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Abstract

Although many researchers agree that teaching is complex and contextually situated, dominant conceptions of teacher learning, and the enactment of such learning in practice, tend to be linear and reductionist. Because simplistic conceptualizations of teaching activity have far-reaching impact on teachers, students, and school systems, generating a complex theory of teacher learning-practice is nothing short of an ethical imperative. To tackle this task, we draw from an emerging body of teacher education scholarship that we consider the beginning of a 'complex turn'. Drawing on this literature, we distill a set of conceptual shifts that, together, offer a set of theoretical tools to (re)think the processes of, and connections between, teacher learning-practice in ways that better account for the dynamic, multiplicitous, ever-shifting nature of these activities.

Keywords: Teacher learning; teacher practice; complexity theory; rhizomatics; cultural historical activity theory

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The difficulty of moving teacher pedagogical learning from pre-service preparation and/or in-service development directly into classroom practice (e.g., Veenman 1984, Beck *et al*. 2007, Chubbock 2008) and the propensity for novice teachers to adopt transmission-based pedagogical methods even when prepared differently (Massengill *et al*. 2005, Flores and Day 2006, Allen 2009, Hong 2010) are well documented. While some researchers have begun to advocate for approaches that can take into consideration the complexity of the relationship between teacher learning and practice (e.g., Opfer and Pedder 2011, Ell *et al*. 2017, Boylan *et al*. 2018), dominant thinking regarding teacher learning and practice remains relatively linear and 'process-product' driven (Opfer and Pedder 2011, Cochran-Smith 2013, Strom and Martin 2017). These linear perspectives, which assume that the teacher has full agency to take her learning and drop it, intact, into the classroom, have far-reaching impact, shaping the way we prepare, support, and assess teachers, as well as students' access to quality teaching and learning (e.g., Cochran-Smith and Lytle 2009, Zeichner 2010, Opfer and Pedder 2011, Strom and Martin 2017). Such thinking also contributes to a revolving door of teachers (Ingersoll 2003, Strong and Ingersoll 2011), which further destabilizes already under-resourced settings, feeding into the well-documented patterns of inequality that have historically plagued educational systems.

In this article, we argue that, given the serious limitations and negative repercussions that linear thinking has on educational systems, generating a complex theory of teacher learning-practice[1] is nothing short of an ethical imperative. To tackle this task, we begin by drawing on research from what we argue is a 'complex turn' in teacher education – that is, scholarship regarding teacher learning and practice that employs sociocultural and sociomaterial perspectives (e.g., Opfer and Pedder 2011, Cochran-Smith *et al*. 2014, Strom 2015) – to distill a set of conceptual shifts. These shifts offer a set of theoretical tools to (re) think the processes of, and connections between, teacher learning-practice in ways that better account for its dynamic, multiplicitous, ever-shifting nature.

Rethinking our thinking about teaching

When we refer to 'linear thinking', we are describing rational humanism, a dualistic ('either/or') logic rooted in the Enlightenment, which 1) conceives of reality in binaries or separations (e.g., mind/body, self/other, white/black, class divisions, and nation-state borders); 2) advances that there is one universal reality and way of being/thinking; 3) reduces complex phenomena to essences and one-to-one correspondences; 4) assumes individual human actors have complete agency (St. Pierre 2000, Braidotti 2013, Strom and Martin 2017). As some scholars have begun to acknowledge (e.g., Opfer and Pedder 2011, Ell*et al*. 2017, Viesca *et al.* 2019, Daly *et al*. 2020), these ways of thinking underscore much of the initial teacher preparation and professional development literature, which views learning as follows: teacher candidates and practicing teachers learn knowledge about teaching (a process that occurs in their minds) while studying in university classrooms or participating in professional development activities; then they take that knowledge into classrooms, where they enact it as teaching practice (a process that is carried out by the body). While the teacher learning literature features a range of theories and models, some of which account for context and other influencing factors to varying degrees, the majority of perspectives still reflect a rationalist approach in which the teacher more or less controls their teaching, the human/non-human elements of the classroom are relatively stable and passive, and teacher learning and teacher practice have a one-to-one correspondence.

We join scholars in diverse fields, ranging from quantum physics and bioscience to animal studies and the digital humanities (Braidotti 2019), as well as Indigenous scholars (Kimmerer 2013, Simpson 2017), in calling for more complex, connected, relational, vital ways of understanding the world. Such a complex perspective entails several onto-epistemological shifts. Chief among them is a move from dualism (binary, individualistic thinking) to monism, also known as immanence (everything-is-connected thinking) (Braidotti 2013). This moves us from an 'either/or' perspective of seeing the world in individual, discrete units to an 'and, and, and' worldview of entangled, co-constructed multiplicities (Deleuze and Guattari 1987). For example, we hyphenate 'learning-practice' in this paper to emphasize that

these are not separate things, but rather intertwined processes that co-constitute, or *co-make*, each other (Barad 2007, Haraway 2016). This immanent perspective also means moving from considering the human as the reference point of the universe to embracing assemblages of elements, both human and nonhuman, with shared agency; from assuming the existence of universal and transcendent 'truths' to accounting for perspective and situatedness in knowledge generation; and from valuing sameness to prizing difference.

These ways of thinking also address deeply entrenched educational inequities perpetuated by rational humanist thought by visibilizing its geopolitical location and relation to knowledge construction (Haraway 1988, Braidotti 2019). For instance, although rational humanism claims to be universal, transcendent, and objective, it comes from a specific time, place, and people – European men during the Enlightenment. Further, these logic patterns are not neutral, but have determined who gets defined as 'human' for centuries. As a result, many 'othered' groups in the world today – and in our schools – have never been granted the rights and privileges of being fully human (Braidotti 2013). By geo-politically locating dominant thought, we expose it as European/ White, colonial heteropatriarchal thinking. Thus, we can problematize its false claims to objectivity and neutrality, as well as expose one mechanism by which institutions such as schools impose Eurocentric logic as 'proper' and intellectually superior.

Adopting a connected, interdependent perspective also offers the potential to disrupt the harmful thinking that informs the 'bootstraps' and 'grit' narratives of educational and social success (Gorski 2016). Instead, this perspective requires an explicitly material analysis, which means that poverty, race, and other material conditions can no longer be dismissed as irrelevant to educational activity, but rather, must be acknowledged as powerful influences on students' schooling. Finally, immanent perspectives also position *difference* as natural, positive and productive – a creative force – rather than defining it in punitive terms (Braidotti 2013). Because systems are not static, but dynamic and constantly changing, difference is the natural state of things (Deleuze and Guattari 1987). Moreover, introducing difference into dynamic systems produces new adaptations – which in turn can open previously unknown possibilities. This way of thinking promotes affirmative attitudes towards pluralism of language, culture, and ways

of knowing/being, as well as appreciation that, across different sets of people, things, ideas, and settings, complex phenomena like teaching may be constructed very differently.

Complex perspectives on teacher learning-practice

In this section, we explore three distinct theoretical perspectives that take into account some or all of the complex shifts discussed above. We chose these three theories because they represent a continuum of complex thinking from more familiar and established (i.e., sociocultural theories/ CHAT) to more unfamiliar/emergent perspectives (i.e., rhizomatics) in terms of the teacher education literature. They also show the ways that this complex turn in thinking is transdisciplinary: sociocultural theories/CHAT come out of psychology, complexity theory comes from physics and mathematics, and rhizomatics is drawn from continental philosophy. We argue that these perspectives – sociocultural views/CHAT, complexity theories, and rhizomatics – illustrate a complex turn in teacher education and offer insights to articulate an emerging framework of teacher learning-practice. We articulate these perspectives separately first and then bring together key ideas into an emerging framework later in the paper.

Sociocultural perspectives/CHAT

First developed by Vygotsky (1978), sociocultural perspectives offer a way to understand learning that views the social and cognitive aspects of creating knowledge as interactive, drawing a connection between thinking and activity (doing). Vygotsky (1978) offered a number of tenets that, taken together, provide a more complex picture of learning than that promoted by behaviorist thinking: 1) learning is a social activity that happens first externally, followed by internal or interpersonal knowledge construction; 2) learning is mediated by artefacts, including symbolic tools (e.g., language, cultural understandings) and physical tools (e.g., textbooks, manipulatives); 3) learning occurs ahead of development, as students engage in mediated, supported, activity just beyond their current abilities; and 4) learning can be observed as changes in participation in activity over time.

Two central concepts in sociocultural theory are the Zone of Proximal Development (ZPD; Vygotsky 1978) and scaffolds (Wood *et al*. 1976). The ZPD represents the area just beyond what learners can do by themselves (their zone of self-regulation), but can accomplish with help from expert others (Vygotsky 1978). Within the ZPD, *scaffolds*, or contingent supports, help the learner achieve what they could not on their own. Although Vygotsky described interaction in the ZPD as occurring between learner and expert, other researchers have acknowledged that, through dialogue with an equal peer (Kuusisaari 2014) or a less-knowledgeable peer (van Lier 2004) new understanding can develop. van Lier (2004) even suggested that by drawing on previously internalized skills and experiences and using self-talk, an individual can provide their own scaffolds.

Cultural Historical Activity Theory (CHAT) is an outgrowth of Vygotsky's work (also known merely as activity theory). Both a conceptual and methodological frame, CHAT rests on Vygotsky's theoretical principles discussed above and involves analysis of a particular activity system. According to Engeström (1999), each activity system includes the following elements: (a) subject (the learner/s); (b) the objects or outcomes (what they are learning about, and what they should be able to do); (c) tools (mediating artefacts used to obtain the object/outcome); (d) community (individuals, groups, subgroups who share the same object); (e) rules (regulations and norms that shape behavior); and (f) division of labor (actual tasks and power roles). CHAT analyses identify each of these elements in a given activity system and theorizes the ways they work together to explain how that particular system functions.

While CHAT is not the only sociocultural perspective relevant to teacher learning, it has been taken up by teacher education researchers across the globe over the last decade-plus to study teacher learning and practice in more complex ways (e.g., Tsui and Law 2007, Saka *et al*. 2009, Valencia *et al*. 2009, Gatti 2016, Andrews *et al*. 2019). These studies provide insights for the teacher-learning process and how that learning may move into practice – for example, in Hong Kong, Tsui and Law (2007) examined teacher learning interactions between a school and university, studying the learning activity of lesson study as a mediating tool that increased teacher development. Focusing on different sets of resources from a teacher preparation program and in

the teaching context as meditational tools, Gatti (2016) examined the influence of these resources on the learning of two U.S. teachers and the ways they affected their relationships with students.

Studies utilizing CHAT also offered a way to analyze local activity and tease apart the ways that interacting factors in schools influence teacher learning-practice. For instance, Andrews *et al*. (2019) used CHAT to understand how factors from the teacher, school, and larger educational system constrained teachers' ability to translate their learning about inclusive teaching into practice in four schools in South Africa. In the U.S., Saka *et al*. (2009) employed a CHAT framework to investigate the ways that two first-year science educators in the U.S. enacted reform-based teaching practices, finding that each situated activity system – the rules of the school community, the resources and orientations the teacher brought, the supports that were available – interacted in different ways and, in turn, these two teachers enacted very different practices. The sociocultural perspective of CHAT, then, provide ways to analyze specific elements of a system – personal, contextual, material, discursive – that work together to structure learning and practice in certain ways, and reveal the patterns of interactions within the system that influence the types of practices enacted over time.

Complexity theories

Complexity theories refer to explanatory frameworks that focus on the spontaneous emergence of phenomena out of what might seem to be chaos. According to complexity thinkers in the social sciences (e.g., Byrne 1998, Davis and Sumara 2006, Mason 2008) human activity (such as teaching/ learning), occurs at the *edge of chaos*, a state that induces enough disequilibrium to spur growth and learning, but not enough to precipitate a plunge into total disorder (Waldrop 1992; Butz 1997). This 'just right' amount of disequilibrium must be present in all living systems, as it introduces conditions that spur the system to collectively adapt and grow.

Systems interacting on the edge of chaos are *nested* – that is, they simultaneously are a system, encompass smaller systems, and are part of a larger system (Davis and Sumara 1997/2006). In education, for instance, the classroom is a system that simultaneously contains

smaller systems (e.g., the teacher and students) and embedded in larger systems (e.g., the school, the district). Because of their nested nature, their boundaries tend to be fluid and overlapping (Davis and Sumara 2006). These nested systems are defined in part by a large number of interconnecting elements (Richardson *et al*. 2001), meaning that connectivity is a key feature of complex systems (Morrison 2008). As complexity is a science of the collective, no system element exists in isolation (Davis and Sumara 2006) – actors and elements comprising each system interact with each other, as well as with actors and elements from all other systems. These interactions within, between, and among systems occur simultaneously, leading complexity theorists to label them 'simultaneities' (Davis and Sumara 2006, Mason 2008).

These networks of systems allow for *feedback loops*, another important characteristic of complex systems (Clarke and Collins 2007). While complex systems have an element of unpredictability, their overall pattern tends to remain constant, thereby maintaining the overall shape of the system (Battram 1998). For example, despite concerted efforts to reform global education, schools in many countries continue to operate via the 'factory model of schooling' (Sleeter 2015, p. 111), whereby students are considered products and are sorted and receive differentiated, but standardized, education according to their economic futures. The tendency to preserve structures that are not optimally effective, known as lock-in (Battram 1998), is supported and maintained largely through feedback. Positive feedback encourages the behavior or adaptation, while negative feedback serves a regulatory or corrective function (Morrison 2008). As the teacher responds to these messages, the responses in turn spur more feedback from the local environment, either reinforcing the behavior produced or regulating it. In this way, cycles known as feedback loops form to moderate the system's behavior (Battram 1998, Clarke and Collins 2007). Much of the feedback in teaching is regulatory – for instance, teachers who attempt to implement progressive pedagogies often receive negative messages from school administrators or colleagues, either explicitly or implicitly, which pressure them to normalize their teaching (Stanulis, Fallona, & Pearson 2002, Saka *et al*. 2009, Newman 2010, Strom and Martin 2015).

Another key feature of complex systems is self-organization. That is, they behave in ways that do not seem to be controlled by one

single central entity. In self-organization, systems interact within and among components and other systems to respond to disequilibrium and generate new forms of order (or new behaviors) that will help it survive. These new behaviors are known as *emergent phenomena* and represent new conditions that are not predictable from initial interactions between system elements (Morrison 2008) and are more than the sum of their parts, so they cannot be reduced back to their former states or attributed to any of its contributing elements. Any change in a system, including the addition of new dimensions or elements, generates a qualitative change, something different than what had existed before, that arises from unpredictable interactions among systems elements. In other words, as elements of systems simultaneously influence and are influenced by each other (Davis and Sumara 1997), emergence of different phenomena, or 'co-evolution', occurs. The ongoing co-evolution of elements means that complex systems are continuously adapting and changing.

Applied to research about teaching, complexity theory provides an ecological approach that allows for a systems-level view of the way teacher learning moves into practice (e.g., Opfer and Pedder 2011, Strom *et al*. 2018, Daly *et al*. 2020). This perspective attunes us to interactions within and between systems (Opfer and Pedder 2011, Yuan *et al*. 2018), as well as helps us rethink teacher learning and practice as emergent phenomena that are co-produced by these interactions (Strom *et al*. 2018, Daly *et al*. 2020). As productions from an entire system, the emergent phenomena – in this case, learning/teaching – that is collectively created will be qualitatively different, meaning that teacher learning/practice will always be hybridized and never a pure 'transfer of learning' or 'high fidelity implementation'. Moreover, a complexity perspective can offer possibilities to examine the ways systems work to constrain or amplify certain practices (Opfer and Pedder 2011, Yuan *et al*. 2018). Such an approach can help us understand the conditions that might be more conducive to supporting emergence of powerful forms of teaching and learning (Daly *et al*. 2020).

Rhizomatics and teacher learning-practice

Rhizomatics (Deleuze and Guattari 1987), a third complex perspective, is based on the figuration of the rhizome, or a tubular plant that

grows unpredictably in all directions, both above and below ground. Rhizomatics offers an affirmative, multiplistic, nonlinear, materialist theory of thought and activity, critiquing what Deleuze and Guattari call 'arborescent' or 'tree' thinking – the dualistic, positivist type of thinking embedded in dominant patterns of thought discussed in an earlier section of this paper. Termed so because of its similarity to the structure of a tree (one trunk, rooted to one spot, stretching up in one direction and sprouting linear outgrowths), arborescent thought is essentialist and hierarchical, claims to mirror the world or reality through a one-to-one correspondence, and proceeds by binary logic that produces ever more of the same kind of thinking: 'the law of the one that becomes two, then of the two that becomes four' (Deleuze and Guattari 1987, p. 6).

Rhizomatics offers an explicitly political analysis. Although some complexity theorists include a direct critique of the simplistic linearity of positivism (e.g., Davis and Sumara 2006, Mason 2008), Deleuze and Guattari push further, explaining that this 'oldest and weariest kind of thought' (p. 5), the binary thinking noted above, is harmful because it perpetuates the status quo. Rational thinking only reproduces itself, which then closes down other possibilities for different ways of knowing and being. Moreover, as described earlier, by deeming dualistic thought as the way all humans think, countless 'others' throughout history (e.g., women, Indigenous peoples, people of color) and the common era with different worldviews have been constructed as less than or not fully human, thereby allowing the rationalization of violence, subordination and erasure of these groups (Braidotti 2013). Acknowledging the harmful outcomes of binary thinking, Deleuze and Guattari (1987) comment, 'We are tired of trees . . . they have made us suffer too much' (p. 15).

As an alternate figuration to the tree, the rhizome expresses a world of decentered, but connected collectives, which are mobile and in constant flux. From a rhizomatic perspective, the frame of reference shifts from individual human actors to multiplicities, which are constantly 'becoming different' from moment to moment as their elements work together. In this view, life/social activity is essentially creative – the various elements comprising multiplicities produce reality. This perspective represents a major shift from traditional thinking and calls for a disruption of the fundamental ontology that dominates not just

the teacher education literature, but also underscores Western logic generally. Deleuze and Guattari (1987) provide multiple concepts that can serve as analytic tools to help educators and researchers make these shifts. We focus here on the concepts of *assemblage* and *rhizomatic lines*.

Assemblage, in particular, helps shift away from a view of the world as populated by agentic individuals and towards one consisting of multiplicities with distributed agency. An assemblage is a mixture of humans, things, ideas, and conditions that interact and produce something (Strom 2015). For example, a classroom is an assemblage, consisting of the teacher, students, the physical space, desks, whiteboards, books, academic content, contextual conditions, institutional forces, and so on (DeFreitas 2012). However, an assemblage is not just a particular grouping, but also refers to the way those work together to produce knowledge, action, or other happenings in particular ways. Thus, assemblage is an analytic tool to help us analyze the situated, multi-faceted, interactional activity of teaching.

The second idea drawn from Deleuze and Guattari (1987) is the notion of rhizomatic lines, which influence the activity of assemblages. Taken as a part of a larger theory of sociomaterial activity, rhizomatic lines help explain how status quos are maintained – or conversely, how they may be disrupted (Strom and Martin 2017). There are three types of lines: molar and molecular lines, and lines of flight. Molar lines are forces or structures that bind activity to the status quo – although these are considered macro-political lines, they can appear at the societal or institutional level (e.g., laws and policies) or at the individual level (e.g., a person's internalization of gender norms). Molar lines are rigid and imposed, upholding binary thinking by dividing the world into static categories (man/woman; black/white; able/disabled). Examples of molar lines in schools are the bell schedule, which divides up the day into periods, and standardized testing, which ranks and rates students according to scores. They also appear as cultural expectations of what it means to be a 'good student' or equating good teaching with an orderly classroom.

In contrast, molecular lines are micro-political, or what Deleuze and Guattari (1987) described as the 'supple fabric without which [the state or institutional] rigid segments would not hold' (p. 213). Flexible molecular lines carry out the work of the rigid molar segments

– or subvert them. The day- to-day work of the teacher is molecular. Although molar lines like testing and bell schedules are imposed on teachers, they have to do the actual task of administering the test or releasing their students at the sound of the bell. While most of the time teachers' molecular work carries out institutional rules and norms, they do at times have some agency providing the possibility of a temporary escape from or subversion of the status quo.

These escapes or subversions, which constitute a rupture in the norm, are lines of flight. For instance, a student might ask an unexpected question, which the teacher stops to explore with the class, taking them into new, unplanned territory. As another illustration, prior to the test, the teacher and their students might discuss ways to show learning, and problematize the test as only one way of demonstrating knowledge. While these are temporary breaks from molarity, the teacher eventually has to return to their objective and give the test (at least if they want to keep their job). Thus, the line of flight will be recaptured by the system. However, that line of flight is also a line of mutation. When it is recaptured, it shuffles the system and troubles molar conditions. Although the changes may be small, lines of flight are reconstructed over time and those subsequent re-shufflings can add up to larger transformations.

The work of Strom (2015) and Strom and Martin (2015) provides examples of the promise of rhizomatic perspectives in conceptualizing teacher learning-practice to honor the complexity and situatedness of teaching activity. In an in-depth case study, Strom (2015) uses the concept of assemblages to present the work of Mauro, a U.S.-based first-year high school science teacher whose practices varied widely between his environmental and earth science classes. The contexts of his two classes differed in terms of class size, subject matter, and testing expectations, and students in each set of classes interacted very differently, which produced different kinds of teaching activity. From her analysis, Strom argued that the teacher is only one element in a larger collective that jointly produces teaching practices, and agency is distributed across that assemblage, rather than held exclusively by the teacher.

As a second example, Strom and Martin (2015) used the concept of rhizomatic lines to examine the ways a beginning ninth-grade physics teacher in the U.S., Bruce, translated his pre-professional learning

about inquiry into practice. The authors argued that there were multiple molar lines, or forces binding Bruce's teaching to the transmission-oriented status quo, some contextually imposed (e.g., his principal valued more traditional teaching) and others which were internal (e.g., Bruce was worried about 'rocking the boat' with inquiry-based pedagogy). Yet, the inquiry-based learning opportunities he created for his students emerged as unpredictable lines of flight. Employing rhizomatic lines to examine Bruce's teaching provided a complex analysis of emerging teaching practice that could not be reduced to one single narrative, speaking to the complexity of constructing teaching practice that disrupts normalized instruction.

As these examples show, concepts from rhizomatics can help to (re)conceptualize teaching as complex phenomena jointly produced by the workings of a constellation of human, non-human, discursive, and material elements. This concept of co-production is critical for a paradigm that decenters the teacher as the 'doer' and 'controller' of classroom instruction, and instead examines teaching as a collective process of negotiation. It also offers a way to analyze the macropolitical factors – power flows, institutional structures, and teachers' internalized disciplinary devices – as well as the highly situated micropolitical forces that carry out or subvert those 'molar lines'. Such analysis resists reductive narratives of teachers as good/bad, and produces textured accounts that more closely express classroom realities.

An emergent complex framework of teacher learning-practice

Taken together, these complex perspectives offer insights that may be integrated into an emergent complex framework of teacher learning-practice. As noted earlier, by 'learning-practice', we signal that learning and practice are not separate processes, but are entangled and inform each other. We also use the term 'emergent' as a qualifier because, although there are seeds of a complex turn in teacher education, much more empirical research is needed to provide a robust foundation for the complex conceptualization we offer.

We acknowledge that each of these three theoretical perspectives has their own genealogy, and as such, some might claim that these theories are not compatible with each other. We argue that each offers

tools with which to construct a useful framework for understanding teaching as complex phenomena – and, consistent with our 'and, and, and' perspective (as opposed to 'either/or'), we advocate for making use of *all* the tools currently available to us (Ringrose and Zarabadi 2018).

Table 1 summarizes the salient characteristics of this frame as a set of shifts with clear implications for an emerging theory of teacher learning-practice. Although we use the language of 'shift from . . . to', we do so for ease of communicating conceptual changes, rather than to indicate that these are linear moves.

An immanent perspective of learning-into-teaching

Our complex framework entails a major ontological shift from dualism to monism, or a worldview of radical immanence (Braidotti 2013). Building on the description offered earlier in this paper, radical immanence is the idea that nothing in the universe exists separate from anything else – all people, things, and places are connected and part of the same plane of matter (Deleuze 1988). The universe does not proceed by way of separations and oppositions, but rather, as series of relations (Kimmerer 2013). That everything is connected does not, however, mean that all matter on this plane is the *same*, or that this shift represents the type of logic underscoring color-evasiveness or statements like 'We are all one race – the human race!' Instead, as Braidotti (2017) puts it, 'we-are- all-in-this-together-but-we-are-not-one-and-the-same'. This shift from an 'either/or', 'this or that' mentality is replaced by 'and, and, and' (Deleuze and Guattari 1987). This means that the world is composed of connected matter, *and* that huge variation exist among that matter.

Taking an immanent perspective regarding teacher learning-practice, then, means rethinking the divides that have been set up between learning and practice settings, which also correspond to the distinction between the theory and practice of teaching. Learning ideas and practicing them are not separate activities–they are intricately connected processes. Further, the actual act of teaching entails multiple interactions and negotiations with an entire assemblage of elements. Learning is bound up in practice and relational; as the

Table 1. A complex framework of teacher learning-practice.

Shift	*Implications for Teacher Learning-Practice*
From Dualism to Immanence	• Learning and teaching practice are entangled processes. • These processes occur via connections and interactions with multiple other human, non-human, and intangible elements.
From Individuals to Multiplicities	• Teaching activity is not done by an individual, but is highly mediated activity actively negotiated with/in a larger multiplicity of factors. • The teacher herself is a multiplicity of which her learning is a part.
From Autonomous to Collective and Distributed Agency	• The entire collective contributes to the production of teaching activity. • Agency is collectively enacted and distributed among the multiplicity, although not necessarily equally.
From Human-Centered to Human-*and*	• Teaching is shaped not just by human actors but also by non-human/material and discursive factors.
From Neutral and Universal to Political and Situated	• The factors that shape teaching are not neutral, but connected up to specific, situated political, cultural, historical, and material conditions and power flows, which requires attending to micropolitical interactions.
From Being to Becoming (Different)	• Teaching and learning are vital and ongoing processes that are constantly changing as different elements in teaching assemblages come into composition and develop/transform in relation to all other elements of an assemblage. • Teaching is emergent phenomena, or becomings, that are a joint, temporal product of a teaching-assemblage. • Teacher development is a non-linear activity that occurs not as a stable trajectory but as a series of 'becomings' – temporal realizations of teacher-self, instances of learning, and/or practice events that occur as 'thresholds' within a larger ongoing process of 'becoming different'.
From Sameness to Difference	• Because teaching is a collective product produced by the joint activity of heterogeneous elements, instances of learning-practice are necessarily hybrid. • The reigning characteristic of teacher learning-practice is *difference*.

teacher continues to interact within particular assemblages, their understandings continue to morph in relation to the other elements of the assemblage (Strom 2015). However, artificially separating theory and practice in teacher preparation, professional learning activities, and educational systems generally (Zeichner 2010) hinders teachers as they engage in the complex, relational work required to enact progressive practices. Therefore, we need to provide preservice and in-service teachers ongoing, recursive experiences that more tightly connect learning *and* practice, and that allow them to reflect and articulate how they are able to enact the ideas and theory they learned about (and why or why not) (Klein *et al.* 2013). For example, rather than having a one-time in-service workshop and expecting teachers to enact the key ideas presented there in practice immediately – which again, keeps the learning and practice activities separate – teachers need opportunities to learn and practice in supported cycles that allow them to attend to contextual negotiations (Desimone *et al*. 2002). Such iterative and interdependent activities help teachers practice the interactional aspect of teaching, rather than reinforce the expectation that teaching is a one-way transaction (Strom and Martin 2017).

Teaching multiplicities with distributed agency

Whether using the terms 'activity systems', 'complex adaptive systems', or 'assemblages', this framework shifts from a unit of analysis centering on the teacher (or other isolated elements) to one of collectives or multiplicities. The teacher does not enact what they learned about teaching in isolation – they negotiate those ideas with their students and other contextual/ material elements (e.g., physical space, school culture, bell schedules). Moreover, the teacher is a multiplicity themself (their background experiences, previous learning, beliefs and attitudes, and physical body) and is also connected or part of the classroom, the school, and the district.

For example, in a complexity-theory informed review of the empirical literature on first-year teaching, Strom *et al.* (2018) described four nested systems that simultaneously shaped the instruction of beginning teachers. One of these was the teacher system, which encompassed the teacher's beliefs, preservice learning, background, experiences, personal qualities, and needs. At a somewhat broader level

was the classroom system, which included the teacher themself, but also students and their needs, teacher–student interactions, available resources, and physical space. Moving further outward, the school system includes the teacher and classroom, as well as administrators, colleagues, mentors, the school vision of teaching, school structures, teaching assignments, and partnerships with various entities. Finally, these three systems are embedded in a macro-educational system that included district, regional, and federal/national educational systems and their policies. Elements from each of these levels also simultaneously interact to shape teaching. Therefore, what a teacher gains from preservice or in-service learning activities is only one part of their own assemblage, which then interacts with an array of other elements in multiple nested systems.

Along similar lines, Opfer and Pedder (2011) identified multiple, interacting systems involved in teacher learning from professional development, including the learning activity system, the teacher orientation to learning system, and the school or organizational system. The authors suggested that the first two systems are nested within the third, although they all interact in an iterative manner to influence teacher learning-practice.

Moving the focus of analysis from individual teachers to multiplicities, as explained above, disrupts norms of thinking in education/teacher education, including the view that teachers and students are separate actors whose activities are independent of one another, which in turn sets up binaries like 'teacher-centered' and 'student-centered' instruction. Instead of examining the teacher as an autonomous actor able to 'do' teaching to students, and students as either passive receivers of information or autonomous performers (e.g., on standardized tests), this perspective examines the entire teaching multiplicity – which includes the teacher, her students, and other dimensions such as the pedagogy, the content, and the context of the classroom and school – and the ways this multiplicity interacts, which we discuss below.

This perspective also more closely corresponds to the research consensus on powerful learning, which is seen as co-constructed *between* teacher and students, or student and student(s), through interaction. That is, learning is not happening in a student's head, nor are the ideas learned transmitted from teacher to student in a unidirectional

transaction (Doherty *et al*. 2003, Teemant and Hausman 2013). Even when learning is internalized, the boundary of *inside* and *outside* is porous, with learning happening internally as a result of ongoing external social interaction within a particular context (Vygotsky 1978). Thus, teaching and learning from a multiplistic perspective is a collective activity (Strom 2015).

For example, Strom's (2015) case study of Mauro, a first-year teacher, details his teaching in two very different classes. In his mixed (11th/12th) grade earth science class, Mauro perceived the students as mature and easy-going, and they responded well to his efforts to build relationships with them. Contextual elements also played a role in his teaching – the content was very familiar to him, the subject was not tested by the State, and the class was small. Together, these elements produced patterns of interactive, small group instruction and inquiry-based and experiential teaching. However, in his ninth-grade environmental science class, student and contextual factors were much different. Mauro perceived the students as boisterous and immature, which presented a barrier to forming the same kind of relationships with these students as he had with his earth science students. The class often featured tense and/or combative interactions between the students and Mauro. In addition, the size of his environmental science class was larger, he was teaching the content for the first time, and the subject was tested by the State, and he was expected to adhere closely to a tightly paced curriculum guide. These conditions, working together, tended to produce lecture-based, whole-class instruction and behaviorist classroom management practices, which he felt were necessary to maintain order in his class.

As these examples show, Mauro clearly was not carrying out his understandings of teaching in a vacuum. To provide an accurate assessment of his teaching, Mauro's practice would need to be understood as jointly constructed between him and his different sets of students and different contextual factors. This shift in the analysis of teaching from the actions of an individual teacher to the interactions between and among the teacher and a multiplicity of elements requires a rethinking of the entrenched notion of the bounded (teacher) subject. Specifically, it requires a humble decentering of the (teacher) individual, which in turn demands a rethinking of human (teacher) agency. Teaching is not something the teacher does as an isolated actor, but

rather is jointly produced by the collective. Therefore, teaching activity, as well as teacher learning, has to be considered as heavily mediated, multiply produced, co-constructed phenomena. Put simply, there is no single causal factor – agency is distributed among the multiplicity, although not necessarily equally. Within the multiplicity, however, the teacher does have *some* agency – they are not a victim of the system – and depending on the elements present in a situated multiplicity, they may have more or less agency to enact particular practices.

A dual case study described by Saka *et al*. (2009) provides an illustration of the collective agency of activity systems. One teacher, Bob, was in a supportive school with a collaborative school culture, high-performing students, and many supports. He also brought an orientation towards collaboration and continued learning. All of these factors worked jointly to aid Bob's construction of inquiry-based teaching – the multiplicity of factors collectively supported those practices. The second teacher, Nathan, taught in a school with low test scores, an administration focused on testing supports, a challenging student population, and less collaborative colleagues. Nathan also perceived his students from a deficit lens, did not put the necessary time into his lesson preparation, and turned down opportunities for professional development. All of these conditions collectively contributed to produce more traditional teaching patterns in his classroom.

Human-*and*

As noted above, taking into account the collective agency of the assemblage means decentering the human elements. The work of the teacher is shaped not only by humans (e.g., the teacher, her students, school leaders), but also by the materiality of schools (e.g., classroom space, desks, available resources) and specific cultural, historical, political, and temporal conditions (Strom and Martin 2017). From an immanent perspective, the work of the teacher is inextricable from these socio-material conditions. Thus, studying teacher learning-practice should be an analysis of the human *and*. In other words, a complex analysis of enacting learning in classrooms must be post-anthropocentric, moving beyond just the human to also consider the impact and agency of non-human/material (e.g., space and resources) and

discursive structures (e.g., White supremacy, English language dominance) in relation to processes of learning-practice.

Strom and Martin (2015) provide an illustration of the agency of nonhuman/material factors in shaping learning-practice in their case study of a first-year physics teacher. Despite teaching a physics class, Bruce had no laboratory space, no physics texts, nor any equipment with which to conduct demonstrations and experiments. The lack of resources and inappropriate physical space constrained the range of activities he was able to engage in with his students. In particular, he was limited in his ability to conduct inquiry-based labs, a staple of his preservice preparation and ongoing induction professional development activities. Instead, he used objects he found around the school – a bowling ball, a towel – to lead demonstrations of phenomena, and brought in his own collection of Nerf guns (toy guns that shoot foam darts) for experiments, which evoked enthusiastic participation from his students. The physical conditions of his classroom and objects he had access to shaped his teaching approach as well as student responses to it. Part of moving to a more complex conceptualization of learning-practice, then, requires examination of the agency of nonhuman others (Braidotti 2019).

Situated politics and power

As many other scholars have pointed out, teaching activity is inherently political (Freire 1970, Cochran-Smith 2004, Nieto 2006). The forces that affect teaching are not neutral – they are connected up to specific political, cultural, historical, institutional, and material power flows that structure teachers' learning-practice. These forces materialize as particular conditions and rules, which serve a political function – namely, to operate as gatekeepers and disciplinary mechanisms to maintain the status quo. Some of these normalizing mechanisms may be explicit, and others implicit. In the U.S., for instance, there are policies that subject students to a constant barrage of standardized tests, which are normed to mainstream (White, English-speaking) American students (Darling-Hammond, 2007), as well as school schedules that 'track' high-performing and low-performing students into college preparatory and remedial classes, respectively (Oakes 2005). Other normative mechanisms are less overt, but no less influential,

such as the valuing of dominant languages over Indigenous ones (Gándara *et al*. 2010, Mitchell 2012, Walker 2016), behavioral norms that privilege quiet classrooms over ones suffused with excited student talk (Weinstein *et al*. 2004) or teacher practices and attitudes that favor White, middle-class ways of knowing (Delpit 2006). Normalizing mechanisms also may be imposed from outside the organization by other institutions or power centers (e.g., a regional authority requiring mandated curriculum for particular subjects) or they could be imposed on oneself from lifelong sociocultural conditioning (Strom and Martin 2013/2017).

For example, returning to the dual case study by Saka et al. (2009), Nathan, who worked in a high poverty school with challenging students and low test scores, struggled to enact his preservice learning in practice at least partially because the school was focused on testing, remediation, and compliance. Not only did these foci privilege a direct-instruction model, but they also represent power flows that often overcode high poverty schools serving large numbers of students of color and bilingual learners, and these political elements also mediated Nathan's teaching.

The case of Bruce (Strom and Martin 2015) provides a second illustration. Bruce limited the inquiry-based practices that were emphasized by both his preservice program and induction professional activities, partially from fear that he would be punished for straying too far from the 'norm' of physics teaching, which was more lecture-based and teacher-led. Although his supervisor had never actually voiced such a concern, Bruce's situated understanding of top-down physics instructional norms, combined with first-year-teaching insecurity, pressured him to self-discipline. As noted by Deleuze and Guattari (1987), normalizing forces like these can be imposed at the macro-level, but they always are carried out locally. Thus, to understand how teaching is shaped by these political, cultural, historical, institutional, and material dimensions, we must look at situated circumstances, the moment-to-moment micropolitical action that produces the instruction.

A process of becoming (different)

One of the most important ontological shifts involved in this proposed complex framework of learning- practice involves a move from

being to *becoming*, along with an understanding that the process of becoming is one of continual differentiation (Deleuze and Guattari 1987, Braidotti 2013). This move entails disrupting a view of the world as ordered and static and instead acknowledging that reality is dynamic and alive, always changing, a view of reality that Braidotti (2006) has termed 'process ontology'. Not only is the world always in process, always becoming, but more precisely, the process is one of relation-ality — a 'becoming-with', or as Haraway (2016) proposes, a *making with*. Further, becomings are always multiple – since activity occurs with/in assemblages, these transformations occur in relation to other elements, both human and non-human. When a process ontology is adopted, then, questions of 'what' become much less important (since the 'what' changes from moment to moment). Instead, questions of 'how', of relations that enable becomings, become vital (Strom and Martin 2017).

A shift from being to becoming, in the context of a theory of teacher learning-practice, means that learning and practices are not static, but are ongoing processes constructed as part of, and in relation to, the situated elements of an assemblage. These processes might produce conditions (or provide feedback, from a complexity perspective) that serve to regulate teaching activity, making it less likely they are able to enact their learning in practice. However, the way the assemblage works together might also create productive conditions that enable new collective growth (or changes that were unanticipated from initial conditions).

These processes are highly situational phenomena, as demonstrated by Strom (2015). Mauro, as noted previously, taught two sets of classes, both 'low track' sections of science, in the same school with the same demographic makeup of students in each class. At the beginning of the year, he was committed to teaching in interactive, inquiry-based ways in both sections of science. However, with different kinds of interactions with his students and different sets of constraining and enabling factors, his practices diverged. In one class he taught in ways that clearly demonstrated elements of co-constructed inquiry, and in the other, he espoused lecture-dominated, whole-class instruction (the antithesis of his pre-professional learning). Thus, his practices became different across the classes in relation to these different multiplicities.

The shift from being to becoming also requires a generative or creative view of teacher learning- practice. That is, teachers do not simply transfer their learning into action in the classroom. Instead, they are one element in a larger assemblage that, working together, *produces* teaching as temporal, emergent phenomena (Strom *et al.* 2018). These becomings are qualitatively different, and cannot be separated and analyzed for causality – the product is greater than the sum of its parts (Davis and Sumara 2006, Strom *et al.* 2018). Teacher development is a non-linear activity that happens not in a stable trajectory but as a series of 'becomings' – temporal realizations of teacher-self, instances of learning, and/or practice events that occur as 'thresholds' within a larger ongoing process of 'becoming-different' – all of which emerge out of the collective activity of a particular assemblage.

Further, *becoming-different* means just that – a process of ongoing differentiation. As elements of a classroom assemblage or system work together, the assemblage as a whole changes, as does what it produces. As Opfer and Pedder (2011) showed in their synthetic review of professional development literature from a complexity perspective, teacher learning and change is highly dependent on the situated interactions between specific sets of elements comprising multiple systems (the teacher orientation to learning system, the learning activity system, and the school system), and therefore the emergent learning-practice may be different across time and context, even when the learning activity is constant.

Because teaching is a collective product derived from the joint, situated activity of heterogeneous elements, instances of learning-practice are necessarily hybrid. Thus, the reigning characteristic of teacher learning-practice is *difference*. This is a major departure from dominant ideas about teacher learning and development, which are characterized by an emphasis on sameness – encapsulated, for example, by concerns about implementing practices with 'high fidelity'. As such, this shift has major implications for policy, assessment, leadership, and more: it is simply not possible to 'train' teachers to implement pedagogies or produce student learning in ways that will be consistently the same across settings (or even across different sets of students in the same setting, as shown above), and as such, we need contextualized approaches to these dimensions of education. However, in terms of research, the concept of becoming-different can

help explain, at least partially, why findings and results from studies regarding teacher learning are mixed or show very different trajectories of impact on teacher practice, such as Opfer and Pedder's (2011) finding that teacher change can happen at any point in the learning/practice process.

Researching with a complex framework for teacher learning-practice

The ontological shifts identified above also must be accompanied by methodological shifts for studying and assessing how teacher learning materializes in practice – some of which we are starting to see happen within the afore-mentioned 'complex turn' in teacher education research. For instance, rather than attempting to link teacher learning outcomes directly to student learning outcomes, we need to design and conduct studies that account for all the mediating elements in-between these, in all their complexity (Strom 2015, Viesca *et al.* 2019, Margolis and Strom 2020). Moreover, research activity needs to be situated and local, with a focus on the particular – for example, investigating how teachers work together with particular sets of students in particular material spaces with particular materials and language, teaching particular content, and within particular cultural, historical, political, temporal conditions, to co-construct teaching practice. We must also take up the question of distributed agency and examine collective agency flows of the teacher, students, and nonhuman/discursive elements.

Analyses of teaching phenomena will also necessarily involve politics, examining how political/historical elements and institutional/contextual constraints shape teaching that is produced, as well as identifying *smooth spaces* (Deleuze and Guattari 1987) where teachers might have more flexibility to enact agency. We need thick descriptions of teacher/teaching 'becomings' over time, articulating multiple ways that teacher learning is entangled within and modified by these processes. Most importantly, within these 'becomings', we particularly need to attend to differentiations, highlighting ways that the unique constellations of teacher-students-pedagogy-content-context produce particular translations of teacher learning-practice – in other words, how teachers are enacting learning with 'low fidelity'.

Conclusion

The field of teacher education requires theories that are equal to the task of preparing and supporting teachers to educate youth in increasingly complex times. In this paper, we have critiqued fundamental assumptions inherent in dominant views of teacher learning and practice that reinforce simplistic binary understandings of the relation of these phenomena. As an alternative, we have offered an emergent complex framework that conceptualizes teacher learning-practice as entangled processes that are jointly produced by a situated multiplicity encompassing the teacher-students-context-policy-*and*. This complex framework provides tools not just to investigate and explain learning-practice in more textured, multifaceted ways, but also to support teacher-learners across their careers and educational pathways.

Most importantly, we regard this framework not as an innovation for the field, but as an ethical imperative. As we explained, the linear thinking that grounds our rationalist worldview and informs the preparation of teachers also underscores the instructional/institutional practices and structures that perpetuate inequalities across class, race, language, ability, and gender expression. Making a 'complex turn' in teacher education is essential to create meaningful lines of flight that can disrupt our inequitable educational status quo.

Note

1. We hyphenate the term 'learning-practice' to emphasize the entangled nature of these processes, an idea that we discuss more fully later in the paper.

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