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THE TRANSLATIONAL LEARNING ECOSYSTEM

Gaetano R. Lotrecchiano*	George Washington University, Washington, DC, USA	Glotrecc@gwu.edu
Marie Norman	University of Pittsburgh, Pittsburgh, PA, USA	mkn17@pitt.edu

*Corresponding Author

ABSTRACT

Aim/Purpose	In this paper we propose an ecosystem for translational learning that combines core learning principles with a multilevel construct that embraces the tenets of translational research, namely, teaming, translating, and implementing. The goal of the paper is to argue that knowledge of learning sciences is essential at the individual, team, and organizational levels in the translational science enterprise.
Background	The two decades that we can now call the translational era of health and medicine have not been without challenges. Many inroads have been made in navigating how scientific teaming, translating knowledge across the health spectrum, and implementing change to our health systems, policies, and interventions can serve our changing global environment. These changes to the traditional health science enterprise require new ways of understanding knowledge, forging relationships, and managing this new tradition of science. Competency requirements that have become important to the enterprise are dependent on a deep understanding about how people learn as individuals, in teams, and within organizations and systems.
Methodology	An individual, team, and organizational conceptual framework for learning in translational ecosystems is developed drawing on the learning science literature, a synthesis of 9 key learning principles and integrated with core competencies for translational science.
Contribution / Findings	The translational learning ecosystem is a means by which to understand how translational science competencies can be reinforced by core learning principles as teaming, translating, and implementation intersect as part of the translational science enterprise.
Recommendations for Practitioners	This paper connects learning science to tailored principles in a simplified way so that those working translational science with less knowledge of theories of learning and pedagogy may be able to access it in a clear and concise way.

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Recommendations for Researchers	This paper provides a framework for researchers who engage in the education of translational scientists as well as those who are charged with training new scientists in an emerging field critical to health and medicine.
Impact on Society	This paper allows for greater inclusion of learning science as a critical aspect of the sciences that seek to help move discovery and research to policy and social impact.
Future Research	The translational ecosystem described can serve to expand how teaching and learning impact scientific advances. In addition, it serves as a means in which to understand the impact of learning on micro, meso, and macro levels.
Keywords	ecosystem, pedagogy, team science, implementation, translation, learning science

INTRODUCTION

Translational science grew out of the realization that important bench research was not efficiently making its way into clinical practice and thus not improving the health of individuals and populations as it could and should (Austin, 2018; Zerhouni, 2003). Scholars have commented on the fact that improving the translation process has proven far more complicated than initially conceived because, as Braithwaite et al. (2018) point out, "The health system is probabilistic and stochastic, not deterministic and causal" and depends at all stages on human systems distinguished by uncertainty, illogic, and unpredictability (p. 3). Translational research, thus, is a tricky enterprise, requiring the best and most nuanced science, conducted by interdisciplinary teams skilled at navigating complexity, engaging diverse perspectives, and thinking outside the box. Conducting and supporting such nuanced, boundary-defying research and application for downstream impact requires that those dedicated to clinical and translational science work where scientific exploration is accompanied by lifelong learning. This is where the learning sciences can significantly advance the success of discovery, application, and dissemination (Norman & Lotrecchiano, 2021).

Translational science requires a deep knowledge of how people, whether individually or in teams and organizations, learn and potentially change as they learn, unlearn, and relearn the traditional research enterprise (B. F. Jones et al., 2008; Wuchty et al., 2007). Decades of research on the mechanisms and conditions that promote deep, flexible, and effective learning have not made their way to the forefront of the translational science movement. Instead, discussions about learning are often narrowly circumscribed, delegated primarily to the context of classroom teaching and training with little regard for the flexible and agile skills necessary to operate within the "the new youngest science, with boundless promise to transform science and medicine" (Austin, 2018, p. 456). We believe, however, that an understanding of the learning sciences has the potential not only to improve the training of the next generation of researchers and practitioners but also to significantly enhance the collaborative skills of individuals in teams and the organizational systems in which they work. After all, because interdisciplinary researchers must constantly teach and learn from one another, teaching and learning infuse everything translational researchers do, from bench to bedside to storefront. An understanding of learning research and its core principles should thus be central, not peripheral, to the work of translational researchers and practitioners (Seyhan, 2019).

The term 'learning sciences' refers to an interdisciplinary field of scholarship that explores the mechanisms by which learning occurs and identifies practices that facilitate learning (P. Brown et al., 2014; Sawyer, 2014; Sommerhoff et al., 2018). The learning sciences draw on a diverse set of disciplines, including cognitive and developmental psychology, neuroscience, computer science, sociology, and anthropology (Ambrose et al., 2010). In addition to challenging long-standing myths about teaching and learning (A. Brown & Kaminske, 2018; Nancekivell et al., 2020; Norman & Lotrecchiano, 2021; Riener & Willingham, 2010), the learning sciences distill research on learning into principles and strategies to enhance teaching. Not incidentally, the learning sciences have evolved over much the same timeframe as translational science, tackling the same problem (bringing research into practice)

in a different sphere, and grappling with many of the same issues, e.g., promoting innovation within large and often hide-bound systems and creating inclusive and welcoming environments that foster intellectual risk-taking and interdisciplinary exchange. In a previous article (Norman & Lotrecchiano, 2021), we identify a set of key learning principles we believe are directly applicable in the educational roles of translational research. These principles synthesize half a century of research on how learning works (Ambrose et al., 2010). They are not specific to any discipline or student level and, thus, apply across learning contexts and modalities. Moreover, they are sufficiently broad enough to encompass new discoveries and formulations. For simplicity, these principles can be organized into three categories: acquisition and integration of knowledge, social and emotional components of learning, and elements of skill-building. While we explore the principles themselves elsewhere (Norman & Lotrecchiano, 2021), our goal in this paper is to bring attention to the central role of learning across the translational enterprise and, thus, the critical role the learning sciences can play in our work, not just in traditional classroom and training settings but also on research teams and across organizations. We outline the role of learning on the individual, team, and organizational levels within the translational learning ecosystem, demonstrate the relevance of learning principles as they apply to these three levels, and argue that learning science is foundational to the success of the translational science movement and is, in fact, the ultimate translational science.

THE TRANSLATIONAL LEARNING LANDSCAPE

Learners in the clinical translational setting are already sophisticated, highly trained individuals and are fully vetted in their own disciplines. These learners have a multitude of professional goals that are often complex and dependent on more than simply learning new tasks. Instructors come from a range of backgrounds from medicine to social work, from statistics to the humanities, and from clinical practice to philosophy. They themselves are typically trained in one area though they are often asked to supplement their own training with cross-disciplinary perspectives where they sometimes struggle. And unlike traditional education, these instructors possess a variety of roles from tenured faculty at universities, to clinical posts, to staff positions and community stakeholders, each providing their own brand of expertise. Duration and time variations range from full degree programs to short professional workshops, face-to-face, hybrid, and online sessions. These often target learning about praxis where theory and practice interface in clinical application, laboratory training and mentoring, technical and social skill training, disciplinary and cross-disciplinary studies, individual and team-taught modules. These different modalities all constitute a complex array of environments where the clinical and translational workforce are involved.

For individuals, the translational learning landscape requires a commitment to human intrapersonal and interpersonal competency-building with a predisposition to lifelong learning (Senge, 2006). The attitudes, behaviors, and cognitions are intentional alterations that allow one to be receptive to collaboration and change (Garvin et al., 2008). At times, individuals will be required to commit to learning about new ways of leading and managing, communicating, problem solving, and most importantly serving as a conduit for building trust into the translational science system (Uhl-Bien et al., 2007).

For teams, whether research teams or administrative units, they represent a microcosm of a learning organization and the working unit by which organizations learn and adapt (Lotrecchiano, 2011). Because the best and most nuanced translational science requires teams skilled at navigating complexity, engaging diverse perspectives, and thinking outside the box (Zerhouni, 2003), our goal should be fostering learning teams that are the direct product of learning organizations and thus are nurtured and supported by environments that see knowledge as the true mediator in translational science. In other words, groups perform both taskwork and teamwork to ensure that attitudes, behaviors, and cognition are calibrated to ensure designed outcomes and goals are achieved (Garvin et al., 2008).

For organizations, the question of how to foster institutions that prioritize learning, adaptation, and agility has been addressed in the literature on complexity leadership and continues to be a concern in the team science literature (G. Jones, 2000). It promotes a departure from the leader-centric notion

of influence typical of the manufacturing economy with its emphasis on leader characteristics and relationship with workers to the adoption and management of emergent and non-linear environments and systems that typify the knowledge and information economy that dominates the 21st century (Fiore, 2012; Fischer, 2000). Complex and distributed leadership models reorient organizations and teams around knowledge, learning, and flexibility (Fiore, 2012; Lotrecchiano et al., 2020; Yeo, 2020). Individuals, groups, and organizations serve as unique components of entire systems and thus leadership is more so the influence over processes rather than people and things (McHale et al., 2019).

First, we acknowledge that, as described, clinical translational efforts are intrinsically dependent on learning on the individual, team, and organizational levels. Thus, we need to consider different types of learning—applied, academic, scholarly, and social— as equal partners in the same ecosystem. Instead of applying complex techniques to this 'new vision' for learning in the clinical translational landscape, we find it more appropriate to speak from the position of competence needed to accomplish these goals. As such, we draw the basic competencies found in translational, team, and implementation sciences as guiding foundational tenets as we describe how core learning principles are used within it (Achtenhagen et al., 2003; Northouse, 2007; Uhl-Bien et al., 2007). These, coupled with definitions and examples, are needed so that those less versed in learning science can embrace what is known from it while they equally apply their expertise to the scientific tasks at hand (Seyhan, 2019).

Second, to accomplish what we have stated in the last points, there is a need to simplify the otherwise complex tablature of educational theory and practice in the clinical translational setting. Teaching is a reflective practice requiring continual self-awareness, reflexivity with one's environment, and an acute recognition of how one's positionality to issues and problems affects their conscious and subconscious bias (Volberda, 1996). We have chosen to be specific and to highlight teaching and learning principles based on their applicability to Clinical and Translational Science (CTS) using enduring principles that can be applied to the micro, meso, and macro levels, backed up by self-reflection questions for instructors and learners to utilize in their own contexts as they seek to apply the principles. These questions will allow those who generally do not embrace an evidence-based learning approach to adopt practices quickly and easily in their work that will contribute to better decision making about instructional content and the development of more inherently sound learning environments.

Third, we provide insight into how understanding the multilevel nature of clinical and translational learning environments provides insights into the unique character of a translational learning ecosystem. Learning principles are applicable to individual, team, and organizational functions. Change and adaptation are key when working across the sciences and across the multiple layers of an enterprise. Our approach addresses this multilevel environment, thus addressing how learning is central to all aspects of the translational science enterprise.

A learning ecosystem for translational research (Figure 1) recognizes the need for individuals, teams, and organizations to embrace the core processes of translation, teaming, and implementation, all of which require learning and change as part of their contribution to enhancing and affecting health and health systems (Schwandt & Gorman, 2004) and are higher order learning activities. These represent the functional and transformational elements that make translational science unique and support the goals of this "newest youngest science" charged with developing "new pathways" (Austin, 2018; Zerhouni, 2003). By the intersection of these contributing core disciplines, five grounding domains of competence are key to successful engagement within the translational learning ecosystem that go beyond mere cognition but also include social and humanistic lifelong learning principles. These are *facilitating team affect (or bonding), team communications, the management of research teams, collaborative problem solving,* and *leadership* (Lotrecchiano et al., 2020).

Each of these domains has both individual, team, and organizational components and represents the catalysts for teaching and learning, namely, *prior knowledge, the organization of knowledge, motivation, mastery, practice and feedback, cognitive load, climate,* and *metacognition* (Figure 1). Critical to achieving the goals of this multilevel learning system requires a deep knowledge of these learning principles that, once understood, will assist in ensuring that the goals of the translational science community can be met using sound learning science. To extrapolate these principles, we provide an overview of these core principles, applications on the individual, team, and organizational levels, reflective questions about how one might apply each principle, and implications for the overall ecosystem.

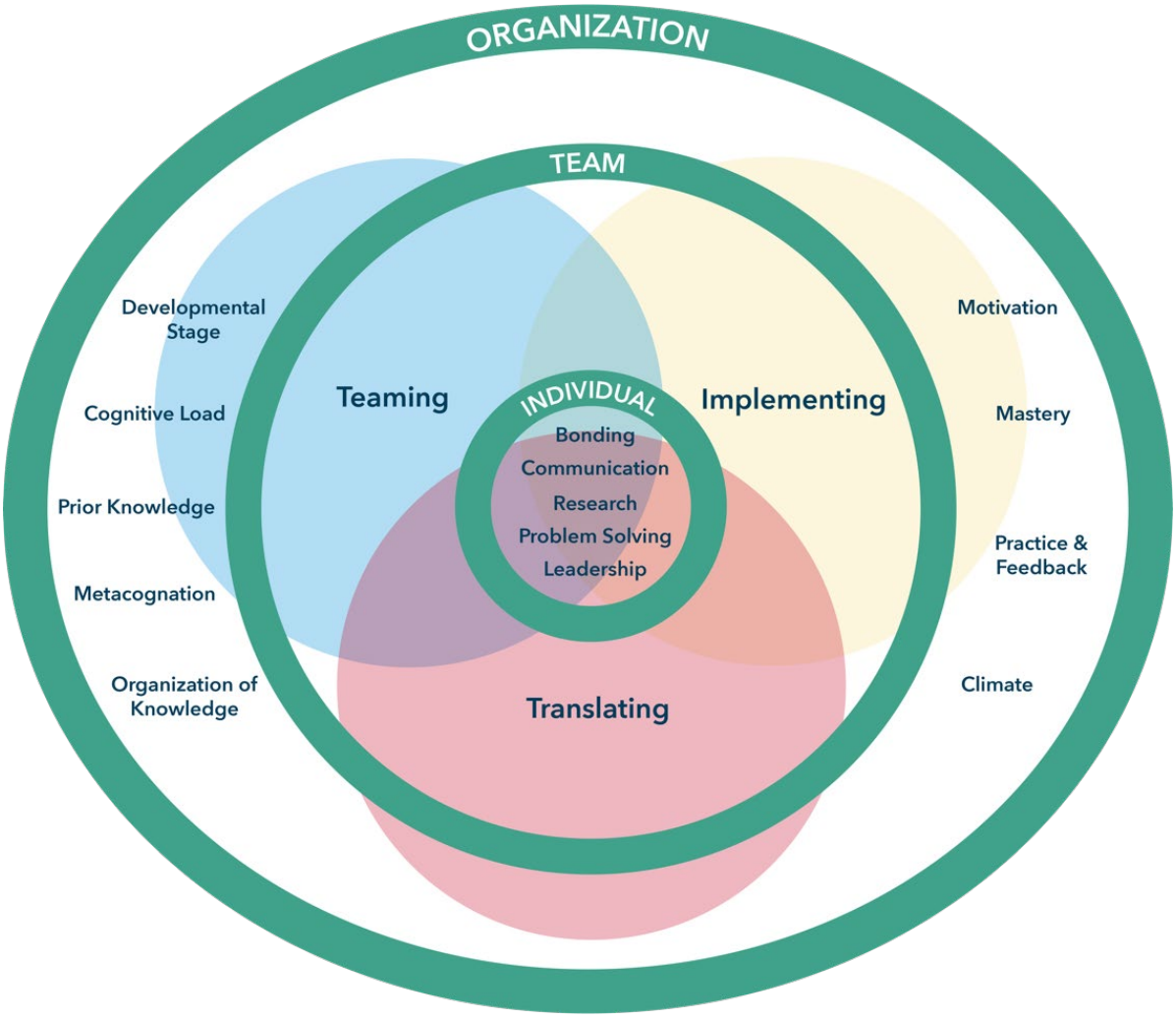

Figure 1. The Translational Learning EcoSystem

THE TRANSLATIONAL LEARNING ECOSYSTEM

We utilize the term ecosystem in a way that has been adopted not only in learning but also across several fields to describe the complex arrangement of efforts within translational science. "A learning ecosystem is a system of people, content, technology, culture, and strategy, existing both within and outside of an organization, all of which has an impact on both the formal and informal learning that goes on in that organization" (Eudy, 2018). Much emphasis has been placed on the psychological and cognitive properties of learning in individuals (Center for Leading Innovation & Collaboration, 2021); indeed, most conceptualize learning as an individual level vocation. However, other approaches to learning have emerged that are more highly steeped in group and social learning, emphasizing that learning requires social grounding and interactions within groups (Moore & Khan, 2020). Others have even promoted that life-long learning has sensemaking properties that require one to constantly problem solve through the culmination of (a) cues or information from one's environment that act as triggers or that signify that meaning is required; (b) a framework or knowledge structure (Klein et al., 2020; Lotrecchiano et al., 2016; McAllister, 1995; Schön, 1987; Weick, 1995) that includes a set of elements, rules, or values that have served as a guide to understanding; and (c) a relationship, or script, that links the new information to the framework, all of which would suggest that learning in an interactive engagement with one's surroundings and the entire environment in which they interact on emotional, behavioral, cognitive, and humanistic levels (Schwandt, 2005). Unlike oversimplified constructions of learning, here, making 'sense' of the world and applying one's interpretation are matters of grounded identity, retrospection, awareness of one's environment, through social, ongoing, focused cues that are driven more by plausibility than accuracy (Jain et al., 2010). Table 1 serves as a means of organizing core learning principles as they apply to different levels of the translational environment, along with universal reflective questions for instructors and learners, as well as the implications of the principles to impact the overall ecosystem.

Table 1: Learning Principles, the Characteristics of Effective Learning at Individual, Team, and Organizational Levels, Reflective Questions, and Implications for Influencing the Ecosystem

Core Learning Principles	Individual level	Team level	Organizational level	Reflective Question	Implications for Influencing the Ecosystem
Acquisition and Integration of Knowledge					
Prior Knowledge: Learners' prior knowledge can help or hinder learning	Successful Learners seek to connect new knowledge to existing knowledge, while identifying and addressing gaps, misconceptions, and other prior knowledge problems.	Learning Teams create opportunities for members to share knowledge, recognizing and speaking to the knowledge gaps of team members from different domains.	Learning Organizations nurture the exchange of knowledge from multiple inputs.	*What do learners currently know or believe that I must address to effectively build new knowledge?*	Develop mechanisms and opportunities in courses, on teams, and in organizations to discuss the knowledge that differently positioned learners bring, as well as misconceptions and knowledge gaps that might impede progress. Use this information to collectively build more robust knowledge structures.
Organization of Knowledge: How learners organize knowledge influences how they learn and apply what they know	Successful Learners develop effective and flexible ways to organize knowledge to meet varied goals.	Learning Teams combine different types of expertise and create opportunities to explain contextualize how they organize knowledge within their respective domains	Learning Organizations utilize agile mechanisms to organize, share, and disseminate different types of knowledge.	*What organizational frameworks do learners need to connect and use information effectively, and how can I help them develop these frameworks?*	Allocate space and time in group settings to discuss various ways of organizing knowledge to reconcile cognitive frameworks and develop shared mental models.
Cognitive Load: The intentional connecting of seemingly unrelated or extraneous information	Successful learners will be skilled in how to integrate knowledge for the purpose of expressing thoughtful meaning.	Learning teams will emphasize how constant emphasis on navigating similarities and differences in collective expertise is necessary.	Learning organizations will develop structures so that integrate knowledge become an emphasized and normative activity.	*What learning processes need to be developed so that learning is a foundational tenet while decreasing extraneous cognitive load?*	Emphasize how the task of translation is to exchange, integrate and simplify the complexity associated with teaming, translating, and implementing.

Core Learning Principles	Individual level	Team level	Organizational level	Reflective Question	Implications for Influencing the Ecosystem
Metacognition: To become self-directed learners, learners must monitor and adjust their approaches to learning.	Successful learners assess the demands of a task, evaluate their own strengths and weaknesses, devote time to planning, monitor their progress as they work, and take time after a project to reflect on their performance.	Learning Teams allocate time for task assessment and planning, designate opportunities mid-project to assess and modify processes, and take time after project completion to discuss and capture lessons learned.	Learning Organizations designate opportunities for collective reflection to identify and foster effective practices.	*How can I provide appropriate opportunities for planning, monitoring, and reflection to promote metacognition?*	Build structured opportunities (during classes and trainings, at the mid- and endpoints of projects, and after major new institutional initiatives) to reflect and distill lessons learned. Be deliberate about developing the habit of reflection. Establish mechanisms for preserving and acting on the insights generated as a normative throughput activity.
Social and Emotional Components of Learning					
Motivation: Learners' motivation determines, directs, and sustains what they do to learn.	Successful learners are aware of the important role of expectancy and value (including autonomy, mastery, relatedness, and purpose) in motivation, and leverage them to maintain motivation and persistence.	Learning teams identify the goals and motivations of team members and seek to align them to reach optimal performance.	Learning organizations provide recognition and rewards matched to the goals and ambitions of members, while minimizing obstacles to success.	*How can I help to build value and expectancy to spark and sustain motivation?*	Work to increase the factors that enhance motivation, whether in classrooms, on research teams, or among faculty and staff. Look to align individual goals with group goals, highlight the larger purpose of tasks and outcomes, reduce unnecessary obstacles, encourage independence, create opportunities to demonstrate mastery, and foster strong social connections.
Climate: Learners' current level of development interacts with the social, emotional, and intellectual climate of the course to impact learning.	Successful learners attend to their own learning needs and seek out environments that support their intellectual growth	Learning Teams recognize the importance of trust and work to build an environment that promotes psychological safety.	Learning Organizations prioritize the development of an equitable and inclusive work environment.	*How can I foster and sustain an environment that provides learners the support and safety they need to thrive?*	Draw on the knowledge and expertise of learners. Be aware of how subtleties in tone and messaging affect climate and actively work to create inclusive team and organizational environments.

Core Learning Principles	Individual level	Team level	Organizational level	Reflective Question	Implications for Influencing the Ecosystem
Presence: The ability of learners to engage through social, cognitive, and teaching presence	Successful learners engage with others, content, and instructive influences equally to maximize learning outcomes	Learning Teams exercise engagement in multiple ways that include interpersonal, mental, and exploratory experiences.	Learning Organizations construct avenues and secure resources that ensure presence is a priority no matter the modality or context.	*How can one utilize learning opportunities to respond to the social, cognitive, and relational needs of learners?*	View learning opportunities as holistic experiences that tend to the social, cognitive and relational needs of all involved and utilize instructional design to satisfy these different needs.
Elements of Skill Building					
Mastery: To develop mastery, learners must acquire competent skills, practice integrating them, and know when to apply what they have learned.	Successful learners recognize that mastery is developmental and work to acquire key skills, seek opportunities to practice integrating them, and learn to use them appropriately in diverse contexts.	Learning Teams develop collective mastery by identifying and integrating members with necessary skill sets and working to utilize these skill sets effectively across contexts.	Learning Organizations identify desired areas of specialization and create opportunities for skill acquisition, integration and application.	*What are the domains of mastery I hope to develop, and how can I help learners acquire the relevant component skills, learn to integrate them, and apply them in appropriate contexts?*	Be aware of and work against expert blind spots in all contexts. Recognize that mastering complex skills requires time and patience. Provide opportunities, both for individuals and groups, to analyze complex tasks, break them into their component skills, practice these skills in isolation and then in combination, identify when and where these skills are applicable, and learn to apply them effectively to a range of problems.
Practice and Feedback: Goal-directed practice, coupled with targeted feedback enhances the quality of learning.	Successful learners identify skills they need to build, pursue opportunities for practice, and seek out feedback.	Learning Teams designate opportunities for members to learn and practice new skills and prioritize the sharing of feedback.	Learning Organizations create a culture in which regular sharing of feedback is normative.	*What specific skills do learners need to practice and what kinds of feedback can I provide to help them improve?*	Identify skills and subskills that individuals, teams, or organizations need and lack, and create opportunities for deliberate practice, allowing sufficient time for repetition. Create mechanisms and opportunities to provide constructive, timely feedback on individual and group performance.

DISCUSSION

Translational research, team science, and implementation science share a core reliance on ongoing, multi-dimensional, distributed learning. Moreover, the history of these pursuits and of education have moved on parallel tracks, shifting increasingly towards a team orientation, geographical distribution, technological mediation, attention to "soft" skills, and a mandate for diversity, equity, and inclusion. As such, these enterprises have much to learn from and teach one another. It is our contention that the principles of learning – rarely brought to the forefront of consideration in translational science discussions – underlie essential facets of learning at the individual, team, and organizational levels and in all aspects of translational research, team science, and implementation science. Moreover, as the individual competency domains necessary to ensure productive, satisfying teamwork and agile organizations become more clearly defined in the literature (Uhl-Bien et al., 2007), the mechanisms by which we acquire these competencies and teach them to others will become more salient.

As demonstrated, there is much that learning science offers to translational research. This includes a deep understanding of the psychology of motivation, recognition of how new knowledge builds on prior knowledge, and strategies for shaping our work environments to foster inclusive learning. The learning sciences explain why the way we organize knowledge influences how we are equipped to use it, whether working alone or in teams, how feedback can be most effective, and how enlisting the cycle of metacognition more intentionally can make us more reflective and adaptive as learners. A deep understanding of the learning sciences and its explication of the core mechanisms of learning can illuminate learning at all the levels – individual, team, and organization – explored here, helping us to become more effective teachers, mentors, team members, and administrators and positioning our students, teams, and organizations for the rapid evolution and innovation required of our fast-changing, complex world.

STUDY HIGHLIGHTS

In this paper, we have sought to *connect* the learning sciences with translational science. We have tried to *tailor* the principles we have extracted from voluminous scholarship in the learning sciences to fit the contexts in which translational learning occurs, and we have attempted to *simplify* those principles, paring them down to make them accessible and useful to people outside education. We have argued that, because *learning is the ultimate translational science,* learning sciences are tailor-made for the most essential goals of translational science, and it is time we made better use of this rich and relevant literature. The argument we make is based on the following key points.

- Learning is intrinsically linked to translation, teaming, and implementation in the clinical translational enterprise.
- The integration of learning science is critical to the success of the clinical translational enterprise.
- The clinical translational enterprise needs to give equal attention to learning on the individual, team, and organizations level to maximize success.

CONCLUSION

We hope this article will consolidate the understanding of and provide a shared vocabulary for those already engaged in explicitly educational work and familiar with the learning sciences, while at the same time using the learning sciences to shed new light on the translational landscape, where learning constantly unfolds yet learning research has rarely been applied. We offer this as the beginning of what we hope will be a long and fruitful discussion about avenues to foster learning in all aspects of translational science.

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CONFLICTS OF INTERESTS

None.

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AUTHORS

Dr. Gaetano Lotrecchiano, EdD, PhD, is an Associate Professor of Clinical Research and Leadership at the George Washington University School of Medicine and Health Sciences where he specializes in team science. He is the University Associate Dean for Innovative and Collaborative Pedagogy and leads the Instructional Core for Advocacy, Research and Excellence in Teaching and Learning (ICare). He is the co-editor of Communication in Transdisciplinary Teams. Informing Science Press (2020). He is a Morton A. Bender awardee for Teaching Excellence and a member of the GW Academy of Distinguished Teachers.

Dr. Marie Norman, PhD, is an Associate Professor of Medicine and Clinical and Translational Science at the Institute for Clinical Research Education at the University of Pittsburgh. She directs the Innovative Design for Education and Assessment (IDEA) Lab and co-directs the Clinical and Translational Science Institute's Team Science core, where she focuses on providing tailored human centered design training to researchers. Norman is co-author of the book How Learning Works: Seven Research-Based Principles for Smart Teaching (2010).