When Complexity Theory Meets Critical Realism:
A Platform for Research on Initial Teacher Education

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Many scholars have concluded that teacher education research needs to take a complex view, resist simplification, and account more fully for teacher education's contexts and processes as well as its impact on teacher candidates' and school students' learning (Cochran-Smith & Zeichner, 2005; Grossman & McDonald, 2008; Opfer & Pedder, 2011). In this article, we describe a research platform for initial teacher education, developed by the Project RITE (Rethinking Initial Teacher Education)[1] research team, which combines key ideas from complexity theory and critical realism (CT-CR) and applies these to teacher education. Our intention in referring to CT-CR as a research "platform" is to suggest that the integration of complexity theory and critical realism offers a potentially powerful framework for exploring how initial teacher education programs and pathways func-

tion as complex systems and why their outcomes are so uncertain and variable. In this article, we suggest that as a research platform, CT-CR has the capacity to open up new questions, point to new places to look for explanations, and offer new ways of understanding the initial conditions, system interactions, and underlying causal mechanisms involved in initial teacher education. In particular, we suggest that the CT-CR platform may support studies of the extent to which teacher candidates learn to engage in patterns of practice that support the learning of students who have been historically marginalized on the basis of race, culture, language, class and gender.

The primary purpose of this article is conceptual in that it is intended to describe CT-CR as a research platform for initial teacher education. To achieve this purpose, the article includes multiple examples of the questions, research methods, and analyses researchers have developed, guided by complexity theory and/or critical realism. In addition, we use our own emerging program of research in Project RITE as a concrete in-progress example that elaborates the CT-CR framework and illustrates some of its applications to initial teacher education research.

Some Key Ideas from Complexity Theory

Complexity theory is not a single unified set of ideas, and multiple scholars have analyzed its major branches and its evolution over several generations (Alhadeff-Jones, 2008; Manson, 2001; Opfer, 2013). Despite variation, however, in the social sciences and in education, "complexity theory" is often used as an umbrella term to refer to a loose collection of theoretical frameworks that take up important questions about individuals, social phenomena and organizations—understood as systems—and how these change, develop, learn, and evolve over time (Mason, 2008; Morrison, 2008; Walby, 2007; Wheatley, 2006). Rather than parts, complexity theories focus on wholes, relationships, open systems, and environments (Byrne, 1998; Davis & Sumara, 2006). Rather than predictable linear effects, complexity theories emphasize that multi-dimensional relationships and dynamic interactions among agents and elements are responsible for patterns and phenomena (Byrne, 1998; Cilliers, 1998; Haggis, 2008). Most applications of complexity theories to the social sciences and education also have in common the major ideas and perspectives they reject. These include: the assumption that how the world works can be explained using Newtonian machine imagery (Davis, Phelps & Wells, 2004; Richardson & Cilliers, 2001; Wheatley, 2006), linear models of cause and effect (Horn, 2008; Mason, 2008; Morrison, 2008; Radford, 2006), analytic/reductionist views of phenomena (Byrne, 1998; Horn, 2008; Radford, 2006; Richardson & Cilliers, 2001), and positivist research methods that aim to reduce complex phenomena to the key factors that determine outcomes (Byrne, 1998; Morrison, 2008; Walby, 2007).

One big idea that complexity theories offer teacher education research is the fundamental distinction between complicated and complex systems (Byrne, 1998; Cilliers, 1998; Davis & Sumara, 1997), both of which have multiple parts and

interactions that may be difficult to discern and understand at first. In the case of complicated systems, however, wholes are equal to the sums of their parts, which means that if a complicated system is taken apart and its pieces closely examined, the nature of the system's functioning can be fully revealed. Cilliers (1998) includes jumbo jets and C-D players among his examples of complicated systems. In contrast, with complex systems, complexity is manifested at the level of the system itself as a result of the interactions and non-linear relationships of component parts and of intricate feedback loops in the system (Cilliers, 1998). With complex systems, wholes are much more than the sums of their parts (Byrne, 1998; Cilliers, 1998). If a complex system is taken apart, key aspects of how the system works and what makes it work in the first place are lost since unexpected consequences arise as a result of the dynamic interactions of parts, which provides challenges to researchers trying to understand the system. Cilliers' (1998) examples of complex systems include bacteria, the brain, and social systems.

Underlying the CT-CR research platform we are proposing here is the assumption that teaching and learning, learning to teach, and initial teacher education programs/pathways need to be regarded as complex, rather than complicated, processes and systems. In fact, a number of scholars who have connected complexity theories to teacher education have suggested that teacher education actors, organizations, and processes at multiple levels can be fruitfully conceptualized as complex systems, including individuals (teacher candidates, teachers, teacher educators, students, principals), classrooms, schools, school districts, teacher education programs/pathways and courses, professional learning contexts, school-university collaborations, and supervision and/or mentoring arrangements (Davis & Sumara, 1997; Davis, Sumara, & D'Amour, 2012; Opfer & Pedder, 2011; Radford, 2006; Reynolds, 2011; Schneider & Somers, 2006; Smitherman Pratt, 2011; Waks, 2011).

Informed by key concepts from complexity theories, a growing body of case study research and rich analyses of practice have emerged in teacher education. For example, Clarke, Erickson, Collins, and Phelan (2005) used the notion of learning systems along with a self-study research design to explain the longevity, quality, and workings of an alternative cohort and inquiry-based teacher education program. Kiefer (2006), a professor of English, used the ideas of nonlinearity and emergent self-organizations to describe and unpack the dynamics of physical and virtual writing classes. Cvetek (2008), a language teacher educator, drew on ideas from complexity theory to explicate the difficulties student teachers described in planning and carrying out lessons in language classrooms. Guided by the notion of complex adaptive systems along with the notion of complex transformation as something that occurs from the bottom-up, Zellermayer and Margolin (2005) studied the evolution of professional learning groups of student teaching supervisors and teacher educators during a period of dramatic curricular transition. They concluded that a series of critical events, which allowed contradictory outcomes and involved conflicts and dissonance, were pivotal to the group's learning and led to the

group's self-organization. Focusing on feedback loops, disequilibrium, and nested layers of systems, Nielsen, Triggs, Clarke, & Collins (2010) studied a bi-monthly conversational community of cooperating teachers and teacher educators over two years; they concluded that the community operated as an "open-ended, diverse, and emergent phenomenon, attentive to a variety of futures through self-examination and reflection on current practices" (p. 839). The major contribution of studies like these is that they (re)theorize and explain salient aspects of teacher education from complexity lenses and, at the same time, offer trenchant critique of problematic but persistent ideas, such as transmission-oriented approaches to teacher training, linear views of teaching and learning, process-product logic regarding teachers' learning, and university-school knowledge hierarchies that separate theory and practice.

It is worth asking what complexity theories offer teacher education research that is not already offered by socio-cultural, ecological or other context-sensitive and systemic perspectives. Along these lines, anthropologist Michael Agar (1999) suggested that while complexity theory does not change many of the fundamentals of ethnographic research, it adds considerably to this research by overcoming the "bias" of an anthropological approach toward localized groups and by emphasizing trends in larger interacting systems with a focus on mechanisms that show how things work, not simply how they are. Our argument here is that the integration of complexity theory with key ideas from critical realism, which we describe below, has the capacity to help us examine *how things work* in teacher education, not simply *how they are*. This kind of understanding is essential for change and improvement, an idea to which we return in a later section of the article. Next, however, we describe key ideas from critical realism.

Some Key Ideas from Critical Realism

Like complexity theory, critical realism is not a single movement in the philosophy of science and the social sciences; rather it involves a variety of perspectives and developments (Archer, Bhaskar, Collier, Lawson, & Norrie, 1998). Especially in European countries and some other parts of the world, critical realism is a robust philosophical and applied perspective, which has been embraced and debated in philosophy of science, sociology, health, history, information sciences, and management and organization (Archer et al., 1998; Clegg, 2005; Corson, 1991; Danermark, Ekstrom, Jakobsen, & Karlsson, 1997/2002; Shipway, 2010; Steinmetz, 1998).[2] Despite many variations in this work, our aim here is to provide a brief overview of some of the basic ideas of critical realism.

With its origins in the early and continued work of Anthony Bhaskar (Archer et al., 1998; Danermark et al., 2002), critical realism is a philosophy that connects aspects of the natural and social worlds at the level of deep causal mechanisms (Bhaskar, 1978, 1986; Sayer, 1992). Proponents of critical realism suggest that it provides a viable conceptual alternative to both positivism and postmodernism (Archer et

al., 1998; Reed & Harvey, 1992). Along these lines, education philosopher, Ernest House (1991), suggested that critical realism might have the potential to resolve conflicting views about the nature of science underlying the U.S. "paradigm wars" about educational research. Elaborating this argument, Maxwell (2008) pointed out that critical realists reject "naïve realism," which is the common-sense viewpoint that our perceptions of reality directly represent its objective nature, but they also reject radical postmodernist perspectives, which hold that reality does not exist apart from our perceptions and constructions of it.

Critical realists work from the perspective of "ontological realism" coupled with "epistemological relativism" and "judgmental rationality" (Archer et al., 1998, xi). Although detractors of critical realism have asserted that this coupling is contradictory, others (Danermark et al., 2002; Maxwell, 2008) have suggested it is critical realism's hallmark:

> [Ontological realism] implies that there exists a reality which is stratified, differentiated, structured and changing. [Epistemological relativism] tells us that our knowledge about this reality is always fallible but, as [judgmental rationality] suggests, there are some theoretical and methodological tools we can use in order to discriminate among theories regarding their ability to inform us about external reality. (Danermark et al., 2002, p. 10)

As Danermark and colleagues have stressed, although critical realism holds that there is a reality independent of human consciousness, this does not imply that reality is either fixed or empirically accessible. Rather our knowledge of reality is always "conceptually mediated" and thus it may be more or less "truth-like" (p. 10).

Stratified reality has layers, some immediately perceivable and some that are hidden. People's observable behavior is underpinned by other layers such as tacit belief systems, patterns of social interaction and organizational structures, and deep and contingent causal mechanisms, which are not immediately perceptible but which do lead to patterns that we can see. This notion of a stratified reality that includes underlying causal mechanisms has the potential to contribute to research in teacher education. From a critical realist perspective, then, investigating causation involves trying to understand the "interaction of a multitude of underlying causal entities operating at different levels" (House, 1991, p. 7) including human reasoning, even though causes that are alike do not necessarily produce results that are alike. Maxwell (2004a, 2004b, 2008) has elaborated on critical realism and qualitative methods in educational research, arguing that by conceptualizing actors' meanings and their situations as "real" phenomena that interact causally with each, critical realism provides a conceptual basis for considering causality in qualitative research, including case studies.

In the complex world of initial teacher education, there has been much research focused on the beliefs, attitudes, meanings, reasoning and experiences of teacher candidates and other actors in the teacher education system. However there has been

much less attention to figuring out how the meanings of differently-positioned actors interact causally with one another and with the larger contexts and structures in which the actors operate to create learning opportunities for teachers and students. When critical realism is integrated conceptually with complexity theory, a union we describe below, it offers a way to explore complex and contingent causality in teacher education, in part because it accounts for both beliefs and larger contexts and structures.

A second major contribution that critical realism offers research on teacher education has to do with Bhaskar's (1986) idea that the goal of a critical realist approach to social science is to create explanatory social critique. As Collier (1998) has explained, from the perspective of Bhaskar's critical realism, social science is intended to study society, which exists by virtue of the fact that human agents act in accordance with ideas that "reproduc[e] and transform the social structures" of that society; these structures maintain advantages for some and disadvantages for others (p. 445). From the perspective of critical realism, in order to get the study of a society "right," explanatory theories must include not simply analysis of the ideas that make the society possible, but also critique of those ideas. Challenging the structures that reproduce inequalities is thus dependent on adequately interpreting the social world in the first place. Corson (1991) concluded that critical realism's approach was consistent with many of the tools already being used in social science and education research, including discourse analysis, ethnography, and participant observation, which were intended to "uncover the reality of the accounts and reasons which constitute mechanisms in research theories" (p. 237) in order to make change possible. Either by design or default, teachers and teacher educators are agents who help to maintain or challenge the status quo of inequalities in learning opportunities and educational outcomes for students who are marginalized on the basis of race, culture, language, class and gender. However, as a field, teacher education has lacked explanatory theories that embrace complexity as well as causality regarding these issues. We suggest below that complexity theory integrated with critical realism has the potential to do so.

When Complexity Theory Meets Critical Realism

There are myriad examples in teacher education research and practice that attest to the fact that relationships between teacher preparation, on one hand, and teacher candidate/teacher performance, the learning of their students, and other outcomes of preparation, on the other hand, are complex and non-linear. The apparently inherent complexity of teacher preparation and teacher learning makes complexity theories appealing to many teacher education researchers and practitioners. However, as we noted above, there are multiple versions of complexity theories, which have evolved over time, and there are multiple challenges involved in using complexity theory as a framework for educational research (Horn, 2008; Morrison, 2008; Radford, 2006).[3]

To address some of the theoretical challenges in using complexity theory as a

framework for research on teacher education, CT-CR integrates many of complexity theory's key ideas with ideas from critical realism, drawing on the work of scholars who have taken up this same task in sociology (Byrne, 1998, 2001; Reed & Harvey, 1992; Walby, 2007). Byrne (1998) and Reed and Harvey (1992) have suggested that synthesizing complexity theory with critical realism deals with some of the central problems of sociological theory: a way to relate macro and micro issues without being reductionist and a way to describe the agency-structure relationship that accounts for human agency by acknowledging that human beings may have the capacity to initiate certain causal sequences.

Applying this perspective to teacher education, we are suggesting that the theoretical integration of ideas from complexity theory and critical realism—and the CT-CR research platform for initial teacher education that we have derived from this integration—deals with three persistent issues involved in studying and theorizing initial teacher education. First, CT-CR provides the theoretical underpinning for the investigation of teacher education understood as complex systems with multiple interacting parts and players that cannot be separated from one another without losing key aspects of how the system works and what makes it work in the first place. Second, CT-CR seeks the development of complex and contingent causal explanations that include actors' beliefs and meanings as well as the processes and contexts in which they are located and thus accounts for the agency (and responsibility) of teacher candidates, teacher educators, and other actors in the teacher education system whose job it is to initiate causal sequences that culminate in learning. Third, CT-CR provides a framework for analysis of teacher learning during initial preparation (and beyond) in terms of complex intersecting systems of social inequality that have to do with power and access to opportunity. Explanatory social critique of the role these intersecting systems play in teacher candidates' and students' learning is essential for the development of teachers' patterns of practice that promote equity. We discuss each of these below.

Integrating complexity theory and critical realism, we conceptualize initial teacher education in terms of multiple, overlapping complex systems, including: individual teacher candidates and other teacher education participants (school-based mentors, university instructors, supervisors, school students, administrators) as complex systems; the classrooms and schools where teacher candidates engage in fieldwork and student teaching as complex systems; teacher education programs/pathways as complex systems with open ambiguous borders and with other complex systems overlapping or embedded within them; the complex systems of larger professional/policy environments; and multiple, intersecting and non-hierarchical social systems of inequalities based on race, culture, language, class, and gender. It is self evident that this way of conceptualizing initial teacher education means that we cannot understand it in terms of process-product or knowledge-transmission logic.

Rejecting linear causal logic, however, does not mean that we cannot investigate causality or the processes through which agents endeavor to initiate causal

sequences. As a research framework for teacher education, CT-CR offers a way to focus on the initial conditions, contexts and circumstances within which teacher candidates' learning emerges in open systems. This is widely variable and unpredictable, but *not* random and *not* inexplicable. Rather this requires complex and contingent notions of causality and responsibility that depend on deep understandings of the local (e.g., initial conditions, sequences, and transformative events) linked to larger understandings of processes and outcomes at various intersecting systems levels. As Byrne (1998) notes, "The essential elements in [critical] realism are the assertions that that which we observe in the world is real and that it is the product of complex and contingent causal mechanisms which may not be directly accessible to us" (pp. 37-38). In teacher education research that builds on the CT-CR platform, the focus is on the identification and exploration of complex "causal" or "generative" mechanisms, which are part of teacher education as a complex system. In addition, because critical realism conceptualizes individuals' reasons and meanings as part of the real world, this means that beliefs, perceptions, and interpretations can be studied as underlying causal mechanisms in interaction and conjunction with other causes.

Finally, some critics have suggested that complexity theory does not deal with values and power inequalities, which are endemic to education (Morrison, 2008). Integrating complexity theory with critical realism helps to address this challenge. When research on teacher education is animated by CT-CR, it links the emergent reasoning and practices of teacher candidates in differing local circumstances and contexts to larger complex social structures, processes and systems. This has the potential to provide valuable new insights about how teacher candidates understand and respond to many aspects of teaching, learning and schooling, including inequalities across various levels. Along these lines sociologist, Sylvia Walby (2007) used complexity theory to reconceptualize the traditional notion of social systems. She suggested that a social system could not be regarded as a hierarchy wherein some sub-systems were nested within others. Rather she argued that each social system (economy, polity, civil society) and each set of social relations (gender, ethnicity, class) took all other systems as its environment. Consistent with critical realist approaches to complexity theory, Walby concentrated on the multiple intersectionalities of social systems of inequality, including inequalities based on class, gender and ethnicity. Walby suggested that her approach to understanding social systems opened up the theoretical agenda, which was closed by traditional systems thinking. We would suggest that in teacher education, this perspective also opens up the research agenda by allowing examination of the influence of multiple simultaneous inequalities while also focusing on complex social structures and systems.

Project RITE:
Getting Started with CT-CR as a Research Platform

As we noted above, there is a growing body of teacher education studies grounded

in complexity theories. However, we located no scholarly work on initial teacher education guided by critical realism[4] and no studies of teacher education that integrated complexity theory with critical realism. The work that is most consistent with CT-CR as a platform for research on teacher education is Opfer and Pedder's (2011) review of research about experienced teachers' professional learning from the lens of complexity theory. Conceptualizing teachers' professional learning in terms of three overlapping and recursive complex systems, they argued that professional development is often ineffective because it is driven by an underlying process-product logic that fails to account for the fact that teachers' learning is deeply embedded in their professional lives and in the complex working conditions of their schools. Although Opfer and Pedder did not mention critical realism per se, they connected their complexity perspective to the work of sociologists whose studies are consistent with critical realism (Marsh, 1982; Tilly, 2008), and they argued that the overall goal of research on professional learning should be the identification of "emergent patterns of interaction within and between levels of activity that would constitute an explanatory theory of teacher learning as a complex system" (p. 379). Opfer and Pedder's analysis is consistent with the CT-CR platform we are proposing here.

In the remainder of this article, we discuss the work of Project RITE as a way to illustrate some of the contributions the CT-CR framework may be able to make to research on initial teacher education. A fundamental premise underlying Project RITE is that the ultimate goal of initial teacher education, as a values-oriented professional enterprise, is to prepare teachers who not only understand how intersecting systems of inequality operate, but also know how to promote and support marginalized students' academic, social, emotional, civic, and critical learning within a range of school environments and contexts. It is this phenomenon—teacher candidates/graduates challenging inequities and engaging in patterns of teaching practice that promote students' learning—that is the major object of interest in Project RITE. Accordingly, the ultimate goal of RITE, as a research endeavor, is to develop an explanatory theory of teachers' learning during the critical period of initial teacher education (and beyond) that helps us understand the complex, contingent, and multiple influences on whether, how and to what extent teacher candidates/teachers learn to engage in patterns of teaching practice that support students' learning and challenge existing inequities in the system. To achieve this goal, the concrete task of Project RITE is to pose new questions and conduct a series of interrelated, mixed methods empirical studies, grounded in CT-CR as described above, which will lead collectively to an explanatory theory of teacher learning in the context of initial teacher education.

New Questions and Approaches to Data Collection and Analysis

With initial teacher education research guided by the CT-CR framework, unintended consequences and variability in outcomes are expected, and the goal

is the development of explanations that can account for both "multifinality" (apparently very similar experiences, which under some circumstances and for some persons, lead to notably dissimilar outcomes) and "equifinality" (apparently very different experiences, which under some circumstances and for some persons, lead to notably similar outcomes) (George & Bennett, 2005). With these goals, we have suggested that one contribution CT-CR makes to teacher education research is new questions and new or modified data collection and analysis tools (Cochran-Smith, Ell, Ludlow, Grudnoff, & Aitken, 2012, 2014).

One new cluster of questions prompted by the CT-CR framework focuses on teacher education programs/pathways as complex systems. A short list of examples includes: How does a teacher education program/pathway function as a system? What are its key elements (actors and structures), and how do they interact? How does the system learn/grow/adapt/change? How do differently-positioned participants (who are themselves complex systems) understand the system and function within it? From the perspective of CT-CR, we also need to understand systems' initial conditions and limits and examine recursive interactions to trace the effects of feedback and other mediating factors on candidates' practice. As we have suggested (Cochran-Smith et al, 2014), questions along these lines include: What initial conditions, interactions, feedback loops, and school contexts are associated with the emergence (or non-emergence) of teaching practices that enhance student learning and challenge inequities? What are the key causal processes or generative mechanisms that account for both multifinality and equifinality? A second cluster of questions about programs/pathways as systems has to do with the policy environments in which they are embedded. In contrast to linear views of policy implementation, CT-CR suggests that the introduction of new policy may initiate the process of self-organization, which is fundamentally non-linear and tends to produce unintended consequences. Examples of questions along these lines include: How does the introduction of new policy requirements create disequilibrium in the functioning of a teacher education program/pathway? What emerges in terms of learning opportunities for teacher candidates and students? How do system elements interact, grow, and change in response to new policy or, on the other hand, resist, recast and co-opt it?

A third cluster of questions has to do with how teacher education systems interact with schools as systems. This set of questions is based on the premise that systems are sensitive to their environments, and when an element of a system is also part of another system, the two are mutually constitutive. In many situations, teacher education is assumed to exist as an entity separated by both time and space from the contexts in which teacher candidates work with students. In contrast, CT-CR suggests that these systems overlap at their boundaries, which also provides a rich source of questions: How do teacher education systems interact with schools as systems? What learning opportunities emerge from different interactions and relationships? To what extent are teacher candidates' abilities to enact teaching that

enables student learning influenced by the interactions and relationships of school systems and teacher education systems? Questions that examine the boundaries between systems shift the focus away from individual teacher candidates toward teaching practice environments and organizations where previously unexplored explanations may be found. Finally, the CT-CR framework opens up a fourth cluster of questions about "multiple intersecting social inequalities" (Walby, 2007) in initial teacher education. In some traditional frameworks for teacher education research, gender, race and class are characterized as variables and treated as characteristics of individuals. With the CT-CR framework, different questions are possible: How do social inequalities shape the initial conditions and enabling constraints that frame candidate learning opportunities in programs/pathways? What roles do systems of inequalities play in feedback loops within programs/pathways? What social, organizational, and intellectual structures of programs and pathways, which are themselves intersected by multiple systems of social inequality, help teacher candidates develop critical and applied understandings of those systems with the goal of emancipatory teaching practice?

The questions we have enumerated above are intended to be suggestive—the beginnings of a different kind of empirical research agenda in teacher education, guided by CT-CR, which may be of interest to other researchers and practitioners in teacher education. What these sample questions show is that applying the CT-CR framework to initial teacher education research gives us new ways to consider how things might be related and may have the capacity to generate a new body of evidence toward an explanatory theory of initial teacher learning. To pursue questions like these, we need appropriate research methods. Neither complexity theory nor critical realism offers a package of methods for data gathering and analysis, which need to account for and foreground relationships, interactions and processes across levels and systems with particular attention to system boundaries and to the spaces where systems interact and co-evolve.

We have proposed three possibilities for data collection and analysis in teacher education research informed by CT-CR (Cochran-Smith, Ell, Ludlow, Grudnoff, Aitken, 2014; Ell, Cochran-Smith, Grudnoff, Ludlow & Haigh, 2013), one originating from organizational studies, one from health care, and one from political science (Cochran-Smith, Ell, Ludlow, Grudnoff, & Aitken, 2012; 2014). These can be used in combination with each other and/or with other existing qualitative, quantitative and mixed methods approaches to lead to promising new lines of research in teacher education. Drawing on work about consensus mapping and concept mapping (Ruiz-Primo & Shavelson, 1996), we suggest that system mapping has potential as both a data collection tool and a data analysis approach in teacher education research as a way to identify: how and to what extent particular initial teacher education programs/pathways function as complex systems, similarities and differences in the ways various actors and agents within programs conceptualize the value and role of various system elements, and what various actors see as the boundaries of

the system. System mapping can also be used to suggest directions for tracing key processes and/or causal mechanisms involved in teacher candidates' learning, as we suggest below. A second research method, the extended case study, has been used in a number of social science areas, including health care (Anderson, Crabtree, Steele and McDaniel, 2005). Unlike traditional case study designs, which "bound the case," extended case studies focus on the ideas, actions and interdependencies that occur at and across boundaries and emphasize interrelationships, flows, and exchanges rather than formal roles. Extended case studies can easily be adapted to research on teacher education, which already features many case study designs, and has the capacity to shift the focus away from individual teacher candidates and toward the ways individuals' experiences and performances are shaped by complex practice environments and organizations. The third research method we recommend is process tracing, which has been used in political science (George & Bennett, 2005; Collier, 2011), sociology (Marsh, 1982; Tilly, 2008) and other social sciences to uncover the complex causes of social processes. The emphasis in this work is on identifying and understanding the multiple, contingent, and complex causes of particular outcomes within and across cases with a focus on mechanism- and process-based explanations. Process tracing involves the careful description of data at multiple time points in order to analyze trajectories of cause. With multiple cases, the trajectory of causal paths that lead to given outcomes can be charted along with the conditions under which those outcomes occur.

Using CT-CR as a Platform for Studying Initial Teacher Education

As we have suggested, CT-CR is a conceptual framework that the RITE team is in the process of developing. In one sense, then, this means that conducting studies using the CT-CR framework is akin to flying an airplane while still building it. In another sense, however, this means that our empirical studies and the CT-CR framework are recursively related: our empirical studies are emerging from new understandings of initial teacher education generated by the theoretical merger of complexity theory and critical realism (for example, conceptualizing initial teacher education in terms of multiple overlapping complex systems—individuals, schools, preparation programs/pathways, policymaking bodies—that intersect with multiple larger social systems of inequality). At the same time, the challenges involved in developing research questions and data collection/analysis strategies consistent with the CT-CR framework (for example, designing case studies not defined by the traditional notion of the "boundedness" of a case) are informing our revisions and further developments of the framework.

Guided by the CT-CR platform, the Project RITE team has conducted several empirical studies of initial teacher education with additional empirical studies underway or in preparation. Below, we discuss aspects of one empirical study, which we refer to as a mapping study, in order to illustrate concretely some of the questions, research methods, and insights made possible by the CT-CR platform (Ell, et. al., 2013).

Our mapping study had two purposes: (1) to examine how the members of four differently-positioned constituency groups (teacher candidates, school-based mentors, university teacher educators, policy makers) perceived and understood the elements of initial teacher education, conceptualized as a complex system, and (2) to consider the implications of their perceptions for teacher preparation program reform. Using a unique systems mapping task, we asked 76 teacher candidates, school-based mentors, university teacher educators, and policy makers to create "maps" of the elements of the teacher education system, including actors, such as school-based mentor teachers and university-based supervisors, and structures, such as fieldwork seminars and university coursework, which they believed influenced teacher candidates' learning to teach in ways that supported students' learning. Specifically, the study explored these questions: Which elements of the teacher education system do participants identify as influential in the process of teacher candidates' learning to teach in ways that promote children's learning? How much influence do they ascribe to various elements and what relationships or links between elements do they perceive? What are the similarities and differences between and among the perceptions of the various groups?

The teacher candidates, school-based mentors, and university teacher educators in the mapping study were all participants in an elementary level, three-year teaching qualification program at the University of Auckland, Auckland, New Zealand. The program's goal is to prepare teachers who build on children's differing cultural, linguistic, and socio-economic backgrounds and recognize diverse educational needs. The program has a specific focus on preparing teachers with a sound understanding of, and commitment to, enabling the success of Maori learners, New Zealand's indigenous population, and other groups not traditionally well served by the system. All of the teacher candidates in the mapping study had completed 11 weeks of school-based practicum work. In addition, three national-level teacher education policy makers also participated in the mapping study.

Each participant created a map representing his or her understanding of the teacher education system by selecting from a list of 37 possible system elements (actors and structures) and placing them on a large paper sheet with concentric rectangles that were labelled strong, moderate and distant influences on teacher candidates' learning to teach, which was at the center of the sheet. Once elements were selected and placed on the rectangles (and additional elements added, if desired), participants indicated relationships among the elements using connecting lines or circling groups of elements. Data were analyzed by creating composite maps for each constituency group, which revealed which elements each group perceived as part of the teacher education system and how strong those elements were in influencing teacher candidates' learning to teach to support students' learning. Cluster analysis and multi-dimensional scaling were used to analyze the linkages the groups perceived among the elements.

In the interest of space limitations, we discuss just one set of results from the

mapping study, which was unexpected and striking. Among the list of 37 elements offered for creation of system maps (for example, university supervisors, courses, school-based mentor teachers), participants in all four constituency groups selected the same three elements as strong influences on teacher candidate learning, which we refer to below as "core" elements: teacher candidates' personal beliefs and values, mentor teachers, and children in classrooms. Teacher candidates selected only this core group of three elements as having a strong influence on their learning to teach all students effectively. Interestingly, school-based mentor teachers selected the same three core elements plus three additional elements (practicum supervision, the assessment processes connected to the practicum, and the practicum school) as having a strong influence on teacher candidates' learning. Meanwhile university-based teacher educators selected the core of three plus the same three additional elements selected by the school mentors plus four more additional elements (course lecturers, courses, prior knowledge, and prior experience as a learner) as having a strong influence on teacher candidates' learning to teach. Policy makers selected the same three core elements plus university courses and the New Zealand curriculum. Interestingly, as this indicates, across all the constituency groups, candidates' personal beliefs and values were perceived to be a stronger influence than teacher candidates' knowledge or experience.

This set of findings is important in its own right in that it points to key junctures and disjunctures in the teacher education system as potential levers for reform. Many interventions and innovations in teacher education focus on the role of knowledge in teaching or the role of practice. While many educators acknowledge the importance of teachers' beliefs and values, the connection between beliefs and practice is often simply assumed, and we know relatively little from research about how beliefs are actually related to practice or which beliefs and practices are related to students' learning. Our mapping study findings point to the importance of systematically addressing the interactions of beliefs and practices as key leverage points in initial teacher education. In contrast, the other two elements of the system that were selected as the strongest influence on teacher candidates' teaching—mentor teachers and children in classrooms—are situated in the complex systems of schools, which interact with teacher education program systems, but are more outside the purview of university teacher education. This set of findings from the mapping study suggests that the feedback loops operating in the overlapping spaces of schools and universities are particularly fertile places to look for understandings of how things work in teacher education. As many teacher education programs move toward closer and different kinds of partnerships among universities, schools and communities, there will be greater overlap among the complex systems of individuals, programs and schools; these will engender new feedback loops that may amplify or diminish teacher candidates' learning in the school space in important ways.

This one set of findings from our mapping study provides some preliminary information about which events, actors, and structures in the system are pivotal to teacher

candidates' learning. They point to useful starting points for tracing the processes through which teacher candidates learn about and then employ core patterns of practice that support the learning of marginalized students. The identification of three core elements by all the constituency groups strongly suggests that these elements are key places to look further for causal pathways in learning to teach. Areas which all respondents identified as strong influences on candidates' learning to teach to promote students' learning are likely to have strong positive feedback loops operating within them.

The Project RITE research team is currently engaged in a series of studies intended to uncover the extent to which, and the complex causes of, teacher candidates' learning to enact "patterns of practice for equity." We define these as interdependent clusters of beliefs, attitudes, habits, interpretive frames, actions, and interactions that combine to promote the academic, social-emotional, critical and civic learning of all students, especially those historically marginalized on the basis of culture, language, race, socio-economic status and gender. To do so, we are utilizing adaptations of forward and backward "process tracing" that borrow from work in political science (George & Bennett, 2005; Collier, 2011) and from the extended case studies used in health care research and sociology (Anderson et al., 2005; Burawoy, 1998). The emphasis in this work is on identifying and understanding the complex causes of teacher candidates' learning that supports students' learning with a focus on mechanism- and process-based explanations.

Conclusion

As we noted at the beginning of this article, research on initial teacher education is faced with many difficult challenges. One of the toughest is providing coherent explanations for how the outcomes of teacher preparation happen and why they are so uncertain. We believe that CT-CR has promise for initial teacher education as a research platform that embraces complexity but also reclaims causality and, at the same time, helps us examine the impact of intersecting systems of inequalities on how teacher candidates learn to teach marginalized groups. As a framework based on notions of complex contingent causality, CT-CR may have the potential to help meet the challenge of providing explanatory frameworks without being reductionist.

We conclude by suggesting that CT-CR may be able to serve as the basis in teacher education of what Byrne (1998) calls an "engaged science," not founded in "the assertion of an absolute knowledge as the basis for social programs, but rather in a humility about the complexity of the world coupled with a hopeful belief in the potential of human beings for doing something about it" (p. 45). Developing CT-CR as a research platform is a step toward an "engaged science" of teacher education that recognizes the responsibility of teachers and teacher educators and embraces the possibility of human agency in creating change. This approach acknowledges that these notions must be treated with great appreciation for uncertainty, complexity and unpredictability. This aim, along with the above understandings of causality,

human agency, and responsibility for challenging inequalities, are central features of CT-CR as a platform for teacher education research.

Notes

[1] Project RITE is a program of research and practice in initial teacher education, led by researchers at the University of Auckland in New Zealand and Boston College in the United States. The major purpose of Project RITE is to conduct and disseminate research, informed by complexity theory and critical realism, on the relationships between initial teacher education policies and practices and school students' learning.

[2] Also see: the International Association of Critical Realism—http://criticalrealismblog.blogspot.com/search/label/About%20IACR; Routledge Publishers book series on critical realism—http://www.routledge.com/books/series/routledge_studies_in_critical_realism_SE0518/; and the Journal of Critical Realism—http://www.maneypublishing.com/index.php/journals/rea/

[3] We have discussed these and other critiques in detail elsewhere (Cochran-Smith, Ell, Ludlow, Grudnoff, & Aitken, 2014).

[4] Shipway (2010) briefly discussed teacher professionalism and emancipation in his conceptual consideration of critical realism and educational research, he did not discuss teacher education specifically.

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