Journal of Clinical and Translational Science

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Education Special Communication

Cite this article: Schwarz RM and Bennett LM. Team effectiveness model for science (TEMS): Using a mutual learning shared mindset to design, develop, and sustain science teams. *Journal of Clinical and Translational Science* **5**: e157, 1–6. doi: 10.1017/cts.2021.824

Received: 13 February 2021
Revised: 9 July 2021
Accepted: 13 July 2021

Keywords:
Team science; mutual learning; team effectiveness model for science (TEMS); shared mindset; norms; values; assumptions

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Team effectiveness model for science (TEMS): Using a mutual learning shared mindset to design, develop, and sustain science teams

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Abstract

In this paper, we introduce the Team Effectiveness Model for Science (TEMS) and describe a multiphase set of interventions for forming a new team or developing an existing team. TEMS uses a shared mutual learning mindset as the model's central and guiding element. It shows how team mindset leads to behavior and to results and how this affects the characteristics of effective team functioning. TEMS addresses two related questions: *What are the variables that contribute to effective teams?* and *How do the variables need to be designed to make their relevant contributions?* Team models often answer the first question without fully answering the second. By addressing three gaps, TEMS contributes to enhancing science team effectiveness. Gap 1 is the absence of explicit core values, assumptions, and norms that serve as the foundation for developing and maintaining science team effectiveness. Gap 2 is the absence of a process for integrating the science and relationship aspects of a science team. Gap 3 is the absence of team processes and structures that are derived from the team's values, assumptions, and norms. Using TEMS to design new or intervene with existing teams focuses on shifting mindset, developing behavioral skills, and designing processes and structures congruent with the new mindset.

Introduction

The nature of scientific problems that researchers are addressing increasingly requires assembling scientists with diverse backgrounds and employing cross-disciplinary approaches to innovatively answer them [1, 2]. Many researchers in the Science of Team Science community have identified salient characteristics that facilitate and/or hinder science team effectiveness [3–5].

In this paper, we introduce the Team Effectiveness Model for Science (TEMS). TEMS is a normative model that integrates each of our separate works [5–8]. The TEMS uses the mutual learning (ML) shared mindset as the model's central and guiding element. It shows how team mindset leads to behavior and to results and how this affects the characteristics of effective team functioning.

At its essence, TEMS seeks to answer two related questions: (1) what are the variables that contribute to effective teams? and (2) how do each of these variables need to be designed to ensure that each one makes its relevant contribution? Team models often answer the first question without fully answering the second question. Consequently, teams that rely on such models may understand *what* they need to create, such as a shared vision, mutual trust, or strategies to effectively manage conflict, but do not learn *how*. For example, managing scientific as well as relationship conflict productively is a key variable in team effectiveness, and a model needs to make explicit the specific values, assumptions, and behaviors that constitute the process for achieving the desired results [5, 7].

By answering these two questions, the TEMS model addresses three gaps in the research on science teams in a way that enhance science team effectiveness, including productivity. Gap 1 is the absence of an explicit set of core values, assumptions, and specific norms derived from the values and assumptions that serve as the foundation for developing and maintaining science team effectiveness. Gap 2 is the absence of a process for integrating the science and relationship aspects of a science team. Gap 3 is the absence of team processes and structures that are derived from the team's values, assumptions, and norms. Gaps 2 and 3 are often result from Gap 1.

Gap 1: The Absence of an Explicit Set of Core Values and Assumptions, and Specific Norms Derived from the Values and Assumptions, for Developing and Maintaining Science Team Effectiveness

Effective teams operate from a shared mindset: a set of core values and assumptions that team members hold and that guide their behavior [6, 7]. Research has identified the value of shared cognitive constructs [9] and identified values, attitudes, beliefs, habits of mind such as open-mindedness, curiosity, self-reflectiveness, and non-defensiveness [10, 11] that are central to team effectiveness.

Missing is a coherent set of shared values and assumptions that frame how members think about themselves and others when they are engaged in the conduct of science or intrapersonal reflection with or about others and that serve as a team operating system, ensuring that all team functioning is congruent with this mindset. This includes an explicit set of behaviors that are derived from the values and assumptions that: (1) serve as team norms; (2) produce effective behavior under challenging conditions; (3) are specific enough to answer the central question *"Exactly what do I say and/or do in this situation"*; and (4) can be reliably measured.

Addressing Gap 1

Mutual learning and unilateral control

The TEMS addresses this gap through the ML approach. ML comprises a set of core values and assumptions (what we refer to as mindset) and a set of specific behaviors derived from them that, together, cultivate effective human working relationships (Table 1) [6, 7]. ML is a way of thinking and acting that enables learning with and from others, particularly in challenging situations such as scientific disagreement or difficult interpersonal discussions. The ML core values are used with the behaviors to inherently take full advantage of differences and to create integrative solutions. This is the essence of team science.

The unilateral control (UC) approach is the contrast of ML (Table 1). UC is rooted in trying to control the outcomes of interactions with others. Under conditions of UC, little learning can occur with and from others because people approach interactions with the mindset "I understand, if you disagree, you don't. I'm right, if you disagree, you're wrong. I will win." This mindset is extremely common when stakes are high, people have strong and different views, and feel threatened in some way. UC makes it difficult for scientists to jointly and productively reflect on their differences and develop integrative solutions that increase team effectiveness. ML addresses this core challenge. Both models are based on the work of Argyris and Schön [11–13] and further developed by Argyris and others [6, 7, 14–16].

Espoused mindset and mindset-in-use

In considering whether and how shared mindset contributes to team effectiveness, it is essential to distinguish between mindset-in-use and espoused mindset [11–13]. Mindset-in-use is the set of core shared core values and assumptions that actually guides a team's thinking, language and behavior, and design. Espoused mindset is the set of values and assumptions the team espouses, which may or may not match the mindset-in-use [11–13]. It is common for teams to espouse a ML mindset and have a UC mindset-in-use, especially under challenging conditions.

We think of a team's mindset-in-use as its shared operating system and the basis for designing and running the applications it needs to accomplish its work including the science and relationship norms, processes, and structures. By definition, a team can only design and, in keeping with the analogy, "run applications" that are compatible with its operating system; in practitioner parlance, *how we think is how we lead.* For example, imagine that a team espouses the value of curiosity, but when anyone speaks up during team meetings and questions results or interpretations, they are told they "Are wrong" or "Don't get it." Here, the espoused value is incongruent with the value-in-use and the behaviors that follow from it. However, when the reaction to questioning results or interpretations is one of curiosity, a desire to understand what leads the person to see it differently and belief that the person has pure motives in raising the topic, then the espoused value, the values-in-use, and the behaviors are congruent.

In general, individuals and teams are unaware of their mindset-in-use, the gaps between it and their espoused mindset, and its effects. That is, until they learn to observe and analyze them. Given that behavior is derived from mindset-in-use, the lack of self-awareness and congruence leads teams to behave in ways that reduce their effectiveness, while not understanding how they are contributing to the reduced effectiveness.

In the TEMS, the team explicitly agrees to use the ML mindset to guide its work together including in establishing the values and assumptions for the conduct of the team science and for building and sustaining the team relationships. This is in contrast to many team cultures which often develop through a combination of implicit and explicit processes.

Mutual learning norms

Team norms are expectations that team members have for each other about how they should act. In the TEMS, the team agrees to use the eight ML behaviors as team norms (see Table 1; see [6, 7] for a more extensive descriptions of the ML behaviors), which put the ML values and assumptions into action.

Because the behaviors are universal, they apply regardless of whether the team is engaged in discussing scientific results, interpretation of data, and what conclusions can be drawn, or whether the team is managing conflict about sharing credit, who should present at the international meeting, or not meeting expectations. Neither the content of a conversation nor the relative authority and technical expertise of members affect how ML is used. The norms increase the team's ability to solve problems, make decisions, and manage conflict, rather than providing procedural guidance (e.g., start on time and end on time). The team norms are specific enough to enable team members to reliably assess whether they are being used, or not. This differs from team relationship norms such as "treat others with respect," which are often a mix of values and behaviors, and where the meaning of "respect" may differ among members.

Finally, the mindset and eight behaviors are designed to be self-correcting. By being transparent and curious, and by sharing all relevant information, explaining reasoning and intent, testing assumptions, and focusing on interests, doing all of these jointly, a team increases the probability of detecting and correcting deficiencies in its own effectiveness.

Gap 2: The Absence of a Process for Integrating the Science and Relationship Aspects of a Science Team

The research literature explores how team functioning can increase integrative capacity that improves scientific productivity [4]. The methods recommended for collaboration often involve developing a set of agreements regarding numerous issues but without a meta-level set of values and assumptions to ensure that these collaborative solutions are internally consistent and guided by some more foundational agreed upon principles [5, 8, 17].

We use the term team science mindset and norms to refer to the set of values and assumptions that guide the team's conduct of scientific work and the behavioral expectations regarding that work. Similarly, we use the term team relationship mindset and norms to refer to the set of values and assumptions that guide the team's

https://doi.org/10.1017/cts.2021.824 Published online by Cambridge University Press

Table 1. *Mutual learning and unilateral control mindsets and norms [25]*

	Mutual learning	Unilateral control
Mindset		
Values	Transparency	Win, don't lose
	Curiosity	Be right
	Informed choice	Minimize expressions of negative feelings
	Accountability	Act rational
	Compassion	
Assumptions	I have information; so do other people	I understand the situation; those who disagree don't
	Each of us see things others don't	I am right; those who disagree are wrong
	People may disagree with me and still have pure motives	I have pure motives; those who disagree have questionable motives
	Differences are opportunities for learning	My feelings and behavior are justified
	I may be contributing to the problem	I am not contributing to the problem
Norms (Behaviors)	State views and ask genuine questions	State my views without asking for other others' views and vice versa
	Share all relevant information	Withhold relevant information
	Use specific examples and agree on what important words mean	Speak in general terms and don't agree on what important words mean
	Explain reasoning and intent	Keep my reasoning private; don't ask others about their reasoning
	Focus on interests, not positions	Focus on positions, not interests
	Test assumptions and inferences	Act on untested assumptions and inferences as if they were true
	Jointly design next steps	Control the conversation
	Discuss undiscussable issues	Avoid, ease into, or save face on difficult issues

relationships and the behavioral expectations regarding the building and sustaining of those relationships.

Addressing Gap 2

The TEMS addresses Gap 2 in three ways. First, it defines three interrelated facets of team results: scientific productivity, working relationships, and individual well-being, with each comprising a number of elements (see Table 2). While the purpose of research teams is to solve a complex problem, the TEMS holds that a team's scientific productivity cannot be sustainable without creating and maintaining effective working relationships and well-being [18]. Second, the TEMS explicitly states that for a team to achieve and maintain all three results, it needs to pay continual attention to each.

Third, by having agreed to treat the ML mindset as the team's operating system and the eight behaviors as norms derived from the mindset, the team is well prepared to develop mindsets and norms for the science and relationship aspects that are congruent with, and more contextually specific than, those of ML and that contribute to each of the three results.

This component of the TEMS model cannot be over emphasized. It represents the step where science teams use their ML values, assumptions, and norms to articulate their science and relationship values and assumptions as well as design the norms that derive from them. Essentially, ML provides the fundamental framework of values and assumptions, which, together with the science and relationship values and assumptions, define *what* kind of culture the team wants to create. Similarly, ML provides the fundamental norms that together with the more focused science and relationship norms, identify *how* to create the culture.

Integrating science and relationships involves using ML to managing differences within and between them [17]. It also facilitates integration both within and between the epistemic and social modes of a team [19]. Together, these include the values and norms, the use of language and communication competence, and create shared meaning, which have been identified as central for integration. Adapting Repko and Szostak [20], we define integration as a process by which different values and assumptions, norms, processes and structures, data, tools, methods, and/or theories are synthesized, connected, and/or blended.

Gap 3: Absence of Team Processes and Structures That Emanate from the Team's Values, Assumptions, and Norms as the Building Blocks

Many team models identify processes and structures that are necessary for team effectiveness. These often include processes for problem-solving, decision-making and conflict management and structures for allocating roles and accountability. Missing from this topic is the premise that "*how we think is how we design.*" Just as our behavior is a function of our mindset-in-use, so are the team structures and processes they design [21]. Winston Churchill's statement, "We shape our buildings, and afterwards our buildings shape us," holds true for teams [22]. Awareness of the values and assumptions that teams embed in their processes and structures, enables design or redesign that facilitates effectiveness.

https://doi.org/10.1017/cts.2021.824 Published online by Cambridge University Press

Table 2. *Team effectiveness model for science (TEMS) results*

Scientific productivity	Examples include: High-quality decisions
	Greater innovation
	Shorter implementation time
	Reduced costs (resource, time, etc.)
Working relationships	Greater commitment
	Increased trust
	Increased learning
	Reduced defensiveness
	Productive conflict
	Appropriate dependence on others
Individual well-being	Increased motivation
	Increased satisfaction
	Richer development opportunities
	Reduced stress

Addressing Gap 3

The TEMS addresses this gap by making explicit that values, assumptions, and norms are the basic elements of process and structure and by describing how values, assumptions, and norms become embedded in the design of science and relationship processes and structures, which together we refer to as team processes and structures. Science processes and structures address the conduct of science in general as well as the conduct of science for the specific problem the team is exploring. The processes and structures focus on the scientific productivity team result (see Table 3). Relationship processes and structures address universal needs that arise when team members work interdependently. These processes and structures focus on the working relationships and individual well-being team results. Intentional design of science and relationship processes and structures assure that they (1) are congruent with the team's explicitly agreed to ML, science, and relationship values and assumptions; (2) complement each other; and that (3) together, they facilitate the three team effectiveness results.

We define a team process as a repeated series of actions involving team members that leads to some result. Science processes may have relationship processes embedded in them because science processes sometimes specify how individuals who are working together in a process communicate, coordinate, and manage conflict that may arise.

Team structures are the relatively stable cycle of events that result from a pattern of repeated interactions among team members [23]. Like process, science structures may have relationship structures embedded in them.

Context represents the structures, processes, and other elements that exist in the team's environment that have a significant effect on the team and that the team, in some cases, may be able to influence (see Table 3). For science, examples include the promotion and reward system in which they operate [24], obtaining needed reagents and equipment, and access to state-of-the-art technologies. For a team whose members represent different organizations, their team functioning context reflects potential influences from all their organizations.

Table 3. *Team structures, processes, and context*

Team structure	Clear mission and shared vision
	Clear hypotheses and/or goals
	Motivating work
	Appropriate membership (e.g., skills and preferences for working interdependently, expertise needed, diversity of perspectives)
	Clearly defined roles and responsibilities
	Effective team culture
	Team norms (mutual learning, science, and relationship)
	Workload that enhances rather than hinders the three team effectiveness results
Team process	Effective problem-solving
	Appropriate decision-making
	Productive conflict management
	Direct and accountable communication
	Clearly defined boundaries with other entities
Team context	Clear organizational mission
	Supportive culture
	Recognition, review, and reward for interdisciplinary research
	Relevant information, including feedback
	Resources
	Training and development
	Physical and virtual work environments

Mutual learning as a reflective, self-correcting process

The TEMS includes a reflective loop to improve team effectiveness. Because this process uses the ML mindset and norms, science teams have the skills to engage in this process at any time in their normal course of work, creating a psychologically safe environment in which to productively address important and challenging issues. As Fig. 1 indicates, any element of the model is relevant and appropriate for reflection and redesign.

Using TEMS to Create a New Team or Develop an Existing Team

In this section, we describe a four-phase intervention, built on TEMS and ML, for forming a new team or improving an existing one. The same set of interventions is used for both new and existing teams, but the order and timing of the interventions may differ. These differences are noted below.

The intervention phases match the steps in the TEMS model (Fig. 1): (1) training to establish individual and shared ML mindsets and skillsets; (2) team developmental facilitation and individual coaching to broaden and deepen ML skillset and mindset, including self-reflection and redesign; (3) team effectiveness consultation to design mindset, norms, structures, and processes for team science and team relationships; and (4) team effectiveness evaluation for feedback and comprehensive reflection and redesign.

The scope of this paper prevents describing in detail the nature of these interventions. Creating a ML team almost always

https://doi.org/10.1017/cts.2021.824 Published online by Cambridge University Press

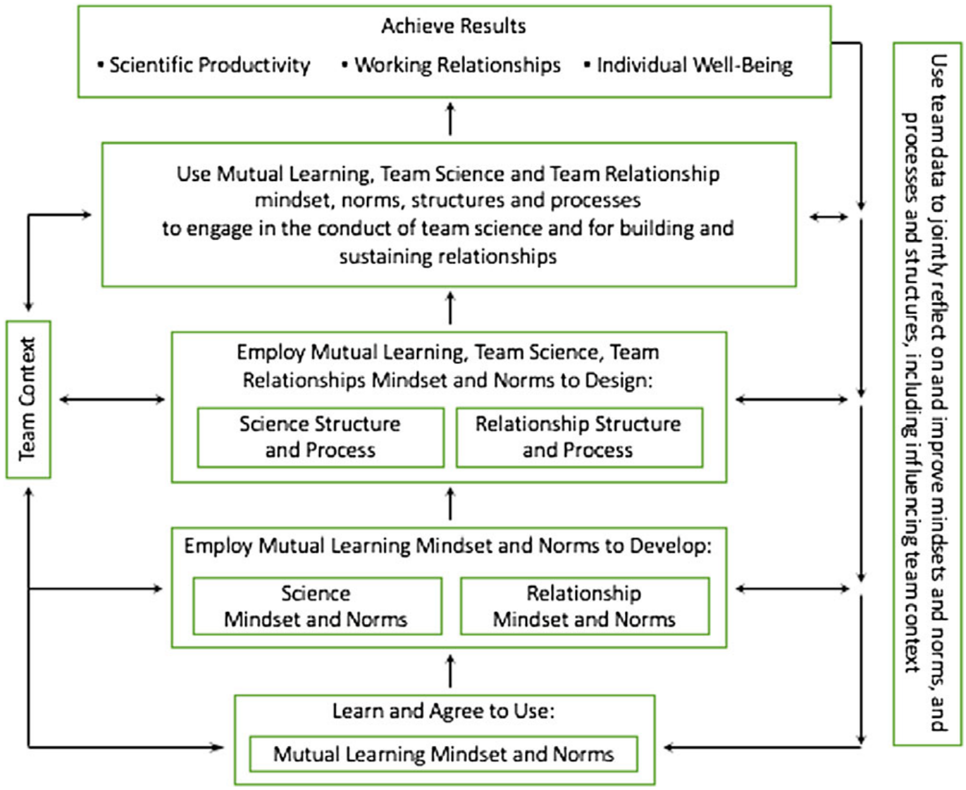

Fig. 1. Team effectiveness model for science (TEMS).

represents a culture change from UC and, by definition, requires changing a team's shared mindset. Because shared mindsets usually function outside of the awareness of those who hold them, it is very difficult for a team to shift its shared mindset without outside support, to help a team learn to reflect on, analyze, and shift their mindset in real time. The primary focus of these interventions is not increasing knowledge, but rather shifting mindset, developing behavioral skills, and designing processes and structures congruent with ML.

Intervention Phase 1: Training to Develop Individual and Shared Mutual Learning Mindsets and Skillsets

Training enables the team members to (1) identify the UC and ML approaches in real time in themselves and their teammates; (2) begin changing their individual and shared mindsets; (3) begin producing ML behaviors individually and as a team; and (4) begin providing feedback to their teammates in real time to improve individual and team functioning. The team achieves these results through rigorous practice on their real work challenges and feedback from their peers and workshop instructors. A workshop provides the team with enough knowledge and experience to make a relatively informed choice about whether ML is a good fit and worth their commitment.

Intervention Phase 2: Team Developmental Facilitation and Individual Coaching

Team developmental facilitation and individual coaching enable the team and its members to broaden and deepen the ML skillset and mindset. These two interventions occur in parallel and may continue through or restart in later phases depending on the team's needs.

Team developmental facilitation

Developmental facilitation enables the team to immediately apply and strengthen the ML mindset and skillset to their regular team meetings. Unlike basic facilitation, in which the facilitator's goal is to lend their expertise to help the team through a particular meeting, in developmental facilitation, the facilitator's goal is to help the team develop its own expertise and reduce its dependence on help from outside the team [7].

In developmental facilitation, a facilitator observes and intervenes with the team during its regularly scheduled meetings as it is solving problems and making decisions on important and challenging issues. Over a series of meetings, the team becomes increasingly self-sufficient at using ML to manage its own process effectively. The team is able to jointly design and move through an agreed-upon agenda efficiently, stay on track, identify untested assumptions and inferences, address differences openly and productively, and solve problems and make decisions that the full team is committed to implementing.

Continual reflection and redesign

Developmental facilitation strengthens the team's ability to continually reflect on its functioning in real time, redesign the team, and enable it to achieve and maintain the three team effectiveness results. Reflection in real time is a central aspect of ML. Team members develop this skill during phase one, begin to apply it to real-time team issues during their interactions in phase two, and continue to do so throughout the life of the team. This process,

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which can address any elements of the team, is illustrated by the feedback loops on the right side of Fig. 1.

Individual coaching

Individual coaching provides team members help applying ML to achieve more effective results regarding their particular work challenges. Working with a coach, the team member sets goals, has specific follow-up actions and supports team members in developing skills and mindset to effectively raise issues in the team that were previously undiscussable.

Intervention Phase 3: Team Effectiveness Design

Design consulting empowers the team to design or redesign its team science and team relationships mindsets, norms, structures, and processes. For example, the team agrees on its mission, the tasks on which it will work interdependently as a team, how they will be accountable to each other, how they will manage meetings, and how various kinds of decisions will be made and by whom. All science and relationship processes and structures are designed to be congruent with ML values and assumptions. All interactions employ and strengthen the ML mindset and skillset developed in Phase 1.

Intervention Phase 4: Team Effectiveness Evaluation and Feedback

A team effectiveness evaluation measures each element of the full TEMS model including ML, science, and relationship: (1) mindsets (i.e., values and assumptions); (2) behaviors; (3) structures and processes; (4) context; and (5) each element of the three team results. It enables a team to identify and discuss whether and how each of the elements of the team is contributing to or hindering the team's overall effectiveness. A survey is conducted a number of months after the team has implemented its agreements from the team effectiveness design session. And, re-evaluation at future time points can help the team assess its progress.

Summary

The TEMS model increases science team effectiveness, including maximally benefiting from disciplinary diversity, by placing the ML shared team mindset and norms as a central and guiding element that integrates the design and functioning of a science team. Creating a team using TEMS requires a multiphase set of interventions to develop the shared ML team mindset and skillset, to design the team science and team relationships mindset and norms, and to design the team structures and processes, all of which contribute to scientific productivity, stronger working relationships, and improved individual well-being.

Disclosures. The authors have no conflicts of interest to declare.

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