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A framework for developing team science expertise using a reflective-reflexive design method (R2DM)

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Effective integration and implementation of knowledge in research are dependent on team science expertise grounded in collaboration principles and techniques that advance individual and group scientific agendas. The Science of Team Science (SciTS) provides evidence-based research and best practices that strive to develop scientists' collaborative skills so that they can work across disciplinary boundaries while developing strong and diverse teaming relationships. Identifying the motivations of those involved in collaborative teaming can contribute to maximizing team effectiveness and applying the knowledge emerging from understanding these to shape teams' adaptation of a shared mutual learning mindset as a core tenet of scientific teamwork. In addition, surfacing motivations has the potential of helping team members examine their own needs in relation to their scientific and career goals. In this paper we draw from the domains of the Motivation Assessment for Team, Readiness, Integration, and Collaboration (MATRIC*x*) framework, Maslow's Hierarchy of Needs motivational theory, and The Team Effectiveness Model for Science (TEMS) to develop a Reflective-Reflexive Design Method (R2DM) that focuses on the development of intra-personal attributes within the context of a team. Approaching expertise development from this design method invites individual reflection in the context of group reflexivity to serve as the cornerstone of deep team science expertise. We used a design thinking approach to identify a framework that merges individual reflection with group reflexivity. The core questions we asked are: (i) *What constitutes expertise to succeed in science teams?* and *(ii) How might we approach the design of learning engagements that enable the development of the needed expertise?*

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Introduction: the individual in the context of the team

The Science of Team Science (SciTS) provides a wealth of literature representing the research, practices, and interventions to enhance team effectiveness, especially those that have expectations of knowledge producing outcomes (Cooke and Hilton 2015; Hall et al. 2019; Lotrecchiano et al. 2016). Yet, with the continued and expanding interests in and the recognition of the necessity for team science, there are parallel, as yet unmet needs for interventions, learning strategies, methods, and tools to support team science at the individual, team, and organization levels (Börner et al. 2010).

Contributory expertise in team science remains largely centered on the capabilities and transactions that occur within teams, especially based on the contributions of knowledge producing teams (KPTs) (Lotrecchiano et al. 2016), and less on the individual collaboratory skills of those who are part of teams (Batorowicz and Shepherd 2008; Bennis 1997; Cartright and Zander 1968; Cooke and Hilton 2015; Hall et al. 2008; Ross et al. 2010). We would like to shift the conversation to focus greater attention on the interactional expertise in team development as core team science expertise (Collins and Evans 2007). Interactional expertise emphasizes team development as a process during which a group purposefully evolves from an assembly of individuals into an integrated and interdependent team. Part of this development includes making several key decisions influencing how an evolving team will work together, both scientifically and through their team dynamics. The decisions include agreeing on a shared mindset to sit at the core of their work together, designing and establishing the norms they will use, and developing a shared understanding of their integrating and individual motivators. (Bennett and Gadlin 2012; Eigenbrode et al. 2007; Lacerenza et al. 2018; Lambert and Monnier-Barbarino 2005; Lotrecchiano 2017; Lotrecchiano et al. 2016; Salazar and Lant 2018; Schwarz and Bennett 2021; Tuckman 1965).

Implicit motivators are the factors that drive an individual to meet their own goals while collaborating to achieve explicit scientific team goals in relationship with colleagues. Individual motivations are rarely made explicit in science teams, and are often overlooked in the analysis of team effectiveness within SciTS; however, when personal motivations are shared within the context of a team for the purpose of identifying one's desires and needs, there can be an enormous impact on a team's ability to develop shared mental models for intentional collaboration (Kanfer and Heggestad 1997; Kanfer and Kerry 2012; Salazar et al. 2011). This purposeful work is occurring at a time when members are establishing frameworks for how they will be interdependent with one another and will form the scaffolding to support each other in relationship and in the scientific work the team takes on. For clarification, the terms and definitions used in this paper are provided to the reader as a primer of concepts to this discourse (Table 1).

We perceive a major gap in the team science literature and practice as it relates to individual needs satisfaction when choosing to be part of a science team. While it is appreciated that team preparedness or team readiness is an essential pre-requisite for team effectiveness (Bennett et al. 2018; Lotrecchiano et al. 2014), little or no attention has been paid to the steps an individual must take to achieve the goal of becoming a *ready* teaming expert.

Conscious team readiness preparation for both the task work and the relationship work required in team science is highly beneficial for successful results (Fiore et al. 2019). Teams usually want to dive into the science activities prioritizing project needs at the expense of relational needs. Purposeful focus on individual and team preparation results in maximizing the time devoted to research pursuits by providing a solid foundation to the team relationships and creating an environment of psychological safety, which is an essential feature of highly innovative and effective teams (Edmondson 1999). The alternative can lead to challenges in managing difficult conversations, disagreements about methodology, or deciding how credit will be assigned (de Dreu and Gelfand 2008; Falk-Krzesinski and Klein 2017; Youtie and Bozeman 2016).

Expertise in team science requires that individuals bring their scholarly background and their desired individual goals to the team project, necessitating a deep self-knowledge about their own needs and having those understood by others on the team (Jeschke et al. 2016; Jordan et al. 2005; Stevens and Campion 1994). This often requires team members needing to learn a new vocabulary or new definitions for shared concepts, providing some introductory didactics to outfit team members with essential knowledge, or rethinking one's own methodological approaches when faced with different perspectives (Bennett and Gadlin 2012; van Ginkel et al. 2009).

Experts recognize that differences can precipitate tensions in teams, whether they be scientifically based or relationship focused. Such differences can also promote new learning, challenge others to think differently, and be catalysts in createing something entirely new (Deutsch 1969; Jehn and Chatman 2000; Jehn et al. 1999). A strong foundation in building and sustaining team relationships (Edmondson 1999), enables experts to freely and openly engage in productive conflict around those differences for the benefit of both the individual and the team. This is the crux of the intersection between *reflective and reflexive* actions that support good teaming (Gonnerman et al. 2015).

Reflective agency puts the individual deeply in touch with their own self while reflexive agency enables the development of teaming processes (inter-personal and group dynamics). This is sometimes framed in the context of intrinsic and extrinsic motivations (McClelland et al. 1989). Because individuals lie at the core of any team, developing their self-awareness, attitudes, readiness, mindset, cognitive and emotional skills, and the competencies necessary to contribute to the team is meaningful for individual accomplishment and overall team effectiveness (Bennett et al. 2010; Fiore 2008; Fiore et al. 2019; Klein et al. 2020; Lotrecchiano et al. 2020; McCormack and Levites Strekalova 2021). Therefore, integrating reflective and reflexive agency into a reflective-reflexive design method (R2DM) offers us the opportunity to support the development of individual readiness and abilities, the nurturing of team efforts and functioning, and negotiating shared structural, cultural, and climatic factors for improved collaboration. (Börner et al. 2010; Falk-Krzesinski and Klein 2017; Lotrecchiano and Norman 2021; Schwarz and Bennett 2021) *A combination of reflective and reflexive agency is required for individuals to serve their own needs and to integrate with others to achieve a shared vision and effective teaming* (Gao 2013).

Reflective-reflexive design method (R2DM)

We introduce a design method focused on enabling individuals to (i) assess their degree of intra-personal collaboration readiness, (ii) surface their thoughts and values with the science team they are working with, (iii) develop a shared understanding of the motivators of team members, (iv) establish shared team mindset and behaviors, and (v) evaluate the readiness of the other individuals within the team. This design method is based on the assumption that reflection and reflexivity are necessary dynamics for teaming success and that interventions that build successful teams take advantage of both dynamics in context and as intersection points (Schippers et al. 2015, 2020).

Figure 1 illustrates the intra- and inter-personal dynamics that form the foundational framing for the proposed design method

Table 1 Concepts and definitions.

Concept	Brief Definition
Contributory Expertise	Superior skills that are the result of one's ability to integrate knowledge as a thought leader and team member representing some synthesis of different traditions of science and/or scholarship (Collins and Evans 2007).
Design Method	Design procedures and techniques used throughout the design thinking process to action placing each phase of the process within the broader context (Koper 2006).
Design Thinking	The process of designing that is both intentional and iterative that includes the following framework: Empathize, Define, Ideate, Prototype, Test, Implement (Foster 2021).
Expertise	A high level of performance within a specific set of tasks or domains (Bourne et al. 2014).
Explicit motivators	Controlled or conscious information processing and propositional reasoning (McClelland et al. 1989).
Implicit motivators	Automatic and non-conscious information processing (McClelland et al. 1989).
Interactive expertise	Superior skills that are implicit and express one's abilities to team and interact with others outside of subject matter or area of scholarly expertise (Lotrecchiano et al. 2020)
Interdisciplinary	Researchers from different disciplines work jointly to address a common problem. Some integration of perspectives occurs, but contributions remain anchored in their own disciplines (Rosenfield 1992).
Knowledge Producing Teams (KPTs)	Collaborating scientists and stakeholders that share a mental model that is focused on scientific problems requiring multiple perspectives and methodological approaches (Lotrecchiano et al. 2016).
Multidisciplinary	Researchers from different disciplines work sequentially, each from their own discipline-specific perspective, with a goal of eventually combining results to address a common problem (Rosenfield 1992)
Reflective	"reflecting-in-action" allows experts to internalize unexpected experiences and conduct 'experiments' which serve to generate new understandings and a change in the situation (Schön 1983).
Reflexive	The concept of individual experience of the world is turned back on oneself as a social process that puts the person in dialog with their environment. Reflexivity is crucial to human development (Strauss 1956)
Sense-Making	A cognitive process that begins with exploration of ideas, principles, concepts, facts leading to identification of areas of focus for further inquiry before reaching a judgment that informs a decision (Weick 1979).
Science of Team Science (SciTS)	The philosophical and scientific study of science teams using multiple methods found throughout psychological, humanistic, philosophical, leadership, management, anthropology and sociological lenses (Stokols, Hall et al. 2008)
Shared Mental Models	Sociocognitive behaviors that build effectiveness in teams (Van den Bossche et al. 2011)
Socialization	The process in which individuals teach and learn about their world through reciprocal interaction with it (Macionis 2013).
Team Development	Purposeful evolution from a group of individuals to a team that has established a shared mindset, agreed norms, and integrated motivators. A period during which members design how they will be interdependent with one another and will form the scaffolding to support the relationship and scientific work the team will take on (Tuckman 1965).
Team Science	Collaborative efforts by more than one scientific stakeholder seeking to address a problem often through multiple perspectives and lenses. (Stokols et al. 2008)
Transdisciplinary	Researchers from different disciplines work jointly to develop and use a shared conceptual framework that synthesizes and extends discipline-specific theories, concepts, and methods, to create new approaches to address a common problem (Vogel et al. 2014)
Unidisciplinary	Researchers from a single discipline work together to address a common problem (Rosenfield 1992)

(described in more detail in the rest of the paper). We posit that for collaborative teaming to be effective, individuals need to reflect on their collaboration readiness. To achieve this goal, an individual must first assess their readiness to collaborate and then jointly engage in a reflective practice comprised of continued self-assessment related to motivators, needs, and values. In this way, each team member contributes to establishing shared expectations within the collaborative teaming environment. Once individual readiness is achieved, team members can articulate shared team values and behaviors by engaging in interpersonal reflexivity as a team. Collaborative team readiness can be assessed over time to further strengthen interpersonal reflexivity. This progression of individual and team development is shown in the figure using light gray and dark gray icons.

The relationship of the contributing theoretical models

To address both the intra- and inter-personal dynamics within teams, we have developed a design method starting with the individual and ends with the team purposefully deciding on the shared values and norms that will underpin their collaboration. The development of the Reflective-Reflexive Design Model (R2DM) was itself a transdisciplinary pursuit requiring the integration of models from different disciplines to develop a shared conceptual framework (Klein 2014; Klein et al. 2001; Vogel et al. 2014). In addition to literature from SciTS, psychology, and cognitive sciences, we required lessons and guidance from the fields of instructional design and organizational development (Argyris 1985; Schön 1983; Schwarz 2013; Schwarz and Bennett 2021; Weick 1979). This melding of disciplines enabled the development of an instructional design model that serves as the foundation for our design methodology. The models we have chosen to achieve the development of a framework that could address the implicit motivations of individuals and the design of a means to assess individual and team needs required both measurement of individual motivations, developmental theory and a structure in which to measure mindset in teams include the Motivation Assessment for Team Readiness, Integration, and Collaboration (MATRICx), Team Effectiveness Model for Science (TEMS), and Maslow's Hierarchy of Needs. More explicitly, these three models (i) surface the implicit motivations of individuals, (ii) enable the design of an evaluative tool for individuals and teams, and (iii) provide development theory and structure for assessing team mindset.

The motivation assessment for team readiness, integration, and collaboration (MATRICx). MATRIC*x* identifies motivators associated with team science participation within five domains: Advancing Science; Building Relationships; Knowledge Transfer;

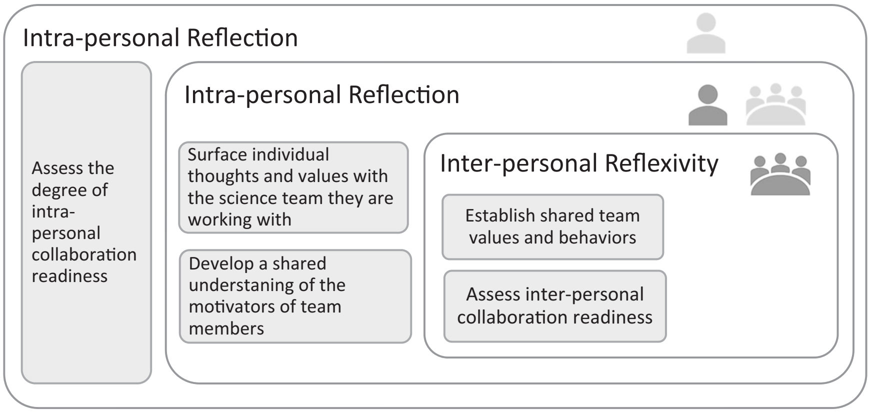

Fig. 1 Intra- and Inter-personal dynamics for team effectiveness. . Intrapersonal reflection is represented in two types. Firstly, in the form of collaboration readiness. Secondly, in the form of intrapersonal reflection in the context of teaming. Lastly, interpersonal reflexivity which is when individuals participate in the establishment of shared values and behaviors and assess their own inter-personal collaboration readiness.

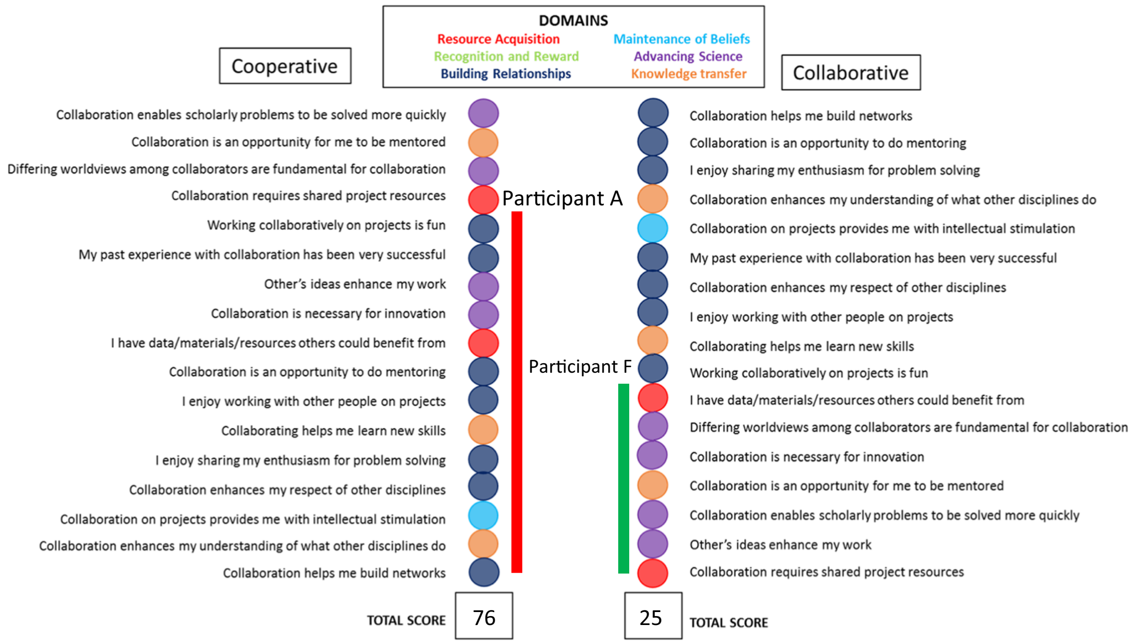

Fig. 2 Hierarchy of MATRICx items based on cooperative and collaborative scales of motivation. Cooperative and collaborative scales are used to map the hierarchy of one's motivation. The cooperative is less interdependent than the collaborative scale. Motivation items are part of a hierarchy of motivations.

Maintenance of Beliefs; and Resource Acquisition. This framework enabled us to identify individual motivators across these five domains and formed the "content" of the learning design effort (Fig. 2). Using this strategy we were able to develop individual reflection interventions for group readiness (Lotrecchiano et al. 2016).

The degree of endorsement of motivating factors in the survey provides a means by which to measure the level of challenge for an individual to identify their own hierarchy of motivations on two scales, cooperative and collaborative (Bailey and Koney 2000) thus setting a way to measure levels of engagement against a developmental framework focused on satisfaction (Maslow 1943).

In research within medical and health science student educational settings as a pretest/posttest scenario in coursework and workshops, we saw that when used alongside group structured learning interventions, scores increased in one's readiness for team engagement evidenced by higher individual MATRIC*x* collaborative scores (Lotrecchiano et al. 2016). More recently, we used the MATRIC*x* to confirm similar and different motivators across three types of health science teams: education, biomedical, and policy. Differences in motivations led us to variables related to needs satisfaction and learning when applying MATRIC*x* outputs alongside semi-structured interview in a mixed method study showing how intra-personal motivations are critical factors in teaming situations (Lotrecchiano et al. 2023).

Maslow's hierarchy of needs. Though not normally included in the team science landscape as an operative model, we gravitated to Maslow's hierarchy of needs to emphasize the relationship between individual teaming motivations and satisfaction of needs as part of one's own development when engaging with a team. Maslow's hierarchy of needs offered us the theoretical grounding to connect the relationship between one's motivations (measured through the MATRIC*x*) and their understanding of self, starting with needing to fulfill the most fundamental needs such as

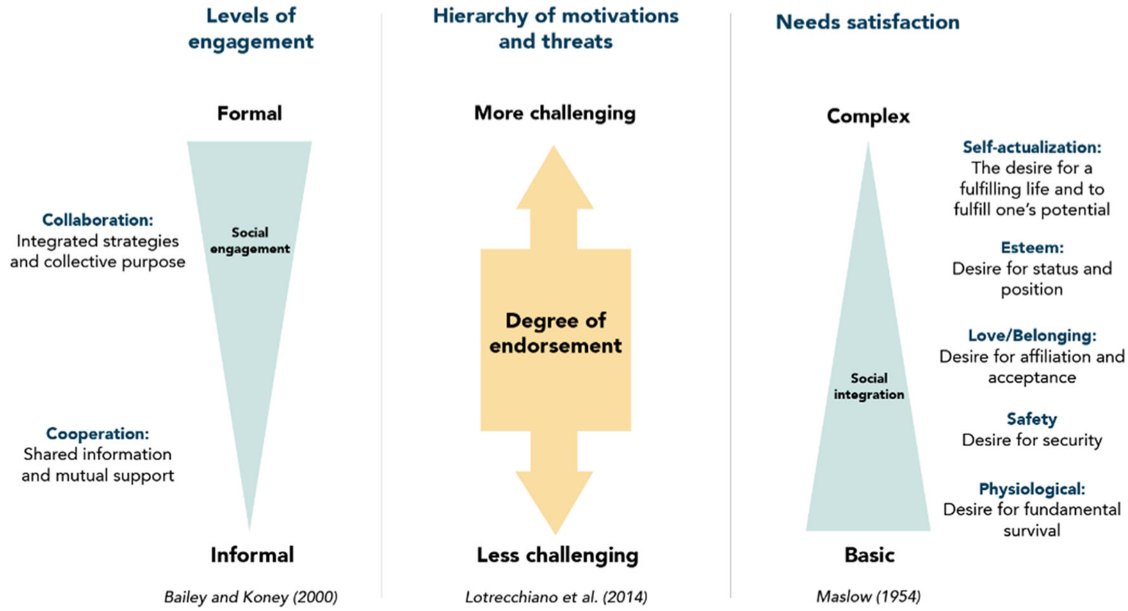

Fig. 3 The MATRICx conceptual model. The cooperative and collaborative scales represent less to more social engagement between teaming members (Lotrecchiano et al. 2016). Less engagement is representative as informal while more engagement represents more formal processes (Bailey and Koney 2000). Informal engagement motivations are less challenging to endorse while more formal ones are more challenging. The social integration necessary for informal less-challenging motivations to be satisfied are more basic requiring less social engagement, while more challenging formal motivations require more social engagement because of their complexity (Maslow 1943).

physiological safety and belonging before being able to achieve higher-order needs including esteem and self-actualization. We posit that to achieve the higher-level needs during teaming, greater interaction with teams is required as one seeks to satify needs higher up on the hierarchy (Fig. 3).

For example, the foundational physiological or safety needs may be more dependent on one's own feeling about whether teams can be safe places, based on an understanding and experience of trust in a team (Edmondson 1999). Simpler needs satisfaction is more individually centered, whereas higher-level individual needs are more dependent on interaction and socialization for needs to be satisfied (Moreland and Levine 2006). To satisfy higher level needs, like esteem and self-actualization, greater reflexivity is required if a team member is to expect greater respect from others (van Ginkel et al. 2009). Maslow's hierarchy reminds us of individual developmental stages and how career choices, including those related to team engagement can affect their own human development (Begg et al. 2014; Guise et al. 2017; Smyth et al. 2022; Zucker 2012). As one's need become more developmentally advanced, the need for more socialization is introduced. This socialization occurs within the science team.

The team effectiveness model for science (TEMS). Integrating what was learned from individual motivations (MATRIC*x*) and from the safety and security need requirements of individual and teams (Maslow) requires a means by which we can associate the reflection about motivations and the reflexive character of team interactions requires a means for agreeing on a team mindset (TEMS).

The TEMS has at its foundation five mutual learning values: transparency, curiosity, informed choice, accountability, and compassion (Schwarz and Bennett 2021). The model guides teams in developing and agreeing on a shared mindset and behaviors to guide their task work and relationship dynamics. This model serves as the reflexive action associated with building an intervention rubric.

There are two fundamental mindsets originally described as Model 1 and Model 2 (Argyris 1985) and more recently the unilateral control approach and the mutual learning approach (Schwarz 2013). The mutual learning mindset, as distinct from that of the unilateral control mindset, embraces values and assumptions that lead to behaviors that enable people to learn from others who think differently, ensure all views are heard and considered, work collaboratively to design next steps together, and facilitate having difficult conversations by testing theories and assumptions and understanding other people's interests. All behaviors benefit maximizing the talents and strengths of individuals who make up the team. In other words, TEMS provides a vehicle for transitioning from an reflective individual to an effective team member. It also serves as a framework for learning to embrace all dimensions of difference from across the team, including individuals' motivations and needs, and incorporating how the needs will be satified within the team.

Just as each scientist's research behavior is guided by their disciplinary mindset, the way in which team members interact with each other is influenced by their individual and team mindset (Bell 2007). Just as disciplinary-specific behaviors impact the scientific results the team obtains, the relationship norms and behaviors will influence their relationship results (Schwarz and Bennett 2021). TEMS encourages the adoption of a mutual learning mindset approach to serve as the team's foundation. It then builds by suggesting the team make explicit a shared mindsets and behaviors for their research project and how they will be in relationship with each other.

Utilizing R2DM

Integrating these three models, MATRIC*x*, Maslow's Hierarchy of Needs, and TEMS, allowed us to consider team science expertise from the perspective of the individual, an aspect of team science that is not yet well explored. Centrally highlighting motivation, need, and values sheds a new perspective on the role of individuals in science teams. R2DM engages the natural sensemaking that people are accustomed to and provided us the platform for the design of activities the guide them through their journey from individual, to individual in the context of a team, to an interdependent team member. In addition R2DM fills an essential gap in the literature and in how team science expertise is conceptualized. Guided self-discovery or *reflection* activities in three dimensions: motivation, needs, and values, enables teams to engage in purposeful *reflexive* teaming, benefiting both individual and team expertise development, which provides a solid foundation upon which the team to interact. Figure 4 highlights the complementary nature of the three models.

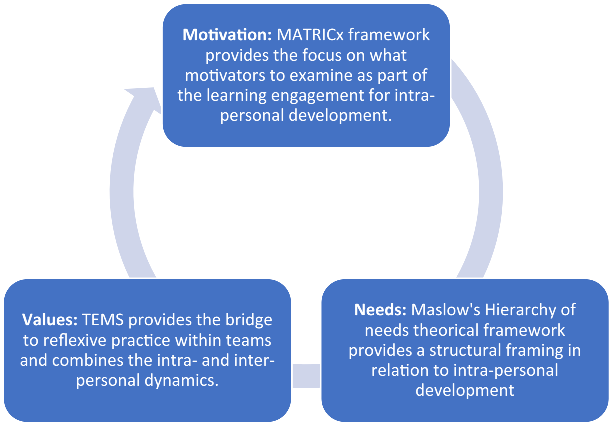

Fig. 4 Integrated framework for addressing intra- and inter-personal dynamics for team effectiveness. Motivation (measured thought MATRICx) provides the focus on what motivators are important top learning engagement and personal development. In turn these can be mapped along a perceived satisfaction of needs (Maslow) that serves as a structural framing for intrapersonal growth and development. This allows participations in teams to enter reflexive practice with others on the team and combine intra- and inter-personal dynamics into the construction of values and mental modes within a team.

Supporting individuals in self-reflection regarding their readiness to collaborate necessitates a developmental approach to the learning engagement. The process of reflection enables one to correct erroneous interpretations resulting, over time, with a changed perspective that could influence future decisions and actions (Dirkx 1998; Mezirow 1990). The instructional design model of reflective sensemaking shown in Fig. 5 stems from the transformative learning theoretical framework and served as guidance for the intra-personal cognitive processing. We define intra-personal cognitive processing as the type of thinking that takes place as part of self-reflection activities starting with exploration, followed by identification, then processing/reasoning, judgment, and integration (Lotrecchiano et al. 2016).

Building individual capacity for effective teaming

The sensemaking activities as we have designed them, align with the Reflective Sensemaking Learning Model (Fig. 4), and starts with exploration (a process of discovery) followed by the selection of specific elements for discussion with the team to support shared information processing (focusing on what is important to them). Through processing and reasoning individuals identify next steps on this reflective journey and the temporal changes required (based on iteration of process in the development of judgments). Each person goes through successive cycles of sensemaking moving them up Maslow's hierarchy and simultaneously providing the team with the knowledge and information to begin the process of deciding how they will work together as a team. In essence everyone is asking: *"Who am I in this collaborative space?"* followed by *"Given all the information we have; how do we make the transition from a group of individuals to a highly effective team?"*

In this way, team mindset and behaviors can be cultivated, bringing together the individual motivations of each team member, and taking advantage of how their individual skills and talents contribute to the overall team goal(s). This provides a sturdy foundation upon which to execute complex team science

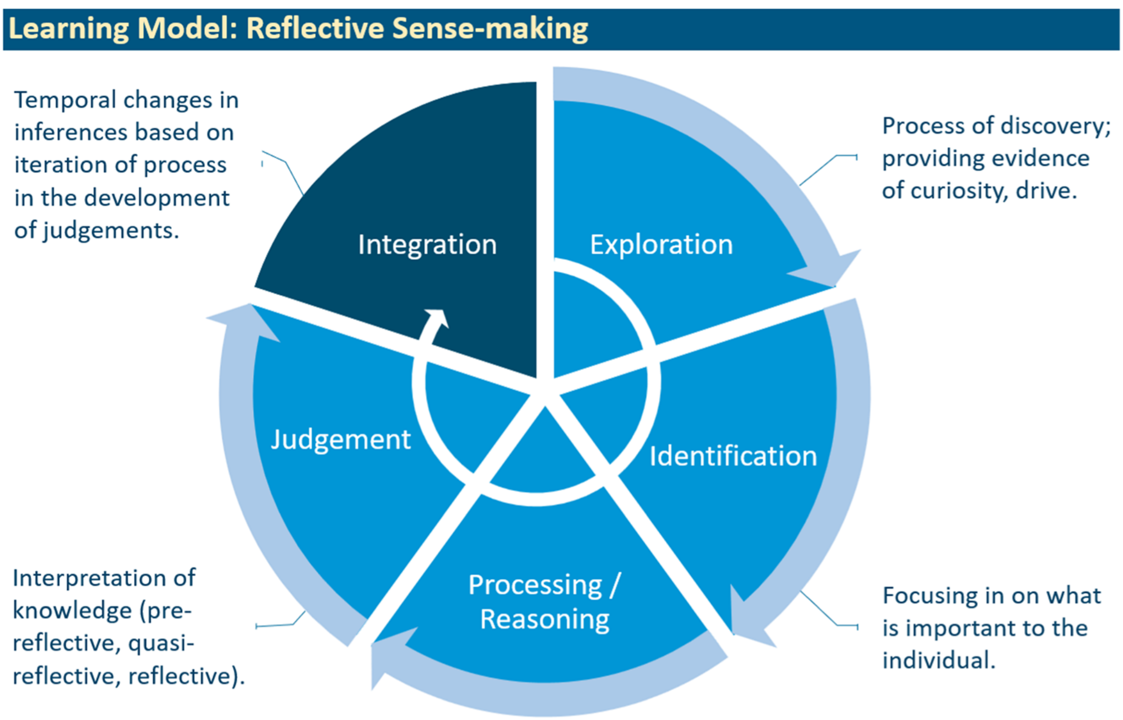

Fig. 5 Reflective sense-making learning model (Lotrecchiano et al. 2016). This learning model emphasizes the transitioning stages from exploration, identification, process/reasoning, and judgment, to integration and the related intrapersonal agency that occurs throughout this sensemaking process.

Table 2 Key components accounted for within each model as our first step in proposing an operational integrated model R2DM.

Reflective	MATRIC*x*	Individual inventory across five domains in relation to cooperative and collaborative experiences (Lotrecchiano et al. 2015)				
		Advancing Science	Building Relationships	Knowledge Transfer	Maintenance of Beliefs	Resource Acquisition
	Maslow Hierarchy of Needs	Physiological Needs				
		What do I need to contribute to advancing the science?	What do I need to feel safe in a relationship?	What knowledge and skills do I need to acquire?	What are my core beliefs about working on a team?	What are my resource needs?
		Safety Needs				
		What do I need to feel safe when contributing to science?	What types of relationships make me feel safe?	What do I need to feel safe to acquire new knowledge and skills?	What beliefs are safe to share?	What are 'enough' resources?
		Belonging Needs				
		What relationships do I need to advance science?	What are the behaviors that I will engage in to sustain trust?	What knowledge and skills do I acquire as part of this group?	What beliefs are shared with others?	What resources will make me feel supported?
Reflexive		Esteem Needs				
		What do I need to be respected and recognized in the advancement of science?	What type of relationships will allow me to strive and learn?	What will I gain from learning with this group?	How do shared beliefs change how I contribute?	What resources will lead to recognition and reward?
		Self-Actualization Needs				
		How does advancing science enhance my potential?	When are my motivations maximized?	What will I become from learning with this group?	What beliefs are part of my long-term goal?	What resources will allow me to become what I desire?

while successfully building relationships and balancing individual goals with science team goals (Lotrecchiano et al. 2016; Schwarz 2013; Schwarz and Bennett 2021).

We argue that an intervention that flows out of the R2DM, which in essence follows a developmental approach to build team science expertise, breaks down the barriers that hinder creating and sustaining a successful team, and is self-reinforcing (Edmondson and Schein 2012; Gray 2008; Tuckman 1965). Operationalizing the integrated model enables us to evolve our understanding of team science expertise by starting with the self and working through the finer points of how to become a collaborative, productive team member.

Design method: motivation, needs satisfaction, and values

The R2DM starts with identifying individual motivators related to engaging in collaboration. Those motivations are then viewed through the lens of Maslow's hierarchy of needs, which enables the individual and the team to assess, consider, and make sense of their individual and team-level needs at each level of the model. This leads to the ability to agree on a team mindset that considers both individual and team goals.

Operationalizing the integrated model shown in Fig. 5 involved unbundling the three distinct models to identify the components that would guide the design of the intervention and create collaboration readiness for the team.

1. *To assess the degree of intra-personal collaboration readiness* we relied on the MATRIC*x* inventory to serve as the triggering event for the integrated model (Mallinson et al. 2016). By starting with the MATRICx inventory, individuals can reflect on their experience within teams and be able to enter a self-reflective aspirational space through activities related to each of the five assessment domains (Advancing Science; Building Relationships; Knowledge Transfer; Maintenance of Beliefs; and Resource Acquisition).
2. *To surface individual comfort levels and needs within the science team and develop a shared understanding of the motivators of team members* we designed activities for each of the five domains along Maslow's hierarchy of needs (Physiological, Safety, Belonging, Esteem, and Self-Actualization). These activities combine self-reflection with social reflection among team members to keep exploring the intra-personal needs in connection with the inter-personal interactions and needs of the project team. We identified focused questions related to needs at each level of Maslow's hierarchy to provide the macro-level operational direction for the intervention design (Table 2).
3. *To establish a shared team culture and behaviors* we identified the learning goals for each activity and designed micro-activities ae aligned with TEMS Mutual Learning Values and Norms to guide the team members in purposefully establishing their team's culture.

The relationship between the MATRIC*x* and Maslow's hierarchy is critical to the establishment of understanding about what drives individuals as they seek and/or are invited into teaming environments. It provides a relational parallel between what one hopes to accomplish and how this can be achieved. In addition, it provides a basis for personal growth that can only happen in the context of the act of teaming. Readiness to engage in teams requires three sets of factors, a movement from the (i) informal to the more formal (Bailey and Koney 2000), (ii) less challenging to the more challenging (Lotrecchiano et al. 2014), and basic to more complex needs (Maslow 1943). The informal, less challenging, and basic dimensions of this trio are more readily achieved as an individual, with the higher order elements requiring an

Table 3 Example of the use of the tool to identify the behaviors and mindset the team would use when conducting a knowledge and skills analysis using the R2DM model.

MATRIC*x* Domains	Learning Goals Per Activity	Maslow Level Alignment	TEMS Values	TEMS Behaviors
Advancing Science	Create a research agenda.	Physiological Safety	Mutual Learning Values ☐ Transparency ☐ Curiosity ☐ Informed Choice ☐ Accountability ☐ Compassion Team Science Values [add your own] Relationship Values [add your own]	Mutual Learning Behaviors ☐ State views and ask genuine questions. ☐ Share all relevant information. ☐ Use specific examples and agree on what important words mean. ☐ Explain reasoning and intent. ☐ Focus on interests, not positions. ☐ Test assumptions and inferences ☐ Jointly design next steps ☐ Discuss undiscussable issues. Team Science Behaviors [add your own] Relationship Behaviors [add your own]
	Recognize the need for others' expertise.	Belonging		
	Advance one's own research agenda.	Esteem Self-Actualization		
Building Relationships	Create a summary of individual values related to collaboration.	Physiological Belonging		
	Inventory the techniques identified by team members that can help support collaboration	Safety Belonging Esteem		
	Create a professional network map for building relationships	Self-Actualization		
Knowledge Transfer	Conduct knowledge and skills analysis	Physiological		
	Identify connections between individual and group knowledge and skills	Safety Belonging		
	Develop a group mentorship agreement and action plan	Safety Esteem		
	Reflect on own knowledge and skills gains	Self-Actualization		
Maintenance of Beliefs	Identify individual beliefs about collaboration.	Physiological		
	Discover shared beliefs among team members.	Safety Esteem		
	Establish group collaboration norms to successfully complete the project.	Belonging Esteem		
	Create a plan to shift beliefs based on project needs.	Self-Actualization		
Resource Acquisition	Create an inventory of project resource needs	Physiological Safety		
	Align individual and team needs related to the project.	Belonging Self-Actualization		
	Confirm an action plan at both the individual and team level for successful collaboration.	Esteem		

Team Mindset Values	Team Norms and Behaviors	Team Results
Mutual Learning Values ☐ Transparency ☐ Curiosity ☐ Informed Choice ☐ Accountability ☐ Compassion Team Science Values ☐ Commitment ☐ Meaningful Work	Mutual Learning Behaviors ☐ State views and ask genuine questions. ☐ Share all relevant information. ☐ Use specific examples and agree on what important words mean. ☐ Explain reasoning and intent. ☐ Focus on interests, not positions. ☐ Test assumptions and inferences ☐ Jointly design next steps ☐ Discuss undiscussable issues.	Conduct knowledge and skills analysis

Table 3 (continued)

Team Mindset Values	Team Norms and Behaviors	Team Results
☐ Teamwork	Team Science Behaviors	
☐ Advancement	☐ Be flexible with each other and their schedules	
☐ Expertise	☐ Attend all meetings and be on time	
☐ Learning	☐ Communicate clearly, especially when unexpected things happen	
Relationship Values	☐ Share expertise generously with each other	
☐ Respect	Relationship Behaviors	
☐ Loyalty	☐ Address tensions at the earliest stage possible, don't wait for red flags	
☐ Communication	☐ Consciously find ways to build relationships	
☐ Patience	☐ Ask others for feedback, especially when things are not working	

interactive teaming engagement. Figure 3 (shown earlier) highlights the parallels in this relationship.

The TEMS mutual learning, scientific, and relationship values and behaviors were integrated to support the increased complexity outlined in Fig. 4 and the progression from reflective to reflexive agency which merges the intra- and inter-personal needs. Specifically, these team evolutions can be challenging, and coming to agreement across a wide array of perspectives can cause tension. Establishing norms for working together supports this critical work. With this in mind, the learning activity design and development that follows describes how we nested the different design frameworks to address such complexity.

Learning activity design and development

We used a multi-level approach with a developmental lens when approaching the design of the learning activities. We did this to maximize discovery of motivations and needs satisfaction, and to promote adoption of team values and norms with a key assumption in mind: that the audience for the interventions will vary. We believe that this approach makes it possible to make an informed choice about adopting a team mindset that will promote strong results for the team.

The learning engagements we designed include activities that guide individual team members toward recognizing their own motivators for collaboration. This individual pre-work to better understand the self is done within a science team such that, as the team is making decisions about how to work and be in relationship together, they can purposely adopt a shared mutual learning team mindset and norms that build from individual motivational self-determination.

For each MATRIC*x* domain, we developed five learning activities directly aligned with Maslow's hierarchy of needs as shown in Table 1 to support intra-personal readiness for collaboration in a team. The learning goals shown in Table 3 reflect the tangible outputs for each domain and show the alignment to Maslow's hierarchy. Going through these activities enables individuals on a team to engage in discussion around team values and behaviors. The table also shows the TEMS values and behaviors in the last two columns which can serve as a point of reference within teams to connect the individual and team needs.

For example, given that one of the learning goals/results in Table 3 is for individuals to be able to conduct knowledge and skills analysis, then using TEMS mutual learning values and norms as a shared point of reference, we would first ask what behaviors the team needs to develop and use to achieve their goal. The mutual learning behaviors in this example could be to share all relevant information and jointly be able to design next steps for the project that the team is responsible for. In addition, the team has identified additional behaviors it thinks are important and shares expertise generously with each other, is one that aligns with the goal(s). Having identified the team behaviors, the team members would then engage in discussion regarding the values that the team would adhere to. In our example the mutual learning values transparency and accountability are important factors to consider as well as values the team identified for itself, learning and patience. Once the values are identified then the team can examine, at both the individual and team levels, how these will be actioned. In essence it provides a continuous feedback loop to be formed to support continuous improvement. See Fig. 3 for a visual representation.

With this example in mind, the learning activities we developed are intended to aid individuals and teams in exploring different facets of the TEMS mutual learning, science, and relationship values. These are a prelude to purposeful designing of the team mindset and norms in the context of discovering what motivates individuals and what they seek to derive from the collaborative experience against the backdrop of their individual needs. Developing this level of individual understanding and understanding others' motivations and needs contributes to fostering an environment where individuals feel safe being transparent and vulnerable with each other. Table 3 is meant to serve team leads with an operational instrument that highlights individual readiness for collaboration (first three columns) and a reference tool that enables to the conversation on team level behaviors and values to establish a shared team culture. It is meant to be used iteratively as individual team readiness develops along with team behaviors and values.

Conclusions

The need for effective teaming, attention to the team dynamics, and understanding the role of mindset in team effectiveness has brought forth several competency-based training efforts that seek to instill evidence-based expertise in the efforts of science teams (Bennett et al. 2018; Bisbey et al. 2021; Brasier et al. 2023; Cannon-Bowers et al. 1995; Lotrecchiano et al. 2020; McCormack and Levites Strekalova 2021; Norman and Lotrecchiano 2021; O'Rourke and Crowley 2013; Salazar and Lant 2018; Schwarz and Bennett 2021). Each continue to push the evolution of what a truly expert community of team scientists might look like and what their skills and competencies could encompass. As important as collaboration skills are, they alone are not enough. Self-reflection and the development of shared norms (e.g. collaboration plans) (Bennett et al. 2022; Bennett et al. 2014), determining how well the team is functioning now and in the future (e.g. assessments) (Misra et al. 2015; Trochim et al. 2008), building skills to have difficult conversations, or providing structure for roles and responsibilities (e.g. RACI Matrix) only scratch the surface of what is needed because they alone cannot lead to desired changes in attitudes, skills, or competencies that are sustained over time (Andersen et al. 2004).

While competence, abilities, and skills are observable traits in the performance of individuals in teams, there is another layer of awareness and expertise that needs to be uncovered. This layer includes the motivations and mindset needed to be experts in doing team science. This is because it is mindset that drives behavior and that in turn drives the results of the team. Desired behaviors can only be sustained over time if they align with a mindset that supports them (Schwarz and Bennett).

Expertise in team science continues to evolve as the demands and recognition of conducting collaborative research and scholarship become more common and accepted as trends within and across scientific disciplines. Research and interventions must incorporate learning from reflexive action to inform the relationship between the team and the individual. Advancing our understanding of what is necessary to nurture readiness for team science and better understand one's motivations for collaborating has the potential to enhance team effectiveness on a level unseen yet on a large scale in the literature.

Developing a mindset congruent with achieving excellent collaborative results (performance, working relationships, individual well-being, etc.) requires purposeful decision-making on the part of the team along with a deep recognition that these results cannot be achieved without a keen connection to individual satisfaction of needs for those who choose to participate and are placed into teams. Individual goals and needs must be incorporated alongside and integrated into team level goals setting and team development.

Teams in the process of forming or working to sustain themselves over time require a continuous cycle of improvement. Teams benefit when each member develops a strong self-understanding and when a shared understanding is prioritized among team members. This way the team develops its culture purposefully instead of leaving it to chance (Schwarz and Bennett 2021).

Learning engagements that target readiness and maximize motivations in the context of teams are important for team development. In the context of this paper, team development is a purposeful evolution from a group of individuals to an interdependent team. This purposeful work is at the core of what team expertise is— the individual awareness, group recognition and process, bridged by mutual mindsets that emphasize and value social learning. Thus reflective-reflexive-action can serve as a key factor in developing and sharing team science expertise.

In closing, we describe the R2DM model that relies on theoretical and applied frameworks to make visible individual needs in relation to team science goals. Motivation is a factor that cannot be overlooked when forming and sustaining teams. In addition, we recognize that motivations are fluid and change with time as individuals travel through their lives and encounter new personal and professional opportunities. For this reason, we emphasis how expertise in team science needs to include what we can glean from the inquiry into individual motivations to inform the individual and team mindsets needed to adjust to the changes that do and will occur in individuals' engagement with teams. Many of these 'twists and turns' will require interventions so that learning and change can in themselves be considered dynamic variables in the definition of continual team science expertise development.

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Author contributions

All authors were materially involved in the writing of the manuscript. GRL as lead author provided the basis for the framework and expertise related to the MATRICx model. LMB, as a consulting specialist and team science practitioner provided insight into the TEMS model and its usefulness in developing the integrated framework. YV is a learning specialist and designer and provided the portion on learning design and the figures related to framework of the paper.

Competing interests

The authors declare no competing interests.

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