Published in final edited form as:
Am J Community Psychol. 2014 June ; 53(0): 475–490. doi:10.1007/s10464-014-9625-7.

21st Century Science as a Relational Process: From Eureka! to Team Science and a Place for Community Psychology

Jacob Kraemer Tebes,
Yale University

Nghi D. Thai, and
Central Connecticut State University

Samantha L. Matlin
Philadelphia Department of Behavioral Health and Intellectual disAbility Services & Yale University

Abstract

In this paper we maintain that 21st century science is, fundamentally, a relational process in which knowledge is produced (or co-produced) through transactions among researchers or among researchers and public stakeholders. We offer an expanded perspective on the practice of 21st century science, the production of scientific knowledge, and what community psychology can contribute to these developments. We argue that: 1) trends in science show that research is increasingly being conducted in teams; 2) scientific teams, such as transdisciplinary teams of researchers or of researchers collaborating with various public stakeholders, are better able to address complex challenges; 3) transdisciplinary scientific teams are part of the larger, 21st century transformation in science; 4) the concept of *heterarchy* is a heuristic for team science aligned with this transformation; 5) a contemporary philosophy of science known as perspectivism provides an essential foundation to advance 21st century science; and 6) community psychology, through its core principles and practice competencies, offers theoretical and practical expertise for advancing team science and the transformation in science currently underway. We discuss the implications of these points and illustrate them briefly with two examples of transdisciplinary team science from our own work. We conclude that a new narrative is emerging for science in the 21st century that draws on interpersonal transactions in teams, and active engagement by researchers with the public to address critical accountabilities. Because of its core organizing principles and unique blend of expertise on the intersection of research and practice, community psychologists are extraordinarily well-prepared to help advance these developments, and thus have much to offer 21st century science.

Keywords

team science; transdisciplinary; interdisciplinary; community psychology; heterarchy; CBPR; philosophy of science; perspectivism

Address correspondence to: Jacob Kraemer Tebes, Ph.D., Yale Division of Prevention & Community Research and The Consultation Center, Yale University School of Medicine, 389 Whitney Avenue, New Haven, CT 06511-2369. jacob.tebes@yale.edu.

In the modern era, philosophers of science have long considered science as fundamentally a relational process governed by social and cultural norms (Kuhn, 1962; Laudan, 1990). The premise of Kuhn's now classic analysis of scientific revolutions – that they are heavily shaped by social and cultural forces -- is widely accepted by contemporary philosophers of science (Giere, 2006; Laudan, 1990; Suppe, 1977). And yet, when one reads historic accounts of scientific discoveries (Dampier, 1948; Silver, 1998) or follows closely how scientists continue to be trained today (Kessel, Rosenfield, & Anderson, 2008; Moody & Kaiser, 2008; Nash et al., 2003), the essential narrative deemphasizes the relational process of science in favor of one that elevates the solitary scientist whose creative insight sparks an extraordinary discovery. This narrative evokes the apocryphal story of Archimedes, the Greek scholar, whose king wanted to know whether his crown was made of pure gold. Archimedes puzzled over this one day while taking a bath, and had a sudden insight into the solution when noticing that his body displaced water from the tub. Without thinking, he jumped from the tub and ran down the street naked yelling, *Eureka!*

In this paper, we challenge this conventional narrative by offering an expanded perspective on how science is practiced, how knowledge is produced, and the place for community psychology in these developments. Specifically, we argue that: 1) trends in science show that research is increasingly being conducted in teams; 2) scientific teams, such as transdisciplinary teams of researchers or of researchers collaborating with various public stakeholders, are better able to address complex challenges; 3) transdisciplinary scientific teams are part of the larger, 21st century transformation in science; 4) the concept of *heterarchy* is a heuristic for team science aligned with this transformation; 5) a contemporary philosophy of science known as perspectivism provides an essential foundation to advance 21st century science; and 6) community psychology, through its core principles and practice competencies, offers theoretical and practical expertise for advancing team science and the transformation in science currently underway. Below we summarize each of these points and discuss their implications for the production of knowledge in science. We then offer two examples of their application from our own work in transdisciplinary team science.

The emergence of transdisciplinary scientific teams

In an influential paper that tracked nearly 20 million peer-reviewed publications in scientific journals since the 1960s, Wuchty, Jones, and Uzzi (2007) demonstrated that team-authored publications increasingly dominate the production of knowledge across disciplines, including the natural sciences and engineering, the social sciences, and the arts and humanities. They also showed that, when compared with publications by single authors, team-authored publications were more frequently cited and had a greater scientific impact. For some scholars, the Wuchty et al. (2007) paper confirmed what has become readily apparent -- that team-based research, which has a successful history in industry, government, and national laboratories (National Science Foundation, 2005), is ascendant (Borner et al., 2010; Kahn & Praeger, 1994).

Over the past three decades, community psychologists, prevention scientists, and public health researchers have also engaged in various forms of team-based research by developing partnerships with community stakeholders to generate knowledge and promote social change (Israel, Schulz, Parker, & Becker, 1998; Kelly, 1988; Tolan, Keys, Chertok, & Jason, 1990; Trickett & Schensul, 2009). By stakeholders we refer to community residents, service recipients and providers, family members, community leaders, and other community members who are not otherwise scientists and researchers themselves (Rappaport, 1977). When stakeholders participate directly as partners in one or more aspects of the research process (e.g., study design, data collection and analysis, dissemination and use of findings), they are engaged in community-based participatory research, or CBPR (Israel et al., 1998; Minkler & Wallerstein, 2008). Similar to teams of scientists working together, in CBPR researchers and community stakeholders function as a team to: a) conduct the research, b) jointly own its various components (e.g., methods, data, analyses, products), c) engage in co-learning and mutual empowerment when carrying out specific research tasks, and d) use an iterative process to incorporate multiple and diverse perspectives into the research endeavor (Israel et al., 1998; Israel et al., 2008; Minkler & Wallerstein, 2008; Tebes, Kaufman, Connell, Crusto, & Thai, 2014).

Unidisciplinary, multidisciplinary, interdisciplinary, and transdisciplinary research

Collaborations among scientists and between scientists and community stakeholders have emerged in response to complex biomedical, social, public health, and global challenges that can no longer be addressed by individuals working in isolation or within a single discipline (Abrams, 2006; Kahn & Praeger, 1994; Stokols, Misra, Moser, Hall, & Taylor, 2008). The mapping of the human genome (International Human Genome Sequencing Consortium et al., 2001; Venter et al., 2001), the work of the CERN inter-governmental particle physics laboratory on the basic building blocks of the universe (Knorr-Cetina, 1999), the use of large-scale scientific networks to address health disparities (Adler & Stewart, 2010), and CBPR partnerships of various kinds, such as to reduce smoking among residents of public housing neighborhoods (Andrews et al., 2012) or to successfully implement HIV prevention strategies (Yancy et al., 2012), each illustrate the wide range of effective team-based scientific collaborations to address complex challenges.

The shift toward team-based research, among scientists or between researchers and community stakeholders, also parallels a gradual move away from unidisciplinary to interdisciplinary research (Kessel, Rosenfield, & Anderson, 2008; Porter & Rafols, 2009). Rosenfield (1992) was the first to define the distinctions among different disciplinary approaches, such as unidisciplinary, multidisciplinary, interdisciplinary, and transdisciplinary research. In unidisciplinary research, science is conducted from the perspective of a single discipline, whereas in multidisciplinary research science is carried out independently by unidisciplinary researchers but informed by the work of one or more other disciplines. The advantage of multidisciplinary research is that the researcher has direct access to findings and approaches from different disciplines for use in one’s own research.

In contrast, interdisciplinary research involves interactive and collaborative engagement among investigators from different disciplines (Rosenfield, 1992). Such research begins with a common problem for which investigators develop a shared cognitive schema and then incorporate new conceptual frameworks, methods, tools, measurements, analyses, and/or interventions to address the problem (Porter & Rafols, 2009; Stokols, Harvey, Gress, Fuqua, & Phillips, 2005). The emergence of interdisciplinary team science represents a special case of interdisciplinary research in which the work is carried out by a team of researchers who are not from the same discipline but who adopt shared cognitive schemas and other innovations (Borner et al., 2010; Kessel, Rosenfield, & Anderson, 2008; Tebes, 2012b).

When the blending of interdisciplinary perspectives produces a hybrid perspective of two or more disciplines, some scholars have called that "transdisciplinary" research (Abrams, 2006; Rosenfield, 1992; Stokols, 2006). In transdisciplinary research, the hybrid innovations that emerge from interdisciplinary collaboration are the foundation for a new discipline that transcends its constituent parts (Hall et al., 2012; Rosenfield, 1992). Bioengineering, cognitive science, women's studies, science and technology studies, and sustainable development represent examples of hybrid disciplines that emerged from the combination of two or more areas of disciplinary study. In practice, however, interdisciplinary investigators rarely create a new discipline from the innovations that blend two or more disciplines. Rather, the shared cognitive schemas and related innovations generate new knowledge that subsequently influences multiple disciplines, but does not lead to a new hybrid discipline (Kessel et al., 2008). In this paper, we use the terms interdisciplinary research and transdisciplinary research interchangeably because both involve conducting science from shared disciplinary perspectives. Their essential difference – the emergence of a new hybrid discipline – does not alter the specific practices among those engaged in the research, but represents an ultimate outcome affirmed by the scientific community well after the research is conducted.

Nevertheless, the term transdisciplinary research may be more useful when describing collaborations between researchers and non-researchers because it connotes that the partnership transcends disciplinary boundaries, perhaps even extending beyond what is traditionally regarded as science (Maton, Perkins, & Saegert, 2006.) For example, whereas partnerships among scientists share a common commitment to generating knowledge through the use of systematic observations and methods, partnerships between researchers and community stakeholders may require navigating different worldviews. In the case of the latter, differences may involve negotiating which action to take to address the challenge prompting the research and about the roles of the various actors involved in the partnership (e.g., researchers, community members, government officials, or research participants) (Maton et al., 2006; Nowotny, Scott, & Gibbons, 2003a, 2003b).

Transdisciplinary scientific teams and the current transformation in science

The emergence of transdisciplinary scientific teams is part of a current transformation in science. Michael Gibbons, Nancy Nowotny, and colleagues have described this transformation in two books -- *The New Production of Knowledge* (Gibbons et al., 1994) and *Re-Thinking Science* (Nowotny et al. 2003a) – in which they posit two types of science: Mode 1 and Mode 2. Mode 1 science is emblematic of the "old paradigm of scientific discovery… characterized by the hegemony of theoretical, or at any rate, experimental science; by an internally-driven taxonomy of disciplines; and by the autonomy of scientists and their host institutions, the universities…(Nowotny et al., 2003b, p. 179). In contrast, Mode 2 science represents "…a new paradigm of knowledge production…(that is) socially distributed, application-oriented, trans-disciplinary, and subject to multiple accountabilities" (Nowotny et al., 2003b, p. 179).

Of particular relevance here, in addition to the authors' observation that Mode 2 science is increasingly transdisciplinary, is that it is also socially-distributed and accountable, that is, embedded in collaborative and contested social, political, and economic contexts and subject to related constraints (Gibbons et al., 1994; Nowotny et al., 2003a). Community psychologists have long identified a central limitation of what is here called Mode 1 science – that it seeks to transcend local contexts so as to achieve universality, but in so doing becomes *decontextualized* so as to lose meaning and relevance for those contexts (Shinn & Toohey, 2003; Susskind & Klein, 1985; Tebes, 2005, 2010; Trickett, 1996; Trickett & Schensul, 2009; Tolan et al., 1990). In *Re-Thinking Science*, Nowotny et al. (2003a) describe how Mode 1 science uses the power and privilege it derives from putatively transcending local contexts to "speak to society" authoritatively. They also note that in Mode 2 science, society increasingly "speaks back" to science to emphasize public accountabilities and societal values (Nowotny et al., 2003a, 2003b). Thus, local context, cultural epistemologies, political realities, public health benefit, economic constraints, and open access and transparency, are increasingly part of the conversation between science and society. Nowotny et al. (2003a, 2003b) call the nexus where that conversation takes place the *agora*, an archaism that refers to the public square where knowledge production, including science, is contextualized, according to considerations like those noted above. Thus, scientific knowledge is no longer produced only by and for other scientists and their immediate constituencies in government or industry, but co-produced by a public whose concerns are embedded in multiple contexts and perspectives (Irwin, 2008; Nowotny et al., 2003a).

It is important to note that the Mode 1/Mode 2 distinction has not been without controversy. Scholars have criticized its apparent limited empirical support, its potential commodification of science for utility and commercial value, and its flawed theoretical analysis (Godin, 1998; Hessels & van Lente, 2008; Mirowski & Sent, 2008). Some have even argued that the description of Mode 2 science represents a hoped for vision for science rather than a depiction of its current state (Godin, 1998; Hessels & van Lente, 2008). In our view, the boundaries between the two modes are far more fluid than depicted by their original authors, which community psychologists and various other scholars involved in community-engaged research know well because they live in both scientific worlds. Nevertheless, the depictions of Mode 1 and Mode 2 science capture many of the essential critiques of contemporary science noted by scholars in community psychology (Cauce, 2011; Gone, 2011; Maton et al., 2006; Shinn & Toohey, 2003; Stokols, 2006; Susskind & Klein, 1985; Rappaport, 2005; Tebes, 2005, 2010; Trickett & Schensul, 2009; Trickett et al., 2011; Tolan et al., 1990), and are useful frameworks for identifying strengths and limitations of the different approaches to contemporary scientific practice. Yes, much of science remains internally-driven, university-based, and authoritative in its stance toward society; however, this mode does have real value for enhancing knowledge and improving the human condition as the many advances in public health demonstrate. And yet, when science is publicly-engaged, responsive to local contexts, and reflexive in scope and purpose to the *agora*, society also benefits. We believe, in fact, that there is an emerging dialectic between Mode 1 and Mode 2 science that reveals the potential benefits and limitations for knowledge production. This dialectic fosters an ongoing conversation between society and science and the development of structures that further this conversation. Transdisciplinary team science, particularly when it involves collaborations between researchers and non-researchers, offers a model for engagement that can blend both modes. What is needed is a way to conceptualize this engagement, its philosophical justification within science, and examples of how it can be done. Each of these is addressed in the remaining sections below.

The concept of *heterarchy* as a heuristic for team science

Implicit in the traditional narrative of how science is practiced is that it involves a key person, the scientist as principal investigator (PI), working in a single discipline who is accountable for the research. Scientific prizes are awarded to individuals not teams, even though the research occurs over many years and clearly requires team effort and intense collaboration. The PI receives funding from extramural sources (government, industry, philanthropy), hires staff (and may involve students) to carry out the research, and leads the research team to write up peer-reviewed publications of discoveries and innovations. The research is theoretically-driven, and seeks to resolve gaps in knowledge identified by scientific peers. Finally, the structures that are accountable for the research are organized hierarchically – from the funder that supports the research, to the institution that receives funding, to the department or center that houses the PI and other investigators and staff, to the team that carries out the research under the PI’s leadership. The accountabilities for the entire enterprise are hierarchical at each level, and so it is not surprising that the public narrative of who is credited for a key discovery is the PI, even though it took extensive collaboration and team expertise to carry out the research.

What Nowotny, Gibbons, and their colleagues have shown, however, is that this public narrative is shifting toward a more socially distributed, transdisciplinary science that contains inherent complexities and multiple accountabilities (Gibbons et al., 1994; Nowotny et al., 2003a, 2003b). What is needed is a framework that takes into account this complexity and provides guidance for scientific practice that incorporates structures and processes essential to collaboration and transdisciplinary scholarship, that is, essential to *science as a relational process*. Building on earlier work by Kessel et al. (2008), we have proposed “heterarchy” as a heuristic that does just that (Tebes, 2012a; Tebes et al., 2014). A heterarchy is “a biological or social organizational system that consists of an interconnected and overlapping network of components that operate dynamically to both emerge from and govern the interactions of constituent components” (Tebes, 2012a, p. 25). Common examples of heterarchies include individuals acting dynamically in various interconnected groups (e.g., families, peers, neighborhoods), specific regulatory processes in living cells, and Wikipedia (Tebes, 2012a).

Our concept of heterarchy is emblematic of complex adaptive systems and entirely consistent with the literature on complexity (Cilliers, 1998; Miller & Page, 2007). A complex adaptive system is one that: a) is comprised of many elements that interact dynamically with one another and with elements outside of the system, and thus is "open"; b) has interactions that are nonlinear that include feedback loops; c) has elements with histories that inform interactions; d) has a range of timelines in which interactions occur as a way to adapt to changing environmental demands; and, e) is not reducible to a single understanding or analysis (Cilliers, 1998, 2013).

Team science requires shared leadership structures to oversee different phases of the research enterprise and organizational processes that foster collaboration and relationally-centered research practice. The concept of heterarchy offers a 21st century heuristic for transdisciplinary team science that promotes the development of new solutions to scientific practice and allows one to readily incorporate public accountabilities into the research process. Heterarchy also provides a new framework for understanding and organizing how researchers can work together to contribute to scientific teams as both leaders and collaborators. Consistent with research on complex adaptive systems, we recognize that specific components of the research process may benefit from being organized hierarchically (Cilliers, 2001, 2013; Holland, 2012), especially when efficient functioning of a unit or team is essential. However, a companion framework that emphasizes heterarchy encourages shared leadership and control over the research process, thus providing guidance for how researchers and community stakeholders can be co-producers of scientific knowledge.

For example, any community of scientific scholars has formal and informal norms for communication and governance (Irwin, 2008; Laudan, 1990), and heterarchy provides a heuristic for bridging such tasks for scholars and the public. In traditional (Mode 1) science, there is a premium placed on norms that emphasize "…rationality, objectivity, universalism, centralization, and efficiency" (Jasanoff, 2005; p. 14). Scientific peer review and accepted standards of evidence are two such norms, grounded in what Jasanoff (2005) calls "old" world modernity. In contrast, the contemporary era increasingly values political and cultural emblems that advance "…pluralism, localism, irreducible ambiguity, and aestheticism" (Jasanoff, 2005; p. 14). Heterarchy blends these two worlds by adopting a *both/and* perspective, that is, it fosters the development of structures that advance communication and participation between and within traditional, Mode 1 science practiced in transdisciplinary teams and new world, Mode 2 science that involves academic-community partnerships.

One structure that illustrates the potential of this heuristic to shape science within a biomedical and public health context is the establishment in 2006 of the Clinical and Translational Science Awards (CTSA) program at the National Institutes of Health (NIH, 2006a; Zerhouni, 2007). Funded through the NIH Road Map Initiative to support interdisciplinary research (Zerhouni, 2003), 61 national centers have now been established through the CTSA program with the goal of speeding translational research, that is, research that translates knowledge from biomedical discoveries to clinical practice and, ultimately, to daily health behaviors (Kon, 2008; Westfall, Mold, & Fagnan, 2007; Zerhouni, 2007). These multiple levels of knowledge translation require breaking down disciplinary boundaries in order to address public health challenges, and the CTSAs have become a leading engine for transdisciplinary team science (Lindau et al., 2011). Importantly, however, the CTSAs have also emphasized breaking down barriers between science and health care practice, and have developed requirements, and related principles for CTSAs to engage local communities in research that benefits communities (Clinical and Translational Science Awards Consortium, 2011; Lindau et al., 2011). The original CTSA program mostly reflects a Mode 1 framework in which science speaks to society (NIH, 2006a). However, the academic-community partnerships required by the CTSAs have created structures in which society, in the form of local community stakeholders, are speaking back to science to identify local needs and priorities, even though fully equitable partnerships may not as yet have been realized (Lindau et al., 2011; Clinical and Translational Science Awards Consortium, 2011; Shepard et al., 2013; Terry & Leshner, 2013). This blend of Mode 1 and Mode 2 science within the CTSA program is emblematic of heterarchy as an organizing framework for transdisciplinary team science.

Another recent development, also at NIH, that is consistent with the concept of heterarchy is the establishment of the multiple principal investigator, or Co-PI, structure for individual research grant awards (NIH, 2006b). The explicit purpose of this structure is to foster team science projects in which multiple PIs "share authority and responsibility for leading and directing the project, intellectually and logistically" (NIH, 2006b. 1). Co-PIs that submit grants under this structure must describe the rationale and operation of a shared leadership structure, including how decisions will be made, communication carried out, and conflicts resolved. This Co-PI structure, however, is not intended to replace the existing PI system, but to supplement it when doing so makes sense scientifically and practically. The use of this heterarchical structure for organizing research is likely to grow along with the trend toward team science.

Not only has team science led to a shift toward heterarchical organizational structures in some CTSAs and in allowing for Co-PIs, it also has led to an emphasis on facilitating interpersonal processes that lead to effective scientific collaborations. Bennett and Gadlin (2012) describe a variety of relational processes they believe to be critical to team science collaboration, including: team building, facilitating trust, creating a shared vision, sharing recognition and credit, effective communication, and fostering enjoyment in the science. Stokols and his colleagues (Stokols et al.,2003; Stokols et al., 2005) emphasize how interactions within scientific teams, even those focused on sharing ideas or specific practices, ultimately involve interpersonal transactions and communications. Giere and Moffatt (2003) use the term "distributed cognition" to describe how collaborative activities among scientists can be both cognitive and social when scientists work together to solve problems. And Dunbar (2000) describes how distributed reasoning occurs in scientific teams to promote creativity and effective problem solving. As these examples show, heterarchy directs our attention to the relational processes and dynamic interactions among scientists working in teams, not their position relative to one another or their accountability to a particular team leader to perform a given task.

A science that is organized by taking into account heterarchy is more likely to incentivize structures, processes, practices, and skills that (Tebes et al., 2014): a) value interdependent expertise critical to the work of the team; b) encourage interpersonal processes that promote and sustain collaborations among investigators; c) favor engagement among a variety of stakeholders involved in the research, including non-researchers, whose involvement may inform innovation and promote discovery; and, d) foster the development of institutional structures that support team science. In this 21st-century-era of relationally-based, networked-mediated, and crowd-sourced solutions to so many previously intractable problems, including in science (Christakis & Fowler, 2009; Newman, 2001; Surowiecki, 2004), heterarchy is a heuristic not only for transdisciplinary team science but for the current transformation in science.

Perspectivism as a foundation for transdisciplinary team science

The trend toward team science and toward public accountabilities and participation in science requires a foundation within the philosophy of science consistent with these developments. Philosophy of science provides the intellectual scaffolding for how science is conceptualized, practiced, and communicated, and offers justification among scientists for approaches to scientific training (Tebes, 2005, 2012a). Traditional or Mode 1 science is rooted in a philosophy of science known as logical empiricism (Manicas & Secord, 1983; McGuire, 1986; Tebes, 2005), a view that succeeded logical positivism but is closely related to it. Logical empiricism represents the joining of "…the rationalist deductive thesis and positivist inductive antithesis…" to form the hypothetico-deductive method that is the cornerstone of science (McGuire, 1986). Thus, a scientist deduces expected observations *a priori*, and then observes whether they survive disconfirmation *a posteriori* through a rigorous empirical test. This approach emphasizes the search for objective truth through use of experimental designs and quantitative methods, and prioritizes internal validity and causal inference above other forms of validity (Tebes, 2005). Over the past four decades, logical empiricism has come under vigorous attack for its inadequacy in addressing questions of meaning, local context, use and control of data, and the participation of the public in the scientific process (Manicas & Secord, 1983; Nowotny et al., 2003a; Tebes et al., 2014).

A practical alternative to logical empiricism accepted by most social scientists is "critical multiplism" (Cook, 1985). Critical multiplism mostly eschews these philosophical debates by acknowledging: a) there is a reality that exists independent of one's social construction of it, and b) that reality is knowable through observation, even if incompletely. Multiple and mixed methods in which quantitative and qualitative approaches are used, together or in sequence, are believed to offer the best opportunity to know that reality.

In our view, critical multiplism represents a transition point away from logical empiricism to a more fully developed position known as perspectivism (Tebes et al., 2014). Perspectivism is a contemporary view in the philosophy of science most thoroughly described by the philosopher Ronald Giere (Giere, 2006) and elaborated for social and behavioral science by McGuire (1986, 1989) and Tebes (Tebes, 2005, 2012a; Tebes et al., 2014). In this view: a) all knowledge is perspectival; b) there is a reality independent of one's ability to know it (realism); c) that reality can be known, albeit imperfectly and incompletely, through careful observation and experiment, that is, through methods grounded in the natural world (naturalism); and, d) the norms of the scientific community are helpful in guiding one's study of reality and in settling disputes about knowledge claims (what Laudan [1990] has called "normative naturalism").

Giere's (2006) writing on perspectivism describes its major features. A core concept is the acknowledgement that each species has a unique experience of the world, what Giere (2006) calls "perspectival reality." Thus, even though there is an "objective" reality out there, species-specific limitations constrainour ability to know it. Thus, even our measurements of the physical world, including putative physical laws, are constrained by our human perspectival reality. This is true even though our models of the world based on those measurements may prove useful for prediction and action because they draw on systematic and careful observations that allow us to know that world to some degree, albeit imperfectly.

The adoption of perspectivism as a basis for science has several implications, some of which we have described elsewhere (Tebes, 2012a; Tebes et al., 2014). First, acknowledging that there are multiple, valid perspectival realities advances the use of multiple theories and methods in science since there is no one theory or method that produces all types of knowledge. Pragmatically, critical multiplism also advances such theoretical and methodological pluralism, but perspectivism offers an underlying rationale for pluralism that transcends mere practicality. Second, perspectivism reinforces the need to enlist public stakeholders as co-producers of scientific knowledge. Although incorporating the *agora* into the scientific process may be complicated and messy, its value to knowledge production in science has never been fully embraced. Heterarchical thinking can yield innovative partnerships that retain some aspects of scientific autonomy common in Mode 1 science while creating meaningful and equitable structures in which public accountabilities are part of the scientific enterprise. Examples of how this has been done successfully in the past are evident in tribal participatory research (TPR) (Thomas, Rosa, Forcehimes, & Donovan, 2011) and in numerous CBPR public-academic partnerships, but even these are likely to change as heterarchical innovations emerge.

Third, perspectivism elevates the importance of explicitly and systematically studying context. For years, community and developmental psychologists as well as sociologists have emphasized the importance of studying context (Ford & Lerner, 1992; Sampson, Raudenbush, & Earls, 1997; Trickett, 1996; Tolan et al., 1990); perspectivism clarifies how dependent on context discovery and innovation actually are. Explicit study of the contexts of discovery and innovation has the potential to yield new knowledge about promising avenues of knowledge production, particularly if those contexts have been shaped by scientists' engagement with the *agora*.

Fourth, and closely related to the study of contexts as central to science, is that perspectivism advances culturally-situated inquiry. Broadly considered, culture includes behaviors, customs, and worldviews that are part of one's identity and one's experiences of oppression and community; markers of diversity, such as gender, race, ethnicity, age, sexual orientation, religion, and ability status (among others) denote key cultural contexts (Cohen, 2009; Tebes, 2010). Historically, Mode 1 science has sought to control for cultural differences statistically rather than study them directly, although this has changed over the past few decades (Trickett & Schensul, 2009). In culturally-situated inquiry, culture is a central context to examine for its influence on human behavior and experience. Of particular relevance are studies of intersectionality, a term derived from feminist scholarship (Shields,

2008) that refers to the intersection of cultural identities (e.g., female, elder, American Indian).

A final implication to note here is that a perspectivist philosophy of science influences the way scientists think about “truth.” Traditional or Mode 1 science makes the operational assumption that knowledge legitimated by a particular community of scientific scholars is our best approximation of the truth, until of course new knowledge emerges that a respected subset of that community shows is a better approximation. Both Giere (2006) and Kuhn (1962) correctly point out that the history of science is characterized by this process; a theory (even a law) is posited and empirically supported, advances explanation and prediction, and then is eventually replaced with one that does all of this a little bit better. However, perspectivism complicates this narrative in two ways, especially in relation to the current transformation in science. First, as more scientists acknowledge that knowledge is perspectival, they are more likely to consider existing knowledge as context-dependent and less willing to defend theoretical or methodological orthodoxy. Second, the norms for determining what knowledge in fact *is*, and whether it should be considered *true*, are likely to require transformation as well to address public accountabilities expressed through the *agora*. This will challenge current scientific practice (Nowotny et al., 2003a, 2003b).

A Place for Community Psychology

Community psychologists, scholars and practitioners, have unique expertise and experience to contribute to the current transformation in science, and particularly team science. Since its inception, community psychology has emphasized collaborative research with other disciplines and research engagement with community stakeholders (Maton et al., 2006). Collaborations have sought to address complex psychosocial and public health challenges and to promote social change (Stokols, 2006; Susskind & Klein, 1985; Tolan et al., 1990; Yoshikawa, 2006). In addition to the field’s commitment to collaborative research, community psychology has also emphasized the integration of research and practice, thus making it well suited to collaborations that involve the application of theory to real world contexts (Yoshikawa, 2006). Below we summarize eight organizing principles for community psychology and then discuss their relevance to team science. We conclude with two brief examples that illustrate a place for community psychologists in team science and in the broader current transformation in science.

Organizing principles for community psychology

Our eight organizing principles for community psychology are drawn from four sources: our collective experience as community psychologists, values and principles of the field from community psychology textbooks (Kloos, Hill, Thomas, Wandersman, Elias, & Dalton, 2012; Levine, Perkins, & Perkins, 2005; Moritsugu, Wong, & Duffy, 2010; Nelson & Prilletensky, 2010; Orford, 2008), examination of the aims and scope as well as recent articles published in the field’s two leading journals (the *American Journal of Community Psychology* and the *Journal of Community Psychology*), and the 18 competencies for community psychology practice adopted by the field’s major professional organization, the *Society for Community Research and Action* (SCRA, 2012). Table 1 summarizes the organizing principles and practice competencies. Although some readers may differ with some one of our proposed principles or their organization, we believe they reflect the general consensus among community psychologists.

As shown in the table, the eight organizing principles are: 1) considering individual vs. systems change, including first-order vs. second-order change; 2) understanding social ecological levels of analysis and intervention; 3) focusing on wellness, strengths, and competence (vs. deficits and disorder), including an emphasis on prevention, resilience, and health promotion; 4) valuing and promoting empowerment and social justice, including liberation from oppression; 5) understanding human diversity and cultural contexts; 6) advancing stakeholder participation, multi-level collaboration, and sense of community; 7) developing empirically-based models for action; and, 8) promoting theoretical and methodological pluralism.

A number of the principles are particularly relevant to theory or practice in team science. *Promoting theoretical and methodological pluralism*, such as the use of multiple theories and methods to understand human behavior in context (Tebes, 2005), is essential for effective transdisciplinary collaboration common in team science. The development of a shared cognitive schema or mental model -- which several scholars consider to be critical to successful team science (Kessel et al., 2008; Salazar, Lant, Fiore, & Salas, 2012; Stokols et al., 2008) -- is only possible when researchers are able to transcend disciplinary boundaries to achieve some level of cognitive integration. Cognitive integration of theories, methods, and/or techniques is described as “vertical” when it also occurs across levels of analysis and “horizontal” when it takes place within a given level (Maton et al., 2006; Stokols, 2006). The work that community psychologists do when bringing together diverse constituencies in community coalitions to take social action (Kelly, 1988) or to engage in CBPR (Jason et al., 2004) are just two examples of how community psychologists are effective in transcending disciplinary boundaries in pursuit of a collective vision for research or action.

Community psychologists routinely *consider individual vs. systems change* processes in human behavior. In contrast to other fields in the social sciences (e.g., sociology, political science, economics, anthropology, urban planning), community psychology features in its disciplinary domain *individual* psychology and behavior (Maton et al., 2006). However, our field seeks to understand the individual in social context, that is, the interdependence of individual and social change processes, thus balancing a focus on individual behavior change vs. systems change processes, including whether the change observed (or targeted) is first- or second-order (Watzlawick, Weakland, & Fisch, 1974). First-order change involves direct action to address a problem (e.g., suspending a school bully to reduce bullying and school violence); second-order change involves alteration of systemic factors that sustain the problem (e.g., changing the school culture that condones bullying and violence). Central to the success of any team science effort is the promotion of second-order change. The shared cognitive schema that emerge in successful scientific teams -- whether those teams consist of only researchers or researchers and community stakeholders -- is a type of second-order change in which the team adopts a broader, systemic conceptualization of the problem that integrates disparate disciplinary or sectoral perspectives among members (Salazar et al., 2012; Tebes, 2012b). Community psychologists who spend much of their time thinking about, examining, and fostering second-order change are well-suited to facilitating this process in transdisciplinary team science, especially when this involves addressing public accountabilities in Mode 2 science.

Closely related to the issue of individual vs. systems change is the emphasis within community psychology on *understanding social ecological levels of analysis and intervention.* Originally based on the work of Kelly (1966) and Bronfenbrenner (1979), and elaborated further by Seidman (1988), a social ecological framework recognizes the *embeddedness* of human behavior in multiple levels of overlapping contexts. Some contexts operate as smaller, self-sustaining social systems (e.g., family, peers, school, or workplace), while others operate in larger-scale social systems (e.g., neighborhoods, socio-political governance structures, economies, and cultural systems). All of these systems exert some measure of reciprocating influence on individual and collective human behavior. Expertise in social ecological principles enables community psychologists to identify social and contextual determinants of behavior at intersecting levels of influence. In addition, experience with relevant data analytic techniques enables community psychologists to specify multi-level influences theoretically and empirically. Such expertise is particularly useful to team science collaborations that focus on molar (vs. molecular) units, such as analyses of individual and group behavior.

The emphasis in community psychology on *understanding human diversity and cultural contexts* is well suited to advancing team science. Beginning with Rappaport's (1977) call for a psychology that values cultural diversity, community psychologists prioritize culture and diversity in theory, research, and practice. As noted, our field defines culture and diversity broadly to include contexts relevant to gender, race, age, social class, ethnicity, religion, sexual orientation, skin color, mental/physical challenges, language or preferred dialect, among others (Tebes, 2010). Trickett and colleagues (1996; Trickett et al., 2011) have emphasized that understanding diversity includes not only the varied cultural contexts that shape individual behavior and social settings, but the varied local contexts that intersect with culture to influence behavior and settings. Sociocultural and cross-cultural competence is also a foundational principle in competencies for community psychology research and practice (SCRA, 2012). Expertise in understanding cultural contexts and in intervening competently in those contexts enables community psychologists to anticipate intergroup tensions in transdisciplinary team science (across disciplines; by gender or race/ethnicity; researcher vs. practitioner; professional vs. community member), and to navigate these as researchers, consultants, and evaluators.

Community psychologists also have an abiding commitment to *stakeholder participation, multi-level collaboration, and sense of community;* a principle that is closely tied to the goals of effective transdisciplinary team science. Although participatory approaches to research or practice are not unique to community psychology, particularly in public health (Butterfoss, 2007; Israel et al., 2008; Varda, Shoup, & Miller, 2012), the field's extensive history in advancing stakeholder-based participatory approaches for research and action make community psychologists well-suited to promoting this work within transdisciplinary scientific teams, whether they involve researchers only or researchers and other stakeholders. This principle also values the relational benefits of a sense of community

(McMillan & Chavis, 1986; Sarason, 1974), which is evident in successful transdisciplinary teams (Salazar et al., 2012).

And finally, related to the above is the community psychology principle of *valuing and promoting empowerment and social justice, including liberation from oppression.* Promoting participation, collaboration, and sense of community in transdisciplinary scientific teams is not the same as promoting empowerment or social justice. However, promoting the latter is an explicit purpose of the *agora* in Mode 2 science as the public speaks back to science (Nowotny et al., 2003a). Disputes about the health benefits of a scientific project, or whether the research adequately captures cultural values and perspectives, or the extent to which community stakeholders are equitable partners in a scientific endeavor, are just some ways in which empowerment and social justice may be critical to transdisciplinary team science, especially in the future. Lindau et al. (2011) describe how a sustainable community health infrastructure was developed in Chicago through an equitable public-academic partnership, and Shepard et al. (2013) summarize how a few CTSAs have created a platform for empowering community engagement in health research. Acknowledging the challenge of doing so, they write: “The issues of power and equity may seem intractable, but they can be addressed when partners have earned each other’s trust, commitment, and goodwill… If we are to achieve the goal of health equity, we need to create systemic change in research protocols and attitudes regarding sharing of resources with neighborhood groups and residents with whom universities and institutions share their community environments and common futures” (Shepard et al., 2013, p. 233). Community psychologists have expertise fostering these sorts of relationships, engaging issues of equity and power, and building effective transdisciplinary partnerships.

Two organizing principles of community psychology are not directly related to team science: 1) focusing on wellness, strengths, and competence (vs. deficits and disorder), including an emphasis on prevention, resilience, and health promotion; and 2) developing empirically-based models for action. However, when team science initiatives overlap directly with either of these principles, community psychologists can inform that work. For example, a team of social work researchers and practitioners may want to evaluate the impact on individuals and family members of a preventive intervention for older persons with mobility impairments. Or a university-community partnership may plan to design and evaluate a local public awareness campaign to prevent domestic violence by integrating the latest research with local data indicators. Respectively, the *content* of each of these team-based efforts directly pertains to the organizing principles above, and so community psychologists may have much to offer.

Below we present two brief examples from our own work to illustrate how principles of community psychology can inform team science. Two of the authors are community/clinical psychologists and one is a community psychologist. All have several years experience in community psychology research and practice, including expertise in program evaluation and consultation.

Example 1: Evaluation and Educational Co-Facilitation of the Interdisciplinary Research Consortium of Stress, Self-Control, and Addiction (IRCSSA)

The first example illustrates our team's evaluation and the lead author's co-facilitation of an interdisciplinary consortium of more than 75 scientists working in project teams to understand the relationship of stress and self-control to various types of addiction, such as smoking, drinking, and overeating (Tebes, 2012b). With funding from the NIH Road Map, the consortium was comprised of nine R01 interdisciplinary research project teams, three P30 scientific "cores," and an R25 research education program for consortium faculty and postdoctoral fellows. The focus of the consortium was translational, seeking to translate knowledge from the lab to the clinic and policy arena across levels of molecular, brain, behavioral, and population-based research. Disciplines represented included: psychology (clinical, community, social), neurobiology, psychiatry, health and behavioral economics, molecular biology, social and public policy, neuroimaging, genetics and proteomics, and neuroscience. In addition to interdisciplinary project teams that met at least weekly, consortium members engaged in a number of other interdisciplinary activities, such as: a) interdisciplinary work groups, whose explicit purpose was to identify common concepts, methods, tools, techniques, and research objectives across projects; b) a weekly core seminar series in which consortium members and outside speakers shared current theoretical and empirical work; c) monthly executive committee meetings of principal investigators and co-investigators; d) inter-laboratory training experiences in which members spent time on another team to learn specific skills; e) completion of interdisciplinary pilot studies to test innovative ideas; and, f) participation in annual two-day site visit presentations to NIH project officers and consortium members that summarized progress to date.

Our evaluation of this initiative, which is currently being completed, has included a multi-level, mixed methods longitudinal design that seeks to identify whether interdisciplinary team science enhances and accelerates interdisciplinary scholarship, scholarly productivity, and scholarly impact, and to identify how interpersonal and social network processes among consortium members are related to these outcomes (Tebes, 2012b). The evaluation includes online surveys of consortium members that tracks social network processes and collaborative activity, systematic observations of seminars and work group meetings, qualitative interviews with principal investigators and co-investigators, and bibliometric analyses of scholarly productivity, impact, and interdisciplinarity. In addition, our educational co-facilitation of the consortium has sought to promote interdisciplinary collaboration and productive exchange among members through coordination of seminars and work groups, development of institutional incentives for team science, and dissemination of project findings in *Science to Policy Briefs*.

A brief example cannot do justice to the breadth of the science that is still emerging from this consortium or to the social and intellectual exchanges among members, particularly how transactions among members represent relational processes that promote discovery and innovation. However, the middle column of Table 2 lists some ways in which community psychology principles informed our work with the consortium to promote these processes. As shown, our background made us comfortable with the search for cognitive integration of theories and methods into shared schemas, which was the explicit focus of the interdisciplinary work groups that one of us helped organize and co-facilitate. Members of two work groups ended up publishing thought pieces stimulated by these group discussions; one publication focused on the effects of stress for a general audience (Arnsten, Mazure, & Sinha, 2012) and another discussed the public health implications of addictive qualities in certain foods (Gearhardt, Grilo, DiLeone, Brownell, & Potenza, 2011). Table 2 provides other examples of how community psychology principles informed our choice of individual vs. system change targets for assessment (individual researchers vs. project teams vs. the overall consortium) and how various schemas, processes, and networks were examined within these socio-ecological levels over time.

Also shown is how understanding of diversity and cultural contexts helped our team identify and attend to various diversity issues within the consortium. One such issue had to do with differences among non-tenured vs. tenured faculty. At the outset of the consortium, the R25 research education team developed a confidential survey to identify key issues of concern among members. One concern raised by some non-tenured faculty and postdoctoral fellows was that engaging in an interdisciplinary scientific team would impede their independent development as a scholar. This finding prompted the consortium leadership to hold open and constructive discussions of this issue among consortium members that encouraged honest exchanges in project teams and supervisory meetings. It also helped establish greater transparency among members about potential academic barriers to team science, such as publication credit and opportunities for promotion for researchers engaged in team science. About two years after the consortium began, its host institution supplemented the criteria for promotion to include valuing contributions to collaborative research and team science (Domino, Budurtha, Nagel, & BIRCWH Program Leadership, 2011), an action that was shaped by consortium leaders and that underscored the host institution’s commitment to faculty development through team science.

Example 2: Evaluation of and Consultation to the Porch Light Initiative

In a second example, our team is evaluating and consulting to a partnership of diverse stakeholders, including leaders of city departments, local funders, artists, community agencies and service providers, mental health consumers, and community members to implement a 4-year study of the impact of participatory public art on individual recovery and community transformation in Philadelphia (Matlin, Evans, & Tebes, 2014; Mohatt, N. et al., 2013; Tebes, Matlin, Evans, Golden, & Ansell, 2012). We define participatory pubic art as acts of collaborative creative expression by a group of individuals to produce something of aesthetic value for permanent public display. Project participants live in distressed urban neighborhoods with high levels of crime, poverty, and victimization. All adult participants also experience significant mental health challenges and substance abuse conditions, and are currently receiving publicly-funded behavioral health services. A small pilot project includes youth living in these neighborhoods.

As shown in the right-most column in Table 2, our work draws on a number of community psychology principles; in particular: promoting theoretical and methodological pluralism, considering individual vs. systems change processes, understanding social ecological levels of analysis, advancing stakeholder participation, and valuing and promoting empowerment and social justice. Our evaluation is longitudinal, multi-level, and uses mixed methods, and has CBPR embedded within a comparative outcome design to assess intervention impact (Matlin et al., 2014; Tebes et al., 2012). This design maximizes scientific rigor while ensuring that diverse stakeholders are able to speak back to the science to share their perspectives.

One way we have employed CBPR is to develop shared cognitive schemas among the various stakeholders about the project; this culminated in a logic model that continues to guide research and programmatic activities. As is common in community intervention research, early in the project the partnership capacity to implement the intervention and related research was limited. Our team thus provided consultation and technical support to ensure effective implementation and appropriate collection, safety, and use of data, and then established ongoing structures to sustain these changes (Flaspohler, Lesesne, Puddy, & Smith, 2012).

In another example shown in Table 3, diversities among stakeholders, particularly involving member roles (artist, participant, funder, provider, researcher), represented differences that needed to be bridged prior to effective collaboration. As several recent studies have shown, promoting diversity in a given group may come at the expense of sense of community (Neal & Neal, 2013; Townley, Kloos, Green, & Franco, 2011). A key diversity has been between “local” members and those living in a city several hours away; the latter’s “outsider” status has been a barrier that requires ongoing attention so as minimize its impact on effective collaboration.

Finally, in contrast to the IRCSSA example, certain community psychology principles have had direct relevance to this work because of their overlap with the purpose of the project. Porch Light explicitly adopts a strengths-based perspective focused on promoting wellness and resilience, and seeks to empower individuals through art. A guiding assumption of the program is that “art is a catalyst for change,” and participants are encouraged to consider how this applies to them at multiple levels – individually, interpersonally, and in their community. Participatory public art is considered a vehicle for emancipation from individual and community challenges, such as coping with significant behavioral health conditions and poverty, among others.

Conclusions

In this paper we discuss current developments in how science is practiced, how knowledge is produced, and a place for community psychology in these developments. We summarize the trend toward transdisciplinary team science, and describe commonalities between transdisciplinary teams comprised of researchers and those consisting of researchers and community stakeholders. We discuss the current transformation in science toward enhanced public accountabilities, pluralism, and socially-distributed engagement, and how transdisciplinary team science is fundamentally consistent with these changes. We also offer the concept of heterarchy as a heuristic that supports these developments, and describe perspectivism as a contemporary philosophy of science aligned with this emerging 21st century science. Finally, we discuss how community psychology, through its core principles and practice competencies, offers unique expertise to support these developments, and briefly illustrate how by providing two examples.

Central to our argument is the assertion that science is, fundamentally, a relational process in which knowledge is produced (or co-produced) through transactions among scientists and other stakeholders, and through public engagement. Language, concepts, models, and tools used to study other relational structures and processes, are thus essential to understanding 21^{st} century science and how discoveries and innovations take place. Although the dominant narrative for discovery in science today may still be *Eureka!*, that is, insight from a lone scientist, we argue that in the 21^{st} century a new narrative is emerging in which that insight is nurtured and elaborated through distributed cognition that draws on interpersonal transactions in teams, and active engagement by scientists with the public to address critical accountabilities. Because of its core organizing principles and unique blend of expertise on the intersection of research and practice, community psychologists are extraordinarily well-prepared to help advance these developments, and thus have much to offer 21^{st} century science.

Acknowledgments

This work was supported by grants from the Philadelphia Department of Behavioral Health and Intellectual disAbility Services, Philadelphia Mural Arts Associates, the Thomas B. Scattergood Foundation, the Robert Wood Johnson Foundation (No. 67921), the National Center for Research Resources (1UL1RR024925), and the National Institute on Drug Abuse (RL5 DA024858 and T32 DA 019426). The authors are grateful to: Carolyn Mazure, Rajita Sinha, and colleagues at the Interdisciplinary Research Consortium on Stress, Self-Control, and Addiction (IRCSSA); Sara Ansell, Arthur C. Evans, Jane Golden, Joe Pyle, and colleagues from the City of Philadelphia, the Thomas B. Scattergood Foundation, and Philadelphia partner agencies and participants; and Susan Florio, Bronwyn Hunter, Nathaniel Mohatt, Roy Money, Frank Snyder, Azure Thompson, and other colleagues from the Yale Division of Prevention & Community Research and The Consultation Center, Yale University School of Medicine.

References

Abrams DB. Applying transdisciplinary research strategies to understanding and eliminating health disparities. Health Education & Behavior. 2006; 33(4):515–531. [PubMed: 16769758]

Adler N, Stewart J. Using team science to address health disparities: MacArthur network as case example. Annals of the New York Academy of Sciences. 2010; 1186:252–260. [PubMed: 20201877]

Andrews JO, Tingen MS, Hurman C. Application of a CBPR framework to inform a multi-level tobacco cessation intervention in public housing neighborhoods. American Journal of Community Psychology. 2012; 50:129–140. [PubMed: 22124619]

Arnsten A, Mazure C, Sinha R. This is your brain in meltdown. Scientific American. 2012 Apr.:50–53.

Bennett LM, Gadlin H. Collaboration and team science: From theory to practice. Journal of Investigative Medicine. 2012; 60:768–775. [PubMed: 22525233]

Borner K, Contractor N, Uzzi B. A multi-level systems perspective for the science of team science. Science Translational Medicine. 2010; 2(49):1–5.

Bronfenbrenner, U. The ecology of human development. Cambridge, MA: Harvard Press; 1979.

Butterfoss, FD. Coalitions and partnerships in community health. San Francisco: Jossey; 2007.

Cauce AM. Is multicultural psychology a-scientific? Diverse methods for diversity research. Cultural Diversity and Ethnic Minority Pyschology. 2011; 17:228–233.

Christakis, NA.; Fowler, JH. Connected: The surprising power of our networks and how they shape our lives. New York: Little, Brown, & Co; 2009.

Cilliers, P. Complexity and postmodernism. London: Routledge; 1998.

Cilliers P. Boundaries, hierarchies, and networks in complex systems. International Journal of Innovation Management. 2001; 5:135–147.

Cilliers, P. Understanding complex systems. In: Sturmberg, JP.; Martin, CM., editors. Handbook of Systems and Complexity in Health. New York: Springer; 2013. p. 27-38.

Clinical and Translational Science Awards Consortium. Principles of Community Engagement. 2. Rockville, MD: U.S. Gov. Printing Office; 2011. NIH Publ No. 11–7782

Cohen AB. Many forms of culture. American Psychologist. 2009; 64:194–204. [PubMed: 19348520]

Cook, TD. Postpositivist critical multiplism. In: Shotland, L.; Mark, MM., editors. Social science and social policy. Beverly Hills, CA: Sage; 1985. p. 21-62.

Dampier, WC. A history of science and its relations with philosophy and religion. Cambridge: Cambridge University Press; 1948.

Domino SE, Bodurtha J, Nagel JD. the BIRCWH Program Leadership. Interdisciplinary research career development: Building interdisciplinary research careers in women's health program best practices. Journal of Women's Health. 2011; 20:1587–1601.

Dunbar K. How scientists think in the real world. Journal of Applied Developmental Psychology. 2000; 21:49–58.

Flaspohler P, Lesesne CA, Puddy RW, Smith E. Advances in bridging research and practice: Introduction to the second special issue on the Interactive Systems Framework for dissemination and implementation. American Journal of Community Psychology. 2012; 50:271–281. [PubMed: 22875685]

Ford, DH.; Lerner, RM. Developmental systems theory. Thousand Oaks, CA: Sage; 1992.

Gearhardt AN, Grilo CM, DiLeone RJ, Brownell KD, Potenza MN. Can food be addictive? Public health and policy implications. Addiction. 2011; 106:1208–1212. [PubMed: 21635588]

Gibbons, M.; Limoges, H.; Nowotny, H.; Schwartzman, S.; Scott, P.; Trow, M. The New Production of Knowledge. London: Sage; 1994.

Giere, RN. Scientific perspectivism. Chicago: University of Chicago Press; 2006.

Giere RN, Moffatt B. Distributed cognition: Where the cognitive and the social merge. Social Studies of Science. 2003; 33:301–310.

Godin B. Writing performative history: The new *new*Atlantis? Social Studiees of Science. 1998; 28:465–483.

Gone JP. Is psychological science a-cultural? Cultural Diversity and Ethnic Minority Psychology. 2011; 17:234–242. [PubMed: 21787055]

Hall KL, Stokols D, Berrigan D. Assessing the value of team science: A study comparing center- and investigator initiated grants. American Journal of Preventive Medicine. 2012; 42:157–163. [PubMed: 22261212]

Hessels LK, van Lente H. Re-thinking new knowledge production: A literature review and a research agenda. Research Policy. 2008; 37:740–760.

Holland, JB. Signals and boundaries: Building blocks for complex adaptive systems. Cambridge: MIT Press; 2012.

Lander ES, Morgan MJ. International Human Genome Sequencing Consortium. Initial sequencing and analysis of the human genome. Nature. 409:860–921. [PubMed: 11237011]

Irwin, A. Perspectives on scientific governance. In: Hackett, EJ.; Amsterdamska, O.; Lynch, M.; Wajcman, J., editors. The Handbook of Science and Technology Studies. 3. Cambridge: MIT Press; 2008. p. 583-607.

Israel BA, Schulz AJ, Parker EA, Becker AB. Review of community-based research: Assessing partnership approaches to improve public health. Annual Review of Public Health. 1998; 19:173–202.

Israel, BA.; Schulz, AJ.; Parker, EA.; Becker, AB.; Allen, AJ.; Guzman, JR. Critical issues in developing and following community-based participatory research principles. In: Winkler, M.; Wallerstein, N., editors. Community-based participatory research for health. San Francisco: Jossey-Bass; 2008. p. 47-65.

Jasanoff, S. Designs on Nature: Science and Democracy in Europe and the United States. Princeton, NJ: Princeton University Press; 2005.

Jason, LA.; Keys, C.; Suarez-Balcazar, Y.; Taylor, RR.; Davis, MI.; Durlak, J.; Isenberg, D. Participatory community research. Washington, DC: APA; 2004.

Kahn RL, Praeger DJ. Interdisciplinary collaborations are a scientific and social imperative. The Scientist. 1994; 8:12.

Kelly JG. Ecological constraints on mental health services. American Psychologist. 1966; 21:535–539. [PubMed: 5935920]

Kelly, JG. A guide to conducting prevention research in the community. NY: Haworth; 1988.

Kessel, F.; Rosenfield, PL.; Anderson, NB., editors. Interdisciplinary research: Case studies from health and social science. New York: Oxford Press; 2008.

Kloos, B.; Hill, J.; Thomas, E.; Wandersman, A.; Elias, MJ.; Dalton, J. Community psychology: Linking individuals and communities. 3. Belmont, CA: Wadsworth; 2012.

Kon AA. The Clinical and Translational Science Award (CTSA) Consortium and the translational research model. American Journal of Bioethics. 2008; 8:58–60. [PubMed: 18570107]

Knorr Cetina, K. Epistemic Cultures: How the Sciences Make Knowledge. Cambridge, MA: Harvard University Press; 1999.

Kuhn, TS. The structure of scientific revolutions. Chicago: University of Chicago Press; 1962.

Laudan L. Normative naturalism. Philosophy of Science. 1990; 57:44–59.

Levine, M.; Perkins, DV.; Perkins, D. Principles of community psychology. 3. New York: Oxford; 2005.

Lindau ST, Makelarski JA, Whitaker E. Building community-engaged health research and discovery infrastructure on the South Side of Chicago: Science in service to community priorities. Preventive Medicine. 2011; 52:200–207. [PubMed: 21236295]

Manicas PT, Secord PF. Implications for psychology of the new philosophy of science. American Psychologist. 1983; 38:399–413.

Matlin, SL.; Evans, AC.; Tebes, JK. Mural Arts Associates. Beauty, connection, healing, and behavioral health: The role of public art in promoting wellness. In: Golden, J., editor. Mural Arts at 30: Growing Up, Growing Out, Putting Down Roots. Philadelphia Mural Arts Program; Philadelphia, PA: 2014.

Maton KI, Perkins DD, Saegert S. Community psychology at the crossroads: Prospects for interdisciplinary research. American J Community Psychology. 2006; 38:9–21.

McGuire, WJ. A perspectivist looks at contextualism and the future of behavioral science. In: Rosnow, RL.; Georgundi, M., editors. Contextualism and understanding in behavioral science. New York: Pergamon Press; 1986. p. 271-303.

McGuire, WJ. A perspectivist approach to strategic planning of programmatic scientific research. In: Gholson, B.; Shadish, WR.; Niemeyer, RA.; Houts, AC., editors. The psychology of science: Contributions to metascience. NY: Cambridge; 1989. p. 214-245.

McMillan DW, Chavis DM. Sense of community: Theory and definition. Journal of Community Psychology. 1986; 14:6–23.

Miller, JH.; Page, SE. Complex adaptive systems: Computational models for social life. Princeton, NJ: Princeton University Press; 2007.

Minkler, M.; Wallerstein, N. Community-based participatory research for health: From processes to outcomes. San Francisco: Jossey-Bass; 2008.

Mirowski, P.; Sent, E-M. The commercialization of science and the response of STS. In: Hackett, EJ.; Amsterdamska, O.; Lynch, M.; Wajcman, J., editors. The Handbook of Science and Technology Studies. 3. Cambridge: MIT Press; 2008. p. 635-689.

Mohatt NV, Singer J, Tebes JK. A community's response to suicide through public art: Stakeholder perspectives from the *Finding the Light Within*project. American Journal of Community Psychology. 2013; 52:197–209. [PubMed: 23743604]

Moody, CM.; Kaiser, D. Scientific training and the creation of scientific knowledge. In: Hackett, EJ.; Amsterdamska, O.; Lynch, M.; Wajcman, J., editors. The Handbook of Science and Technology Studies. 3. Cambridge: MIT Press; 2008. p. 376-402.

Moritsugu, J.; Wong, FY.; Duffy, FG. Community psychology. 4. Boston: Allyn & Bacon; 2010.

Nash JM, Collins BN, Spirito A. Training the transdisciplinary scientist: A general framework applied to tobacco use behavior. Nicotine & Tobacco Research. 2003; 5:S41–S53. [PubMed: 14668086]

National Institutes of Health (NIH). Institutional Clinical and Translational Science Award (U54). 2006a. http://grants.nih.gov/grants/guide/rfa-files/RFA-TR-12-006.html

National Institutes of Health (NIH). Establishment of Multiple Principal Investigator Awards for the Support of Team Science Projects. 2006b. NOT-OD-07-017. http://grants.nih.gov/grants/guide/notice-files/NOT-OD-07-017.html

National Science Foundation. Facilitating Interdisciplinary Research. Committee on Facilitating Interdisciplinary Research & Committee on Science, Engineering, and Public Policy; Washington: National Academy of Science, National Academy of Engineering, and Institute of Medicine; National Academies Press; 2005.

Neal ZP, Neal JW. The (In)compatibility of diversity and sense of community. American Journal of Community Psychology. 201310.1007/s10464-013-9608-0

Nelson, G.; Prilleltensky, I. Community psychology: In pursuit of liberation and well-being. United Kingdom. Europe: Palgrave MacMillan; 2010.

Newman MEJ. The structure of scientific collaboration networks. Proceedings of the National Academy of Sciences. 2001; 98(2):404–409.10.1073/pnas.021544898

Nowotny, H.; Scott, P.; Gibbons, M. Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Cambridge: Polity Press; 2003a.

Nowotny H, Scott P, Gibbons M. “Mode 2” Revisited: The New Production of Knowledge. Minerva. 2003b; 41:179–194.

Orford, J. Community Psychology: Challenges, Controversies, and Emerging Consensus. West Sussex, England: John Wiley & Sons; 2008.

Porter AL, Rafols I. Is science becoming more interdisciplinary? Measuring and mapping six research fields over time. Scientometrics. 2009; 81:719–745.

Rappaport, J. Community psychology: Values, research, and action. New York: Holt, Rinehart, & Winston; 1977.

Rappaport J. Community psychology is (thank God) more than science. American Journal of Community Psychology. 2005; 35:231–238. [PubMed: 15909797]

Rosenfield PL. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Social Science Medicine. 1992; 35(11):1343–1357. [PubMed: 1462174]

Salazar MR, Lant TK, Fiore SM, Salas E. Facilitating innovation in diverse science teams through integrative capacity. Small Group Research. 2012; 43:527–558.

Sarason, SB. Psychological sense of community: Prospects for a community psychology. San Francisco: Jossey Bass; 1974.

Sampson RJ, Raudenbush S, Earls F. Neighborhoods and violent crime: A multilevel study of collective efficacy. Science. 1997; 277:918–924. [PubMed: 9252316]

SCRA: Society for Community Research and Action. Competencies for community psychology practice. The Community Psychologist. 2011; 45:8–14.

Seidman E. Back to the future, community psychology: Unfolding a theory of social intervention. American Journal of Community Psychology. 1988; 16:3–24. [PubMed: 3369381]

Shepard PM, Idehen Al, Casado J, Freeman E, Horowitz C, Seifer S, Strelnick H. Amplifying the community voice in community-academic partnerships: A summary of and commentary on a thematic issue. Progress in Community Health Partnerships. 2013; 7:231–233. [PubMed: 24056504]

Shields SA. Gender: An intersectionality perspective. Sex Roles. 2008; 59:301–311.

Shinn M, Toohey SM. Community contexts of human welfare. Annual Review of Psychology. 2003; 54:427–459.

Silver, B. The ascent of science. Oxford: Oxford University Press; 1998.

Stokols D, Fuqua J, Trochim W. Evaluating transdisciplinary science. Nicotine & Tobacco Research. 2003; 5(Supplement 1):S21–S39. [PubMed: 14668085]

Stokols D, Harvey R, Gress J, Fuqua J, Phillips K. In vivo studies of transdisciplinary scientific collaboration: Lessons learned and implications for active living research. American Journal of Preventive Medicine. 2005; 28(Sup 2):202–213. [PubMed: 15694529]

Stokols D. Toward a science of transdisciplinary action research. American Journal of Community Psychology. 2006; 38:63–77. [PubMed: 16791514]

Stokols D, Misra S, Moser RP, Hall KL, Taylor BK. The Ecology of team science: Understanding contextual influences on transdisciplinary collaboration. American Journal of Preventive Medicine. 2008; 35:S96–S115. [PubMed: 18619410]

Suppe, F. The structure of scientific theories. 2. Urbana, IL: Univ of Illinois Press; 1977.

Surowiecki, J. The wisdom of crowds. New York: Doubleday; 2004.

Susskind, EC.; Klein, DC. Community research: Methods, paradigms, and applications. New York: Praeger Scientific; 1985.

Tebes JK. Community science, philosophy of science, and the practice of research. American Journal of Community Psychology. 2005; 35:213–235. [PubMed: 15909796]

Tebes JK. Community psychology, diversity, and the many forms of culture. American Psychologist. 2010; 65:58–59. [PubMed: 20063917]

Tebes, JK. Philosophical foundations of mixed methods research: Implications for research practice. In: Jason, L.; Glenwick, D., editors. Innovative methodological approaches to community-based research. Washington, DC: APA Books; 2012a. p. 13-31.

Tebes, JK. Evaluation of Interdisciplinary Team Science: Current Status and Future Directions. Invited Address, Presidential Program, 212nd Annual Convention of the American Psychological Association; Orlando, FL. 2012b Aug.

Tebes, JK.; Matlin, S.; Evans, AC.; Golden, JH.; Ansell, S. Individual and community recovery and transformation through public art: A mixed methods comparative outcome trial. Address to the American Psychiatric Association Annual Meeting; Philadelphia, PA. 2012 May.

Tebes, JK.; Kaufman, JS.; Connell, CM.; Crusto, CA.; Thai, ND. Evaluation in prevention and health promotion. In: Gullotta, TP.; Bloom, M., editors. Encyclopedia of primary prevention and health promotion. 2. New York: Springer; 2014.

Terry SF, Leshner AI. Assessing NIH's big idea. Science Translational Medicine. 2013; 5:1–2.

Thomas LR, Rosa C, Forcehimes A, Donovan D. Research partnerships between academic institutions and American Indian and Alaska Native Tribes and organizations: Effective strategies and lessons learned in a multisite CTN study. American Journal of Drug and Alcohol Abuse. 2011; 37:333–338. [PubMed: 21854275]

Tolan, P.; Keys, C.; Chertok, F.; Jason, L., editors. Researching community psychology: Issues of theory and methods. Washington, DC: American Psychological Association; 1990.

Townley G, Kloos B, Green EP, Franco MM. Reconcilable differences? Human diversity, cultural relativity, and sense of community. American Journal of Community Psychology. 2011; 47:69–85. [PubMed: 20978837]

Trickett EJ. A future for community psychology: The contexts of diversity and the diversity of contexts. American Journal of Community Psychology. 1996; 24:209–234.

Trickett EJ, Beehler S, Trimble JE. Advancing the science of community-level interventions. American Journal of Public Health. 2011; 101:1410–1419. [PubMed: 21680923]

Trickett EJ, Schensul J. Summary comments: Multi-level community based culturally situated community interventions. American Journal of Community Psychology. 2009; 43:377–381. [PubMed: 19326207]

Varda D, Shoup JA, Miller A. A systematic review of collaboration and network research in the public affairs literature: Implications for public health practice and research. American Journal of Public Health. 2012; 102:564–571. [PubMed: 22021311]

Venter JC, Adams MD, Zhu X. The sequence of the human genome. Science. 2001; 291:1304–1351. [PubMed: 11181995]

Watzlawick, P.; Weakland, NC.; Firsch, R. Change: Principles of problem formation and problem resolution. New York: Norton; 1974.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Westfall JM, Mold J, Fagnan L. Practice-based research – "Blue highways" on the NIH roadmap. Journal of the American Medical Association. 2007; 297:403–406. [PubMed: 17244837]

Wuchty S, Jones BF, Uzzi B. The increasing dominance of teams in production of knowledge. Science. 2007; 316:1036–1038. [PubMed: 17431139]

Yancey EM, Mayberry R, Armstrong-Mensah E, Collins D, Goodin L, Cureton S, Yuan K. The community-based participatory intervention effect of "HIVRAAP. American Journal of Health Behavior. 2012; 36(4):555–568.10.5993/AJHB.36.4.12 [PubMed: 22488405]

Yoshikawa H. Placing community psychology in the context of the social, health, and educational sciences: Directions for interdisciplinary research and action. American Journal of Community Psychology. 2006; 38:31–34. [PubMed: 16838072]

Zerhouni E. The NIH roadmap. Science. 2003; 302:63–72. [PubMed: 14526066]

Zerhouni EA. Translational research: Moving discovery to practice. Nature. 2007; 81:126–128.

Table 1

Organizing Principles for Community Psychology Research and Practice[a]

1	Considering individual vs. systems change, including first order vs. second order change
2	Understanding social ecological levels of analysis and intervention
3	Focusing on wellness, strengths, and competence (vs. deficits and disorder), including an emphasis on prevention, resilience, and health promotion
4	Valuing and promoting empowerment and social justice, including liberation from oppression
5	Understanding human diversity and cultural contexts
6	Advancing stakeholder participation, multi-level collaboration, and sense of community
7	Developing empirically-based models for action
8	Promoting theoretical and methodological pluralism

Competencies for Community Psychology Practice[b]

Foundational Principles	Ecological perspectives Empowerment Sociocultural and cross-cultural competence Community inclusion and partnership Ethical, reflective practice
Community Program Development and Management	Program development, implementation, and management Prevention and health promotion
Community and Organizational Capacity-Building	Community leadership and mentoring Small and large group processes Resource development Consultation and organizational development
Community and Social Change	Collaboration and coalition development Community development Community organizing and community advocacy Public policy analysis, development, and advocacy Community education, information dissemination, and building public awareness
Community Research	Participatory community research Program evaluation

[a]See: Kloos, Hill, Thomas, Wandersman, Elias, and Dalton (2012); Levine, Perkins, and Perkins (2005); Moritsugu, Wong, and Duffy (2010); Nelson and Prilletensky (2010); and Orford (2008).

[b]Competencies for community psychology practice. SCRA (2012). *The Community Psychologist, 45,* 8–14.

Table 2

Community Psychology Principles and Their Relevance to Two Examples of Team Science

Community Psychology Principles	Example 1: IRCSSA Evaluation & Educational Co-Facilitation[a] (interdisciplinary scientific teams of researchers only)	Example 2: Porch Light Evaluation & Consultation (transdisciplinary scientific teams of researchers & community stakeholders)
Relevance to Team Science		
Theoretical and methodological pluralism	Cognitive integration of theories and methods as shared schemas to examine stress, self-control, and addiction across disciplinary boundaries Multi-level mixed methods integration of quantitative and qualitative data	CBPR process to arrive at shared schema and logic model for the participatory arts intervention Multi-level mixed methods integration of quantitative and qualitative data
Individual vs. systems change processes	Assessment of various indicators of change among consortium members following their involvement in project teams, work group, and overall consortium activities	Evaluation of intervention impact on individual-level recovery and wellbeing and community-level indicators of transformation; exploratory evaluation of intervention impact on agency culture and individual service use
Social ecological levels of analysis and intervention	Assessment of cognitive schemas, collaborative processes, and social networks on the productivity, impact, and interdisciplinarity of individual researchers, project teams, work groups, and the overall consortium	Examination of indicators of recovery, well-being, and transformation across individuals, agencies, and neighborhoods
Understanding human diversity and cultural contexts	Identification of and attention to diversities within teams and across teams by discipline, gender, race/ethnicity, age, faculty-student status, and academic rank	Identification of and attention to diversities within the project team by role (artist, participant, funder, service provider, researcher), race/ethnicity, language, local resident-outsider Culturally-situated participatory arts interventions by agency and neighborhood
Stakeholder participation, multi-level collaboration, and sense of community	Social integration of researchers, project teams, workgroups, and the overall consortium; facilitation of knowledge and resource exchange as well as fellowship through consortium-wide activities	CBPR that includes social integration of participants, artists, service providers, funders, family members, and researchers; facilitation of knowledge and resource exchange as well as fellowship through various project activities
Valuing and promoting empowerment and social justice, including liberation from oppression	Critical theory and feminism informs recognition of power dynamics as these overlap with diversities within the consortium	Critical theory and feminism informs recognition of power dynamics that overlap with diversities within the collaborative Empowerment and social justice promotion and emancipation through participatory public art is an intended outgrowth of the project
Developing empirically-based models for action	Explicitly seeks to obtain empirical science to determine whether interdisciplinary team science leads to accelerated discoveries with greater impact Explicit objective underlying the development and dissemination of *Science to Policy Briefs*	Funding explicitly assesses whether the benefits of participatory public arts involvement are empirically-supported by a rigorous evaluation

[a]IRCSSA = Interdisciplinary Research Consortium on Stress, Self-Control, and Addiction