditions that Support Transfer of Team Training** | • Increases motivation to lean and understand the language, information, and research methodology within the other disciplines | • Lack of motivation to collaborate across disciplines<br>• Lack of trust<br>• Negative feelings toward interdisciplinary research |
| **6. Develop Content of Training** | • Enhances teamwork within team | • Inaccurate information from the team needs analysis due to inexperience<br>• Teamwork competencies have yet to be tested within interdisciplinary teams |

| | | |
|---|---|---|
| **7. Utilize Appropriate Information Delivery Methods** | • Ensures proper delivery method for information regardless of team distribution | • Lack of examples for interdisciplinary teams<br>• Certain delivery methods may be inconvenient for all teams if geographically dispersed |
| **8. Team Development Tools** | • Enhances collaboration throughout the duration of the project<br>• Provides leaders with proper coaching training | • Teams tend to rehash to individual thinking and reduce their collaboration mid-way<br>• Lack of leadership structure<br>• Lack of collaborative skills and management experience among leaders |
| **9. Evaluate Team Training** | • Identifies whether the trained teamwork concepts were accurate for interdisciplinary teams | • Organization issues amongst distributive teams |
| **10. Promote Transfer of Team Training** | • Will advance the current level of proficiency and performance within interdisciplinary teams | • Interdisciplinary teams likely don't meet regularly<br>• Time lags between team tasks |