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Developing a Shared Mental Model of Team Functioning in the Context of Research

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Abstract

Despite the fact that the number of disciplines and specializations in universities has burgeoned over time, education and training remain discipline-specific. Consequently, investigators attempting to address complex problems like the prevalence and severity of psychiatric disorders are hampered by the absence of a template for working together to capture the complex, and often multi-level, nature of these problems and turn their jointly-acquired knowledge into practice and policy solutions.

Effective team functioning relies on the ability of investigators from different backgrounds to communicate with one another, understand one another's work, and develop a shared identity, mission, and goals. This is facilitated by the development of a shared mental model of the research endeavor. Here, after describing various modes of disciplinary collaboration, we describe the development of such a shared mental model in one site of a transdisciplinary team-based research initiative of the U.S. National Institutes of Health. This site that was located at the University of Chicago included investigators from the social, behavioral, and biological sciences, some of whom were clinician-scientists. We describe the stages of the team's development and mechanisms that were used successfully to create a shared mental model. This model took individual investigators outside their home disciplines to create new intellectual space and provided evidence of its success in achieving transdisciplinary functioning. We also provide evidence that the approach increased the item's ability to work collaboratively.

"No one discipline can comprehend the full range of knowledge; science is a collective rather than an individual possession." –Kahn & Prager, 1994

The number of disciplines providing instruction has grown exponentially in the centuries since the first universities were founded in the 13th century [1]. New disciplines and professions emerged as knowledge accumulated, with sub-disciplines or specialties appearing as knowledge bases expanded within each discipline. Medical education came about in the 18th century, as a supplement to the existing apprenticeship system that had operated until that time. Consequently, what began as a handful of disciplines and professions now numbers in the thousands. Despite the proliferation of disciplines and professions, students continue to be trained in just one. This presents a problem, because students who are trained exclusively in one discipline or profession lack a template for working in concert with others. In addition, as science becomes increasingly more sophisticated through knowledge accrual, the daunting nature and complexity of problems facing societies becomes apparent. The simplicity of Gregor Mendel's 19th century discovery that genes are inherited is eclipsed by recent discoveries in epigenetics and 21st century efforts to edit genes by modifying or replacing their DNA.

Although we now know that pressing social problems like the prevalence and severity of psychiatric disorders are underlain by factors as diverse as biological pathways and societal norms that interact in complex ways to determine outcomes [2, 3], disciplinary scholars largely remain siloed in their efforts to control and treat these disorders. Biological, social, and behavioral scientists seldom work together, and their investigations rarely include those providing treatment or setting policy. The purpose of the present article is to describe a system for developing shared identity and communication among scientists and practitioners from different backgrounds who are attempting to work together to address shared problems. This system is based on an initiative of the U.S. National Institutes of Health that was designed to incentivize a transdisciplinary approach to addressing racial and ethnic disparities in cancer mortality [4]. This approach offers valuable lessons for increasing team performance to better address complex problems like those faced by scientists and practitioners around the world. While the abundance of knowledge that has accrued about these problems provides hope, translating this knowledge into effective solutions depends on investigators' ability to work together and to vet their work with practitioners.

1. The Transdisciplinary Approach to Science

Based on knowledge that most problems facing societies have multiple influences, transdisciplinary science has gained attention because it allows scientists to transcend and operate outside their individual boundaries and cultures to capture new, more-expansive realities, mutually inform one another's work, and better address complex phenomena like the outcomes of psychiatric disorders [5]. Here we distinguish transdisciplinary science from other modes of collaboration. The three main approaches to collaboration across disciplines are multidisciplinarity, interdisciplinarity, and transdisciplinarity. All are opposed to an approach in which work is done entirely within one discipline, sometimes referred to as monodisciplinarity.

Multidisciplinary research occurs when scientists from different disciplines work together at some point in the research process. Although they might work on a shared project, they approach it with separate research questions, theories, and methods derived from their disciplines, and devise separate conclusions. This compromises the group's ability to take a broad and inclusive view of the problem they were attempting to address and to work together to devise solutions. Interdisciplinary research usually occurs when two disciplines come together to share knowledge and may result in the creation of a new discipline. While disciplinary scholars inform one another's work and compare their findings prior to the conclusion of a project, McGregor [6] cautions that, "even though the boundaries come down so information can flow between the disciplines, when an answer has been found that serves the needs of the root discipline, the walls come up" (p.1).

Transdisciplinary research occurs when disciplinary scholars operate entirely outside the bounds of their individual disciplines to create new intellectual spaces, which Lattzani [7] has characterized as intellectual outer space. Transdisciplinarity differs from other modes of collaboration in that scholars operate in this newly created space rather than merely transferring knowledge from another discipline to their own. This may entail synthesizing separate disciplinary theories and methods and posing questions that had never been posed in any one discipline.

2. The Benefits of Transdisciplinary Research in Health

Green and colleagues [8] estimate that translating a scientific discovery into practice, even something as simple as prescribing daily low-dose aspirin to prevent cardiovascular accidents, takes up to twenty years. While some of this research-to-practice gap is inevitable, such as the time that it takes to test a treatment for safety and effectiveness, our tendency to work within individual disciplines further slows translation. As an example, investigators' tendency to publish in discipline-specific journals, often reinforced by university promotion practices, reduces the likelihood that scientists from other disciplines are exposed to the work. This impedes the cross-fertilization of ideas and synthesis of knowledge needed to address vexing and complex scientific problems. When knowledge sharing is not built into the design of a center's research approach, disciplinary scholars are challenged to make meaning of disparate results. When they bring their separately derived findings together at the end of the funding period, their efforts to address the problem for which they were funded are hampered by lack of communication along the way. The process of fitting together the results of individual projects can be like trying to fit square pegs into round holes. In contrast, transdisciplinary research speeds translation by fostering communication among disciplinary scholars, who are then more likely to work together, share ideas, and publish in venues read broadly across disciplines and by practitioners and policy makers [9]. The new intellectual spaces created become incubators for ideas that take scholars outside their own disciplines to create new ways of doing science. Sharing occurs across investigators and projects as information is continuously fed from one project to the next through regular communication. Shared results emerge from the cross-investigator and cross-project interactions in addition to those that emerge from individual efforts. Because these results are broader and more holistic, they are more likely to be implementable to address a center's aims.

3. U.S. National Institute of Health Initiatives

Transdisciplinary research can occur within a single research project or across the projects of a research center. The National Cancer Institute (NCI) at the U.S. National Institutes of Health launched three transdisciplinary research center initiatives between 1999 and 2005: Transdisciplinary Tobacco Use Research Centers (TTURC), Centers for Population Health and Health Disparities (CPHHD), and Transdisciplinary Research on Energetics and Cancer (TREC). Each of the three initiatives operated in 3-8 sites across the country, with up to five projects per site. Thus, transdisciplinary ties were possible within individual projects, across projects within a center, and between centers of a multi-site initiative. The author was involved in the administration of CPHHD [4] and TREC [10].

Analyses of the effectiveness of this transdisciplinary initiative on cross-disciplinary knowledge production have been positive. Gehlert and colleagues [11] have been able to demonstrate that features of the TREC initiative's design resulted in a higher number of publications across sites over the initiative's five-year period of operation than in mechanisms that were not transdisciplinary [12]. The nature of the publications also differed. The number of publications by teams of authors from multiple disciplines increased over time as did the number of publications involving authors from different TREC sites [11]. High joint committee and work group activity in the first two years of operation yielded to, and likely generated, higher rates of joint mentorship of students and trainees, publications, and funding applications in subsequent years. Over the initiative's five years of funding, the number of ties across investigators from different sites increased from 15.6% after the first year of operation to 39.7% during the fifth year [11]. The within-site ties remained the same after the first year, suggesting that once investigators within centers maximized their collaborations, they sought investigators from other sites to expand the scope and nature of their questions. This was true of specific investigator's expertise and of facilities shared across sites. One of the five TREC sites had expertise in clinical trials on physical activity and cancer and two of the five sites had high-speed gene sequencers. Sharing this expertise and equipment conserved resources and greatly increased capacity.

4. Creating Shared Identity on Transdisciplinary Teams

Hall and colleagues proposed a four-phase model of the phases of development of a transdisciplinary research team, with development, conceptualization, implementation, and translational phases [13]. The four-phase model is useful in identifying the steps that lead to the final stage, translating research results into real-world applications. The first or development phase includes the process of forging a shared mission and goals, as members become aware of the scope of their team's enterprise [13]. This shared mission and goals then form the basis for developing a shared model across individuals and projects during the team's implementation phase.

As outlined by Hall et al., developing a shared mental model of research is critical to establishing that team communication and problem-solving skills that allow a research plan to succeed [13]. Because research funding is time limited, expedient development of a research plan allows teams the time needed to achieve their strategic aims.

Thus, developing a shared mental model is critical to success. Nonetheless, shared model construction requires actions to decrease the likelihood that projects will operate as separate constellations or decrease the likelihood that the model developed represents the contributions of all center projects. In either case, group cohesion will suffer and teams will fail to achieve their full potential.

Maintaining group functioning often falls to the team leader. The leader's role is important for establishing an environment in which team members feel comfortable to freely exchange ideas in ways that minimize competition and defensiveness. Strategies that privilege one way of knowing over others can be avoided if the leader is vigilant in maintaining a level playing field across investigators and projects. Inevitable mistrust can be counteracted by establishing a system of continual dialogue between projects with adjustment in design as indicated. Hearing new findings from other projects as they emerge can spark unanticipated ties between projects and help them to achieve the center's overall specific aims.

Constantly forcing the bigger picture allows the leader to counteract the inevitable tendency to regress to the mean of monodisciplinary functioning. In the case of the University of Chicago CPHHD center, this was achieved using a guided process in which team members spent time developing a shared mental model of their project or center [14]. In the case of a project, effective use of this method allows individual investigators to articulate their unique contributions to the project. In the case of a center, an effective model is one in which investigators are able to identify their project's unique contribution. When done well, each team member can tell the team's story and point out where and how their work fits into that story.

During its developmental phase, the University of Chicago CPHHD team explored ways of integrating their projects into an articulate whole. It became clear that the four projects had the potential to be mutually informative and that taken together, could provide an ideal mechanism for investigating the pathways through which the social environment shapes biology and health. The group realized that their different disciplinary origins gave them the unique opportunity to consider social, behavioral, and biological aspects of health using shared projects and analyses.

The process of developing a shared mental model challenged the group to incorporate all four projects into a cohesive whole that would accurately represent the contribution of each project. This required each project leader and investigator to simultaneously consider their own project and the center as an entity. This mental balance of project and center depended on an investigator's ability to articulate their own project in terms that could be understood by project leaders from other disciplines and to actively listen to project descriptions by other team members. Ultimately, the University of Chicago CPHHD team refined its shared model of the research center, including its four projects and their interconnections. This was done in a team-wide meeting in which all

investigators were present, using a white board and dry markers, with everyone adding to the model so that it eventually included all projects.

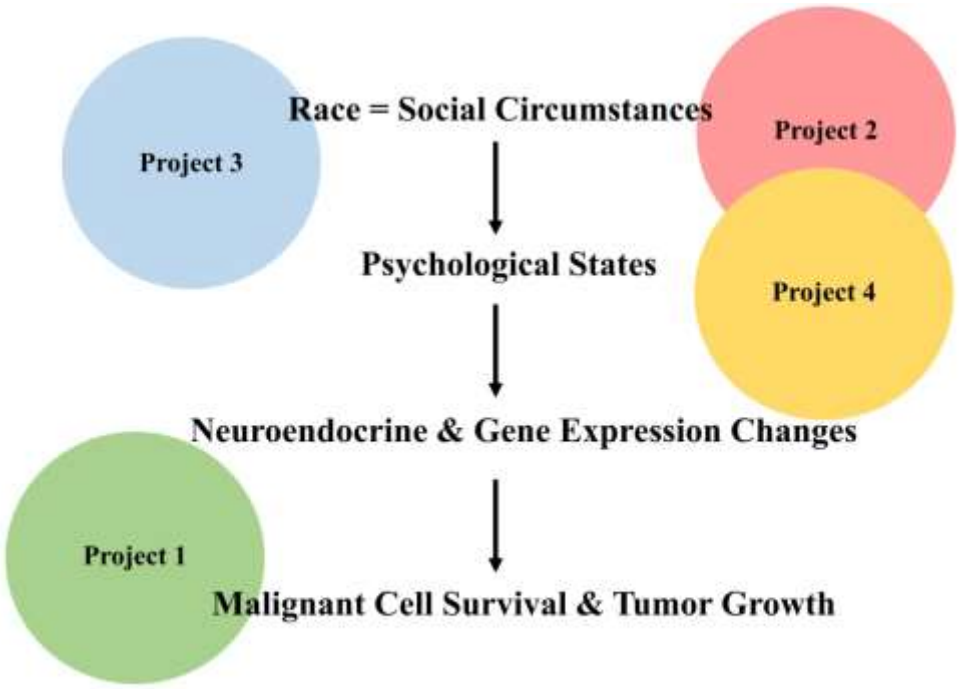

Figure 1. Shared mental model of the four research projects of the University of Chicago Center for Population Health and Health Disparities. The projects are indicated in the figure as they map over elements of the model.

The resulting model represents a multilevel and multifactorial approach to African-American and white cancer disparities that considers influences from within the cell to the level of society. Each project, two of which used animal models (Projects 1 and 4) and two of which worked with African-American women living on Chicago's South Side (Projects 2 and 3), had a place in the shared model [15].

The shared CPHHD story was one in which race for African-American women living on Chicago's South Side determined psychological functioning. Based on findings from animal modeling in Project 1 and focus groups with 503 South Side residents in Project 3, we were able to focus specifically on women's psychological reactions to social isolation. Many women in the study reported feeling lonely in the absence of family and other close social contacts. Also, crime in neighborhoods and the inability to afford safe housing caused women to spend more time at home than desired, prohibiting more casual neighborhood contacts [16]. We found a constellation of three highly correlated social and factors, isolation, depression, and vigilance in response to crime and other threats to safety, which produced two distinct groups of women in factor analysis, one of women who were depressed and lonely, and another of women who questioned their purpose in the world [16].

A mutually informative, iterative approach to science developed that allowed the team to fully explore all components of their shared model, from elements of the social environment, especially features of urban

neighborhoods, to psychological responses to those features, to gene and hormone expression within tumors. By giving each project equal weight, the approach gave investigators the opportunity to explore hypothesized determinants of hormone and gene expression changes, as well as those changes themselves, in equal depth, without favoring any one element of the model.

Over time during the group's conceptualization phase the team began to develop a shared lexicon that incorporated key words from individual projects. The shared lexicon, which included words from each project that tended to be exclusive to that discipline, further cemented the center's team-based mental model. Learning these terms gave team members tangible tools for articulating their shared story to a variety of lay and professional audiences. When leaders presented CPHHD results in pairs, it added to a sense of group unity, engagement, and joint ownership. These paired presentations had the added benefit of informing project leaders about other projects, or the parts of the shared mental model in which they were less expert. Over time, project leaders were able to present the story of the center as a whole, based on their growing understanding of other projects and how they contributed to the center's overall mission.

5. Conclusions

To date, transdisciplinary team functioning remains an ideal. Yet, it clearly is the best path to ensuring our ability to address vexing human problems like the prevalence and severity of psychiatric disorders, cancer disparities, and the COVID-19 health crisis, all of which currently challenge our collective scientific understanding. Much remains to be done to allow the new intellectual spaces to be created that are needed to address modern human problems in ways that capture their complexity. This requires a transnational, transcultural effort to help ensure that the world is a safer and healthier place for all.

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