

ISSUES IN INTERDISCIPLINARY STUDIES  
No. 31, pp. 75-98 (2013)

# REFRAMING INTERDISCIPLINARY AND INTERPROFESSIONAL COLLABORATION THROUGH THE LENS OF COLLECTIVE AND SOCIOMATERIAL THEORIES OF LEARNING

by

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*Abstract:* The purpose of this article is to begin to explore how collective and sociomaterial theories of learning might be applied within interdisciplinary and interprofessional contexts—in particular the team-based collaboration that is playing an ever larger role in both fields. It articulates several key features of interdisciplinary and interprofessional activities and then speculates on how they might be productively reframed through the lenses of the following theoretical perspectives: communities of practice, cultural historical activity theory, complexity science and actor-network theory. The article is not intended to be comprehensive; its aim is to begin the process of developing deeper, more theoretically sophisticated understandings of the collective learning and knowing that emerge—often across deep paradigmatic divides—through interprofessional and interdisciplinary collaboration.

**Keywords:** interdisciplinary, interprofessional, learning theory, teamwork, collaboration, communities of practice, cultural-historical activity theory, complexity science, actor-network theory.

## Introduction

“Collective” and “sociomaterial” are terms used recently by educational theorists to describe learning theories that move beyond the traditional focus on isolated individuals. These theories position other people, social dynamics, tools, and other living organisms with which we interact not as mere backdrops to learning but as fundamental to and inseparable from learning (Davis & Sumara, 2007; Fenwick, 2010). This article explores how collective and sociomaterial learning theories might be employed within interprofessional and interdisciplinary contexts. It begins by briefly describing developments within these contexts, including both the trend towards collaboration and teamwork and the (incongruous) continued treatment of learning as an attribute only of isolated individuals. The article then articulates several central features of interdisciplinary and interprofessional endeavors: diverse perspectives, constructing common ground, negotiating conflicts, and synthesis. Finally, it speculates on how these features could be productively reframed through the lenses of four prominent collective or sociomaterial learning discourses: communities of practice, cultural historical activity theory, complexity science, and actor-network theory. This article is exploratory rather than comprehensive; its goal is to contribute to the development of deeper, more theoretically sophisticated understandings of the collective learning and knowing that emerge—often across deep paradigmatic divides—through interprofessional and interdisciplinary collaboration.

## Developments in Interdisciplinarity and Interprofessionalism

Interdisciplinarity and interprofessionalism are taking on greater importance in teaching, scientific research, healthcare practice, and other areas. This development can be attributed at least in part to the recognition in these circles that many of the most pressing problems society faces—such as poverty, climate change, and the diabetes epidemic—are multifaceted and complex, and that effective solutions require the input and integration of many differing disciplinary or professional insights (Klein & Newell, 1998; Repko, 2008; Stokols, Misra, Moser, Hall, & Taylor, 2008).

Furthermore, within the last decade a focus has been placed on collaboration and teamwork in these contexts. An increasing proportion of healthcare

in Canada and other English-speaking countries, for instance, is being carried out through interprofessional teams composed of physicians, nurses, therapists, social workers, and others who bring to bear differing sorts of professional insights (Nolte, 2005). A new field—"the science of team science"—has recently emerged in the United States, as scientists involved in large-scale research projects seek to consciously assess and nurture their collaborative work (Stokols et al., 2008). In Europe, transdisciplinary collaboration—which seeks to engage not only various disciplinary or professional perspectives, but also affected community stakeholders—has become more prominent, for example, through the *International Northern Search Route Program* (INSROP) (Østreg, 2010).

This increased emphasis on collaboration and teamwork is hardly surprising. The rapid growth of knowledge and increasing specialization means that it is very difficult for any one individual to comprehend and integrate all the disciplinary or professional insights relevant to particular complex problems. Collaborative approaches with collective products—whether research papers or patient treatment plans—appear to be the primary way interdisciplinarity and interprofessionalism will be pursued in the future.

### Individual, Collective, and Sociomaterial Approaches to Learning

Interprofessional practice and interdisciplinary studies would therefore seem to provide ideal contexts for the application and development of collective and sociomaterial learning theories—that is, theories that view social collectivity, dynamic networks, and material artifacts not as mere backdrops to human knowing but as essential to and embedded within all human knowing (Fenwick, 2010).

In the interprofessional healthcare field, however, theories that focus on the isolated individual predominate (Bleakley, 2006). Interest in more sophisticated theoretical approaches is growing in this context; a recent issue of *Journal of Interprofessional Care* (27(1), January 2013), for example, focused on theories used in interprofessional practice and education. There remain, nonetheless, very few writings that take on issues of collective, distributed, or artifact-mediated learning in a sophisticated manner (a few recent exceptions are the works by Bleakley, Bligh, & Browne, 2011; Doyle, 2012; Varpio, Hall, Lingard, & Schreyer, 2008).

Within interdisciplinary contexts, the dearth of literature on collective, distributed, or artifact-mediated learning is more glaring. Those very few

studies on learning that do exist, while helpful, focus squarely on the individual. One example is offered by Boix Mansilla (2010). Based on her empirical research into interdisciplinary learning, she advances a theory of “pragmatic constructivism” and describes the individual capacities required for interdisciplinary thought. These include openness to diverse perspectives, taking a critical stance, thinking holistically and contextually, and achieving creative synthesis.

Another individually-focused account of learning in this context is offered by Brown Leonard (2012). She conducted a grounded theory-based study of integrative learning among undergraduate students. Four major sorts of learning were identified, along the continuum of integration: 1) application of an idea to a new context, 2) comparison of multiple viewpoints, 3) evaluating of the usefulness of these viewpoints in relation to the specific context studied and negotiating among conflicts, and 4) reconciliation or synthesis of the competing viewpoints to produce improved understanding. Each step within this continuum builds upon the previous step and the final step of synthesis is the most difficult to achieve.

A significant amount of literature in both interdisciplinary and interprofessional contexts deals with the conditions that either constrain or support collaboration. Common themes include personal factors like the need for openness, flexibility, trust, and respect, as well as interpersonal factors such as the need for communication, rules for resolving conflict, and an appropriate balance between diversity (or specialization) and common ground (Drinka & Clark, 2000; Kessel & Rosenfield, 2008; Petrie, 1976; Schon & Rein, 1994). Other writers focus on organization-level issues, especially the need for explicit institutional support; this is required because organizations are traditionally organized around uni-disciplinary or uni-professional “silos” and interdisciplinary or interprofessional endeavors tend to threaten the status quo (Henry, 2005; Klein & Newell, 1998). Finally, the literature articulates a number of epistemological factors, including the need to both recognize and negotiate paradigmatic conflict; the utility of conceptual frameworks and “how-to” models for integration; and the importance of having a concrete problem to focus on (Kessel & Rosenfield, 2008; Newell, 2001; Schon & Rein, 1994; Szostak, 2002).

While this research on the conditions for interdisciplinary and interprofessional collaboration undoubtedly offers very useful information, it is rather fragmented. Learning is uncritically assumed to be a property of individuals only; virtually no authors draw upon collective or sociomaterial theories of learning in order to interpret and organize this information. This is unfor-

tunate, as these theories might arguably provide a generative framework for articulating and explicating the complex, conflicted, and multi-levelled learning and knowing processes that occur in these contexts. In what follows I will, first, describe some key features of interdisciplinary and interprofessional collaboration and, second, speculate on how these features could be productively reframed through the lenses of four prominent collective or sociomaterial learning discourses.

### Some Key Features of Interdisciplinary and Interprofessional Collaboration

Theoretical and empirical literature on interdisciplinarity and interprofessionalism has expanded greatly in recent years. Not surprisingly, this literature comes from a wide range of sources, including work associated with the Association for Interdisciplinary Studies (Repko, 2008), European Transdisciplinarity (Østreg, 2010), Team Science writings (Stokols, 2008), and the rapidly growing field of interprofessional healthcare (*Journal of Interprofessional Care*), as well as other influential interdisciplinary thinkers such as Klein (2005), Latucca (2002), and Petrie (1976). The purpose of this section of the paper is not to provide a comprehensive summary of this literature. Rather, it aims to use this literature to identify several widely agreed upon features that distinguish interdisciplinary and interprofessional activities and collaborations.

Klein and Newell (1998) offer the following widely-quoted definition of *interdisciplinary studies*:

A process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession . . . [It] draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective. (pp. 393-394)

The term *interprofessional* signals a similar attempt to draw upon and integrate fragmented professional perspectives; however, as D'Amour and Onadasan (2005) point out, interdisciplinarity focuses on the integration of knowledge and may give rise to new disciplinary areas, while interprofessionalism is concerned with integration of professional practice and “does not imply the development of new professions, but rather a means by which professionals can practice in a more collaborative or integrated fashion”

(p. 9). Whether the aim is integrating disciplinary perspectives to produce new knowledge or integrating professional perspectives to improve practice, these fields' respective literatures share some key features.

*Diverse perspectives:* First, both fields demand diverse perspectives. As Repko (2008) writes, interdisciplinarity is not opposed to disciplinary specialization; rather, specialized disciplinary perspectives provide the raw materials for interdisciplinary research, so it is essential to develop adequacy in the disciplines relevant to a particular complex problem (p. 189). A similar attention to diversity is cited by many authors in the field of interprofessional healthcare and education: Practitioners must be competent in their professional specialties and be given the opportunity to articulate their perspectives and contribute to diagnoses and treatment plans (Beattie, 2003; Drinka & Clark, 2000).

*Constructing common ground:* A second key feature of interdisciplinary and interprofessional endeavors is the need to construct common ground in the form of compatible understandings, group rules, effective communication, and so forth. The interdisciplinary literature focuses most on conceptual aspects of common ground—that is, the need to identify at least some degree of overlap between disciplinarians' understandings (Szostak, 2007). This usually takes the form of a theory, concept, assumption, or overarching metaphor—which only needs to be applicable to the specific complex problem being researched—that provides a basis for interaction between disciplinarians and the subsequent integration of their insights (Newell, 2001). As Kockelmans first articulated in 1979, “the search for common ground is the fundamental element of all [interdisciplinary] investigation . . . [Without it] genuine communication between those who participate in the discussion would be impossible” (pp. 141-143).

Conceptual common ground is also discussed in interprofessional contexts. Numerous authors, for example, assert that it is crucial for members of interprofessional teams to learn one another's “cognitive maps” (Drinka & Clarke, 2000; Hall, 2000). Members should “incorporate the cognitive maps of others into their own framing of ‘what is the problem’ and ‘how can it be solved’”; this requires “making the internal workings of each profession apparent and understandable in nontechnical language” (Drinka & Clarke, pp. 88, 98).

The more personal and interpersonal aspects of common ground are examined in both the interdisciplinary and interprofessional literature. For

instance, numerous authors stress the importance of open-mindedness and effective communication, as well as the presence of structures such as regular meetings (Drinka & Clark, 2000; Kessel & Rosenfield, 2008; Mickan & Rodgers, 2005; Petrie, 1976).

*Negotiating conflicts:* A third feature that distinguishes both interdisciplinary and interprofessional work is the importance of recognizing and negotiating conflicts. What makes working across disciplinary and professional boundaries especially challenging is that each area's theories and methods are often in profound conflict (Schon & Rein, 1994). As Petrie (1976) writes, "[q]uite literally, two opposing disciplinarians can look at the same thing and not see the same thing" (p. 11). However, one cannot—and should not—attempt to avoid or eliminate these conflicts: "[D]ifference, tension, and conflict are not barriers that must be eliminated. They are part of the character of interdisciplinary knowledge negotiation" (Klein, 2005, p. 45).

A similar sensitivity to the importance of recognizing and negotiating conflict is manifested in theoretically sophisticated interprofessional literature. McKee (2003) and Opie (1997), for example, emphasize that differing perspectives within teams should be elicited and openly discussed. Bleakley (2006) notes that what seems like argumentative talk in a team can be reformulated as a source of collective intelligence (p. 153). As Senge (1990) observes,

Contrary to popular myth, great teams are not characterized by an absence of conflict. On the contrary, in my experience, one of the most reliable indicators of a team that is continually learning is the visible conflict of ideas. In great teams, conflict becomes productive. (p. 249)

At a personal and interpersonal level, recognizing and negotiating conflict requires collaborators to be cognitively flexible, to show trust and respect for others, to have mechanisms for resolving conflict, and to be reflexively aware of power issues such as workplace hierarchies and inequalities between disciplines or professions (D'Amour et al., 2005; Drinka & Clark, 2000; Hall, 2000; Kessel & Rosenfield, 2008; Mickan & Rodgers, 2005; Petrie, 1976; Sumner, 2003).

*Synthesis:* The final and fourth feature of interdisciplinary and interprofessional collaboration that I have chosen to focus on is integration or synthesis. Interdisciplinary research attempts not only to juxtapose differ-

ing disciplinary perspectives (mere multidisciplinary) but also to integrate them into larger, more encompassing perspectives (Klein & Newell, 1998). This integration often occurs through the identification of an overarching concept, theme, or metaphor (Newell, 2001). For example, the concept of “patient-centered care” has been used to integrate the diverse biological, psychological, social, and ecological factors relevant to human healthcare — both in the interdisciplinary context of health science research and the interprofessional context of improved patient care.

What is crucial about this sort of integration or synthesis is that it produces something that is “greater than the sum of the parts,” whether those parts are disciplinary insights or professional perspectives (Drinka & Clarke, 2000; Newell, 2001). As Leathard (2003) puts it, “combined, integrative efforts can achieve more than is possible simply by adding contributions” (p. 94).

## Collective and Sociomaterial Approaches/Reframing

Having identified four important features of interdisciplinary and interprofessional collaboration, I will now speculate on how they might be productively reframed through the lenses of four prominent collective or sociomaterial learning discourses. The terms “collective” and “sociomaterial” are used here as umbrella terms for theories that look beyond isolated individuals and see other people, social dynamics, artifacts, and other living organisms with which we interact not as mere backdrops to learning but as fundamental to and inseparable from learning (Davis & Sumara, 2007; Fenwick, 2010).

The specific discourses I will be employing are communities of practice, cultural-historical activity theory, complexity science, and actor-network theory. What these theoretical perspectives offer are useful frameworks for understanding how learning and knowing are not solely the property of individuals’ heads, but rather are distributed across—and enacted through—social collectives, practices, material artifacts, and dynamic relationships. As described above, these theories may be particularly useful in interdisciplinary and interprofessional contexts, since the complex challenges posed in these contexts can often be better addressed by collaborative teams of experts than by any one lone individual, no matter how broad his or her expertise.

*Communities of Practice (CoP):* A perspective on learning, this theory originated in the work of Lave and Wenger (1991). Wenger (2006) defines



communities of practice as

groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly... Communities of practice are formed by people who engage in a process of *collective learning* in a shared domain of human endeavor: a tribe learning to survive, a band of artists seeking new forms of expression, a group of engineers working on similar problems, a clique of pupils defining their identity in the school, a network of surgeons exploring novel techniques, a gathering of first-time managers helping each other cope. (*italics added*, para. 2)

Learning from this perspective is conceived of in social terms. Communities learn through the interactions and shared activities of their members, and this collective learning is embodied in practices, artifacts, and social organization. Furthermore, individuals are understood to learn as they move from the periphery of a community of practice to more central participation, “tuning” their activities and relationships accordingly (Wenger, 1999). This process is analogically compared to the way an apprentice moves from being a novice toward the status and responsibility of a journeyman and eventually a “master.” It also fundamentally shapes participants’ identity and worldview. As Lave and Wenger (1991) put it, this

Knowing is...located in the relations among practitioners, their practice, the artifacts of that practice, and the social organization and political economy of communities of practice. For newcomers, their shifting location as they move centripetally through a complex form of practice creates possibilities for understanding the world as experienced. (p. 122)

Although CoP primarily offers an analytical perspective on learning rather than a specific approach to teaching, practice or research, it does offer several useful insights for these contexts. One is that we should acknowledge and make use of communities of practice in these settings, ensuring that learners have access to participation and to higher-level practitioners—whether those practitioners are educators, health professionals, or researchers. In other words, rather than focusing solely on cognitive processes and concepts, we must attend to what kind of social engagements provide the proper context for learning (Lave & Wenger, 1991).

CoP as a theory of social learning helps to reframe and illuminate aspects

of the key features of interdisciplinarity and interprofessionalism described above. With respect to *diverse perspectives*, it provides valuable insights into how disciplinary and professional knowledge is developed—that is, through increasing participation in existing communities of practice. If we are to nurture such specialized disciplinary and professional competencies—as we saw, a prerequisite for interdisciplinarity and interprofessionalism—then we need to ensure that novice disciplinarians and professionals have access to participation within these communities and to more expert practitioners.

At the same time, this theory illustrates why sharp paradigmatic differences exist and thus why there is a need for *constructing common ground* and *negotiating conflict*. As we saw above, CoPs generate their own diverse concepts, artifacts, and forms of social organization, and they fundamentally shape participants' identity and possibilities for understanding the world. These same processes can also be seen in disciplinary and professional socialization. That is why two different disciplinarians or professionals can, quite literally, look at the same phenomenon and not see the same thing. Given the challenges posed by such conflicting worldviews—epistemological, methodological, and so forth—it becomes more clear why there is a need in interdisciplinary and interprofessional contexts to construct conceptual common ground, to be open-minded and flexible, to show others trust and respect, and to develop structures like regular meetings and formal and informal guidelines for resolving conflict.

Perhaps most importantly, the theory of CoP hints at what may be required to move beyond disciplinary and professional differences. If learning is understood in terms of increasing participation in social practices, then there is a need to establish interdisciplinary and interprofessional communities of practice. To put it another way, integration or *synthesis* is much more likely to occur when it becomes part of an established, evolving community of practice than when it is pursued by isolated individuals. Seen in this light, the literatures on interdisciplinarity and interprofessionalism, and their actual practice in universities, research institutes, hospitals and so on, take on additional importance.

*Cultural-Historical Activity Theory (CHAT)*: Similar to CoP, this theory understands human learning primarily in terms of social processes and collectives. Inspired by Vygotsky, Ilyenkov and other Marx-influenced thinkers, activity theorists reject the traditional Western assumption that isolated individuals must form the starting point of any explanation of human knowl-

edge and practices. Instead, they propose that the primary unit of analysis should be activity systems, which encompass not only communities of people but also tools, rules, divisions of labor, and objects (problems to which activity systems' collective actions are directed). As leading CHAT theorist and researcher Engeström (2001) writes, individual and group actions are "subordinate units of analysis . . . eventually understandable only when interpreted against the background of entire activity systems" (p. 136).

Examples of activity systems include everything from companies to hospitals and community organizations. Engeström (2000) himself uses Finland's professional baseball league to illustrate how the intertwined processes of cultural internalization and individual externalization unfold in practice. On the one hand, the rules and concrete organization of the game itself, he writes, have been "constructed, historically and collectively, by collaboration between humans and their artefacts" (Engeström 2000, p. 302). On the other, individual persons are embedded in this social matrix; their thoughts and actions cannot be understood independently of the activity systems in which they participate. For instance, "[t]he umpire's possibility to construct reality is completely dependent on his place in the configuration of the activity system, mediated by a division of labour" (Engeström, 2000, p. 304).

CHAT offers several additional conceptual insights that would benefit those involved in interdisciplinarity and interprofessionalism. One is the central role played by material artifacts (tools, signs, and technologies). Such artifacts transmit knowledge and mediate humans' interaction with one another and their environments—for instance, the way scientific tools shape experimental design or how patient charts or "maps" mediate communication in healthcare (Kerosuo & Engeström, 2003; Miettinen, Lehenkari, & Tuunainen, 2008; Varpio, Hall, Lingard & Schryer, 2008). Another key insight is the crucial role of tensions or contradictions in learning and development: "internal contradictions [are] the driving force of change and development in activity systems" (*Cultural Historical Activity Theory*, n.d., para 8). One example of the contradictions that drive change within organizations is the tension among professional practice norms, union workload rules, and hospital policies within health care settings (Varpio, Hall, Lingard & Schryer, 2008).

Within the literature on interprofessional healthcare teams, several authors have begun to employ CHAT (Bleakley, 2013; Varpio, Hall, Lingard & Schryer, 2008). Varpio et al. (2008), for instance, use it and the closely-related theory of "knotworking" as frameworks for understanding medical errors and breakdowns in communication among different health professionals:

Each professional comes to the interprofessional collaboration through his or her unique activity system and contributes a distinctive thread of activity to resolve the patient's evolving clinical situation . . . This collaborative performance, when the threads tie together, is a Knotworking knot. (p. S78)

Sophisticated use of CHAT is, however, rare within interprofessional contexts and virtually nonexistent within interdisciplinary contexts. This is unfortunate, as it, too, could generatively illuminate and reframe many key features of interdisciplinarity and interprofessionalism. The role of physical and conceptual artifacts in mediating interdisciplinary and interprofessional collaboration, for example, is something that merits much further study (Lattuca, 2002). The idea that tensions or contradictions drive learning and development within groups is also promising. It helps to explain why *diverse perspectives* are required in order for teams to be effective and collectively intelligent, as well as why the *negotiation of conflicts* is not merely a hurdle to overcome, but an essential characteristic of interdisciplinary and interprofessional activities (Klein, 2005).

In addition, CHAT offers several concepts that may be of particular utility to those studying interdisciplinary and interprofessional activities. One is its characterization of how “expansive learning” (“culturally new patterns of activity”) may occur as two previously disparate activity systems interact to form jointly constructed objects or problems to be solved (Engeström, 2001, pp. 136-139). A concrete example is how biomedical and psychosocial views of a patient may become joined under the wider heading of patient-centered care. Other useful concepts include CHAT's interpretations of “boundary crossing” as movement between discontinuous activity systems and the consequent challenge of negotiation and combination, as well as the concept of “boundary objects”: artifacts that are understood and employed differently in two or more activity systems, but nonetheless may serve as a bridge between them (Akkerman & Bakker, 2011).<sup>1</sup>

*Complexity Science:* Complexity theory or science is a cross-disciplinary

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<sup>1</sup> A parallel to the concept of “boundary objects” can be found in Galison's (1997) metaphor of “trading zones.” His classic research on collaboration between physicists and engineers developing particle detectors and radar describes how they developed a “pidgin” or “creole language” to coordinate their local interactions around objects—even though they might have had “utterly different” understandings of those objects (p. 783).

discourse that has arisen in recent decades. Its focus is complex systems: *living systems* like the brain, organisms, ecosystems, and cities that cannot be adequately explained through traditional, reductive scientific analysis (Heylighen, Cilliers, & Gershenson, 2007). One crucial characteristic of such systems is emergence: They are “more-than-the-sum-of-their-parts.” As Cilliers (1998) writes, a “complex system is not constituted merely by the sum of its components, but also by the relationship between these components. In ‘cutting up’ a system, the analytical method destroys what it seeks to understand” (p. 2).

A complex system thus embodies novel, unpredictable characteristics that emerge at the level of the system as a whole. One example is the way a living human being has possibilities for action that go beyond those of a simple aggregation of bodily organs. This phenomenon of emergence also applies to larger scale living systems like social collectives; a group of people collaborating together as a company or academic community, for instance, can generate more knowledge than those same people working in isolation. (The significance of the idea of emergence for understanding individual and team knowledge in interdisciplinary and interprofessional contexts is dealt with in more detail below.)

Complexity has been embraced by many interdisciplinarians as a framework for modelling complex problems such as acid rain or healthcare (see for example, Klein, 2004; Newell, 2001). Within educational circles, thinkers such as Davis and Sumara (2006) and Osberg, Biesta, and Cilliers (2008) have started to use complexity thinking both to understand learning at individual and collective levels (for example, students and their classes) and to identify conditions crucial to supporting learning in these contexts.

Davis and Sumara (2006) have suggested three complementary pairs of conditions for nurturing the emergence of intelligent human collectives: diversity and redundancy, openness and constraints, and decentralization and organization. *Diversity* refers to the range of different experiences and perspectives present, while *redundancy* is the common ground that enables individuals to interact effectively. *Constraints* describes the rules or boundaries necessary to orient and sustain the coherence of a complex system; it must be balanced against the need for sufficient *openness* for diverse perspectives to be expressed and for the system as a whole to develop in innovative ways. Paradoxically, many constraints can be seen as enabling creativity and freedom—for example, the way rules of grammar enable communication. Finally, complex collectives are always organized, but not in a “top-down” manner by a single agent or external controller; instead,

*organization* emerges “bottom up,” through the *decentralized* interactions of the individuals who collectively give rise to the system.

With a few notable exceptions (Cooper, Braye, & Geyer, 2004; McMurtry, 2010, 2011), this learner-focused brand of complexity science has not been applied to interdisciplinary and interprofessional contexts. Again, however, it seems to offer a number of concepts that may help to reframe and enrich our understanding of interdisciplinary and interprofessional collaboration. There are, for example, strong parallels between (Davis & Sumara, 2006) conditions for nurturing intelligent collectives and the key features of interdisciplinarity and interprofessionalism described above. Both emphasize the need for specialization or *diverse perspectives*, in one case to support collective intelligence and in the other to support interdisciplinary or interprofessional approaches to complex problems (Repko, 2008).

The importance of *common ground* is also a point of agreement. Complexivists use the term *redundancy* to describe a wide range of phenomena that, through their overlap or similarity, support the coherence and robustness of complex systems. Examples include veins in the human body that can take over the functions of adjacent veins if they are damaged; similarities in expertise or competence that allow team members to be more flexible in the roles they play and compensate for one another’s lapses; and overlaps of language and culture that allow different individuals to interact (Davis & Sumara, 2006). Interdisciplinarians use the concept of common ground in a more specific sense: the theories, concepts, assumptions, or overarching metaphors that provide a basis for interaction between disciplinarians and the subsequent integration of their insights (Newell, 2001; Repko, 2008). Interprofessional researchers and practitioners express the importance of common ground through team-oriented imperatives such as clear, jargon-free communication and the sharing of “cognitive maps” (Drinka & Clarke, 2000; Hall, 2000).

The balance between openness and constraints articulated by complexivists also has parallels within interdisciplinary and interprofessional collaboration. Open-mindedness and flexibility are, as we saw, required on interdisciplinary and interprofessional teams. And team rules concerning respect for others, regular meetings, and resolving conflict can be seen as constraints that, paradoxically, enable the emergence of creative solutions. The paired conditions of organization and decentralization can be linked to *negotiating conflicts*. Effective interdisciplinary and interprofessional teams recognize and negotiate among conflicting perspectives; single powerful perspectives should not be imposed in a “top-down” fashion. Similarly, in complex col-

lectives, organization emerges “bottom-up,” through the decentralized interactions of individuals.

Finally, complexity science’s concept of emergence may help to reframe and enhance understandings of integration or *synthesis* within interdisciplinarity and interprofessionalism. Many authors assume that interdisciplinary or interprofessional collaboration, when successful, produces something that is “more-than-the-sum-of-its-parts” (Drinka & Clarke, 2000; Leathard, 2003; Repko, 2008). Unfortunately, few authors provide concrete guidance concerning exactly how knowledge emerges at the level of the team that exceeds the sum of separate individuals’ knowledge. As Chatalalsingh and Regehr (2006) write, “what is underspecified in the literature is the process of how learning and knowledge sharing are enacted within working teams” (p. 31).

A number of theorists adopt an individualistic perspective, asserting that team knowledge can be located in members’ shared “cognitive maps” (Drinka & Clarke, 2000; Hall, 2000; Petrie, 1976). Complexity science, however, offers an alternative way to understand integration or synthesis that illuminates (without conflating) both the individual and the more collective (“more-than-the-sum-of-the-parts”) learning that emerges in such collaborative contexts.

This explanation makes use of both 1) complexity’s characterization of *upward* (or “*bottom up*”) *causation*, the process by which local interactions among the parts of a complex system give rise to it as an emergent whole, and 2) the less well-understood process of *downward causation*. This is a “*top-down*” process by which an emergent whole constrains the activities of its parts, one level down. Examples include the way our body as a whole constrains the functioning of organs and cells in order to preserve its existence, how the conscious mind directs one’s mental processes towards solving certain problems, and the manner in which a democratic society constrains the actions of its members through legislation. Juarrero (1999) encapsulates this simultaneous process of upward and downward causation within complex systems in the following way: “[C]omplex dynamical systems self-organize out of the interrelationships among parts—and then loop back to constrain those parts . . . In other words, self-organizing systems exhibit . . . interlevel causality . . . both bottom-up and top-down” (p. 128).

The concepts of emergence and upward and downward causation can be used to model the learning that occurs within interdisciplinary or interprofessional teams. Obviously, individuals (the “parts”) within such teams will likely adapt and broaden their intellectual horizons as they interact with one

another's differing perspectives concerning a common problem or issue. At the same time, as they elicit, build on, and challenge one another's ideas over time, they will begin to produce new collective knowledge that exceeds their individual "cognitive maps"—knowledge that could not have been predicted in advance of their collaboration. This knowledge is typically embodied in the academic papers, diagnoses and treatment plans, group practices, processes, inventions, and so on that the team produces—and it can be seen as an instance of upward or "bottom-up" causation (McMurtry, 2010; 2011).

At the same time, this emergent collective knowledge will exert a governing influence on the learning of the individuals who create it. Participating in an interdisciplinary research program, for example, will shape the activities and learning of individual members. And interprofessional team decisions about diagnoses and treatment plans will shape the various professionals' understandings and practices. But that does not necessarily mean that these individuals will fully share their "cognitive maps" or understand all aspects of this collective knowledge. And so this complexity science-oriented account of team learning differs significantly from the more conventional, individual-focused accounts described above.

From a complexity perspective, therefore, interdisciplinary and interprofessional collaboration involves two levels of learners: individuals and team collectives. And synthesis or integration in such collaborative contexts involves the construction of emergent, collective knowledge. This knowledge may take the form of, for example, academic papers within research contexts, treatment plans in interprofessional healthcare contexts, or novel team teaching practices and curricula within educational contexts. It is rooted in individual contributions, and individuals certainly learn as part of this process, but it will often exceed the sum of their individual knowledge contributions.<sup>2</sup>

*Actor-network theory (ANT):* Like complexity science, this theoretical

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<sup>2</sup> Keestra (2012) also argues for a multilevel approach to interdisciplinarity, though his focus is integrating insights concerning human action rather than collaborative learning. He describes the complicated interplay of neurological, psychological and sociocultural factors relevant to examinations of human action. His "mechanism-based" explanatory framework does not, however, draw upon complexity science and the idea of emergence (p. 226). Phenomena at each level are explained through a process of "decomposition" and "localization"—i.e. analysis into their component parts (p. 128). They do not embody emergent qualities that exceed the sum of their parts.



approach views learning and knowing as exceeding individual cognition. Specific principles of ANT are difficult to pin down, as many theorists associated with the discourse view entrenched principles as antithetical to the evolving, multi-voiced sensibility of their research; perhaps the only clear principle is an anti-reductionist commitment to dealing with the complexity and messiness of all phenomena (Fenwick & Edwards, 2010).

I will, nonetheless, attempt to identify and illustrate a number of commonly cited ANT concepts. One is the idea of “generalized symmetry.” ANT can be seen as a reaction against discourses that attempt to explain phenomena solely or primarily through one factor or frame, whether it be nature, social constructions, technology, or semiotics (Latour, 2005). It encourages researchers to level hierarchical distinctions typically made between things, culture, humans, and other organisms. Because it places the natural and things on the same plane as the social and cultural, ANT has been associated with the “spatial turn” in social sciences.

A related ANT concept is “relational materialism”:

The most radical claim of actor-network theory is that all social life consists of pattern networks of people, animals, machines, texts, buildings, plants—any material entity that is brought into a network. These entities have no inherent qualities but take their form and acquire their attributes through relationships in networks with other entities. (Clarke, 2002, p. 112)

Each of these entities or “actors” may enable, resist, or otherwise affect interactions, but their stability and meaning are ultimately generated through the assembly and maintenance of relational networks. Keys and locks, for example, may take on significance within social collectives such as schools depending upon how they are used and distributed, but their physical shape, size, and complexity also afford or facilitate certain sorts of actions more than others; a large key fob, for instance, may prevent it from being forgotten or misplaced while a unsophisticated lock may facilitate “break-ins.”

Even learning and knowing are understood relationally in ANT: “[K]nowledge from an ANT perspective is not a latent attribute of any one element or individual, but a property of some actions rather than others as a network becomes enacted into being” (Fenwick & Edwards, 2010, p. 35). Learning and knowing might therefore be understood in terms of effective interactions within networks.

A third important ANT concept is “translation,” the process by which net-

works come together as various actors work upon or “translate” one another in such a way as to perform certain actions and knowledge (Fenwick & Edwards, 2010).<sup>3</sup> To understand the construction of knowledge, therefore, one must attend to the network. As Latour (1987) writes,

The problem of the builder of ‘fact’ is the same as that of the builder of ‘objects’: how to convince others, how to control the behavior, how to gather enough resources in one place, how to have the claim or the object spread out in time and space. In both cases, it is the others who have the power to transform the claim or the object into a durable whole. (p. 131)

Although ethical issues are not explicitly addressed in many ANT studies, this theoretical approach has significant ethical implications. When things combine into networks to produce objects, knowledge, and facts, they displace or suppress differing voices or perspectives. ANT analyses are therefore used by many authors in order to examine *how* particular taken-for-granted facts, classifications, orders, and other hierarchies are generated, as well as to critique these norms and imagine other possibilities (Clarke, 2002; Fenwick & Edwards, 2000).

Clarke (2002) illustrates the stages of translation and network building through a critique of the United Kingdom’s Department for Education and Employment (DfEE) “Skills for Life” program and the manner in which it works to exclude differing perspectives.<sup>4</sup> The first stage is “problematization,” in which a particular goal or problem to be solved is defined, and certain actors get to set the agenda and make themselves indispensable. The DfEE, for instance, defines the problem for which the program was established as certain less-educated portions of the population holding back the country from competing effectively within the global economy. The next stage is “*interressement*”<sup>5</sup> and “*enrolment*,” in which competing interests are excluded and alliances among the various actors in a network are secured. Clarke argues that the “Skills for Life” program, through its nar-

<sup>3</sup> It is important to note that this definition of “translation” is quite different from other common meanings, such as those involving language translation, the translation of basic scientific research to improve practice, or translational sciences motivated by the need to help people in practical ways.

<sup>4</sup> While Clarke’s example can be seen as a negative one from an ethical perspective, it nonetheless highlights key ANT concepts and how the theory may be used to critique the entrenchment of narrow disciplinary or professional perspectives.

<sup>5</sup> A French word that is generally translated as “profit sharing” or “incentive scheme” (<http://dictionary.reverso.net/french-english/int%C3%A9ressement>).

row definition of literacy and institutional practices, sets clear boundaries between “us” and “them” and excludes complexity and dissent. “Mobilization” occurs when the network becomes stable and can be transported into other areas. Such mobilization occurs when “Skills for Life” policies are extended across the country and concepts appear in politicians’ speeches. These networks can be disrupted, however. This might occur if competing definitions and perspectives acquire sufficient strength to penetrate the boundaries of *interessement* and detach some of the network’s actors, thereby destabilizing the processes of translation and mobilization (Clarke, 2002, pp. 115-118).

Not surprisingly, ANT has been criticized for minimizing the uniqueness of human cognition and intentionality. And complexivists might object that complex living systems behave in fundamentally different ways from non-living things—for instance, in their capacity for self-organized adaptation. Nevertheless, ANT offers numerous insights for those pursuing interdisciplinary or interprofessional activities. In the first place, ANT’s close attention to artifacts and the interactions they enable may be useful for illuminating the influence of various texts and technologies, such as computers, textbooks, and patient charts.

Like the other collective and sociomaterial theories described, ANT offers a way to think about learning and knowing that transcends contents of individuals’ heads—in this case as something (or perhaps more accurately, a process) that is enacted through effective interactions within constantly evolving and shifting networks of people and things. ANT’s concept of “generalized symmetry” also prompts thinkers to move beyond characterizations of interdisciplinarity or interprofessionalism based either on the social or on the natural. The social, the natural, and all other such explanatory factors are simultaneously present and intertwined, and they need to be considered in a manner that does not hierarchically privilege one factor over the others. This “interobjective” perspective has only recently appeared within interdisciplinary and interprofessional literature (McMurtry, 2009; 2011).

In addition, ANT may help deepen our understanding of challenges related to *diverse perspectives*, *constructing common ground*, *negotiating conflicts*, and *synthesis*. There appears to be a generative tension between, on the one hand, ANT’s assertion that networks inevitably suppress other voices or conflict and, on the other, interdisciplinary and interprofessional attempts to explicitly include and negotiate conflicts among diverse perspectives. Does the construction of common ground and synthesis of perspectives necessarily require the displacement of dissenting interests and perspectives? ANT

can certainly enliven the discussion of these issues and draw our attention to the often taken-for-granted ways in which facts and knowledge are established within and across disciplines. Conversely, interdisciplinary and interprofessional activities may complicate ANT's depiction of the processes of translation and network formation as something that necessarily narrows and limits possibilities.

## Conclusion

The purpose of this article is to begin to explore how collective and socio-material theories of learning might be applied within interdisciplinary and interprofessional contexts—in particular the team-based collaboration that is playing an ever larger role in both fields. It articulates several key features of interdisciplinary and interprofessional activities and then speculates on how they might be productively reframed through the lenses of the following theoretical perspectives: communities of practice, cultural historical activity theory, complexity science, and actor-network theory. The article is not intended to be comprehensive; its aim is to begin the process of developing deeper, more theoretically sophisticated understandings of the collective learning and knowing that emerge—often across deep paradigmatic divides—through interprofessional and interdisciplinary collaboration.

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