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Teacher Role-Identity and Motivation as a Dynamic System

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Abstract

This paper describes a conceptualization of role-identity and motivation as a complex dynamic system and its application to teachers’ professional role-identity and motivation. The Dynamic Systems Model of Role Identity (DSMRI) conceptualizes role identity as a dynamic system comprised of four components that are continuously emerging to inform motivated action through processes that follow complexity assumptions: interdependence of components, non-reductionism, non-linearity, non-determinism, and contextualism. The paper presents the assumptions and characteristics of the DSMRI and its use in a case study analysis of the role identity and motivational change of a teacher who participated in a science teacher PD. The paper also presents a dynamic system simulation of the model and describes its potential use to inform theory building, research, interventions, and evaluations in teachers role-identity and motivation that conceptualize these phenomena as complex dynamic systems.
Teacher Role-Identity and Motivation as a Dynamic System

Successful, long-term, and motivated teaching requires persistent desire for excellence, a commitment to life-long learning, and access to high quality professional development. Teacher education programs and in-service teacher professional development (PD) are universally employed to prepare teachers for a motivated career, to mitigate attrition, and to improve teacher quality (Loucks-Horsley et al., 2010). However, despite major efforts, teachers’ turnover in low-income schools is very high (Ingersoll & Pedra, 2010), and close to 50% of all teachers leave the profession within five years of certification (Ingersoll, 2012). This situation illustrates a disparity between theory and research on what makes for effective teacher education and PD, and the practical realities of teachers’ professional learning and motivation. Not only is the full application of research-derived best practices rarely possible due to lack of time, inadequate funding, competing tasks, and variability in participant characteristics and organizational constraints, but these practices focus almost exclusively on promoting learning of content knowledge and pedagogical content knowledge (PCK), paying little or no attention to a core developmental-motivational process in teachers’ professional learning and retention—teachers’ professional role identity. For a teacher to apply innovative practices despite pressures to do otherwise, and to persist in the vocation despite unfavorable conditions, these actions must cohere with their core beliefs, values, self-perceptions, self-definitions, and goals for teaching (Richardson et al., 2014). To be successful, teacher education and PD programs must address not only content and pedagogy but also the complex processes that promote the professional role identity development that drives teachers to learn, develop, and sustain strong commitments to new practices and to the profession. However, the literature on teacher professional identities currently lacks a coherent model that can capture the complexity and richness of the teacher identity while providing sound conceptual tools for investigating, intervening and evaluating teachers’ professional identity. In the current paper, we describe an emerging model of teacher role identity and motivation that synthesizes theory and empirical research from the domains of
identity and motivation, and that is based on assumptions of complex dynamic systems, to bridge the gap between theory, research and practice, and to guide theory-building, research, interventions, and evaluations in teacher preparation and PD.

**Teachers’ professional role identity**

In its most basic sense, teachers’ professional role identity (RI) refers to the person’s self-description as a teacher; that is, the extent to which the person has established a personal commitment to the teaching profession and considers being a teacher an important aspect of who he or she is (Beijaard, Meijer, & Verloop, 2004). In addition to the level of commitment to the profession, RI also refers to the content and structure of that identity—a network of self-perceptions, beliefs, values, goals, emotions, and actions that are held as central to the role of being a teacher (Beauchamp & Thomas, 2009; Beijaard, Meijer, & Verloop, 2004; Bullough, 1997; Sachs, 2005; Woodbury & Gess-Newsome, 2002). Two teachers may have similar levels of commitment to being a teacher but hold quite different values, goals, and perceptions about teaching that are more or less aligned with each other, resulting in the enactment of different instructional strategies. RI provides teachers with a framework that implicitly guides them in interpreting and evaluating experiences and events related to teaching, and in making decisions about action (Bullough, 1997; Horn, Nolen, Ward & Campbell, 2008). The central role of teachers’ professional identities in their learning, motivation, and retention has been the subject of increasing scholarly attention in the past decade (Avraamidou, 2014; Jenlink, 2014). Moreover, Lack of change in RI constitutes a significant barrier to teachers’ learning, motivation, and change of practice (Gunersel, Kaplan, Barnett, Etienne & Ponnoock, 2014; Hathcock, Garner & Kaplan, 2014).

Whereas theory and research on self and identity is very broad and diverse (Erikson, 1968; Gee, 2000; Holland et al., 1998; Wenger, 1998), current theory and research on teacher identity and motivation can be generally characterized by two complementary approaches. One approach includes research that focuses on distinct self-related constructs such as task-values,
teaching efficacy, achievement goals, and possible selves, and involves primarily quantitative measurements of these variables to predict the teachers’ instructional decision-making and well-being (Butler, 2007; Richardson & Watt, 2010; Roth, 2014). The second approach includes research that focuses on the holistic subjective meanings of teaching in particular social-cultural contexts (Beauchamp & Thomas, 2009; Horn et al., 2008). This approach involves primarily qualitative descriptive inquiry that integrates the cultural meanings of teaching in the particular social-organizational setting with the teachers’ personal histories and characteristics. Both approaches have strengths, but also limitations. The construct-based approach provides empirical findings and conceptual anchors for PD interventions in specific processes such as teachers’ self-efficacy beliefs or goals in order to promote adoption of certain actions. However, this approach is limited by its reduction of the complexity of teacher identity to simple, linear, and deterministic relations among few specific variables. It fails to capture the rich, contextualized, diverse and dynamic nature of the individual teacher’s RI, and the complexity and variability of an individual teacher’s reactions and actions within a particular PD setting or classroom (Kaplan, 2014a). In comparison, the social-cultural approach provides a holistic, in-depth, and complex description of the teachers’ lived experiences and action in the particular setting, which captures the contextualized, dynamic, and social nature of RI and the individual teachers’ decision-making. However, because it does not focus on particular constructs or result in replicable and generalizable findings, the approach fails to provide guides and tools for measuring and intervening in teachers’ RI across groups of teachers and multiple, diverse contexts.

Based on theory and research in the domains of motivation and identity (Kaplan & Flum, 2009; 2010; 2012; Kaplan, Sinai & Flum, 2014), our design and evaluation work in the area of science teacher PD (Garner et al., 2012, 2013, 2014), we have built on recent applications of complexity science assumptions to psychological phenomena (Guastello, Koopmans & Pincus, 2009; Kunnen, 2012a) to developed a model of science teacher professional RI that integrates the strengths and compensates for the limitations of these two approaches. The model—the Dynamic
Systems Model of Role Identity (DSMRI)—provides a framework for conceptualizing teachers’ learning, motivation, and role identity development, and for guiding the design of teacher education and PD that aims to intervene in these processes and to promote teachers’ identity development and instructional change.

The Dynamic Systems Model of Role Identity (DSMRI). The DSMRI involves four primary contextually constructed and interdependent components that underlie teacher action (see Figure 1): (1) ontological and epistemological beliefs; (2) purpose and goals; (3) self-perceptions and self-definitions; and (4) perceived action possibilities. All these factors were identified as paramount to people’s action in previous distinct literatures (Kaplan, 2014b).

The role of ontological and epistemological beliefs in action manifests, for example, in research on people’s attributions of causality for events of success and failure (Weiner, 2011), research on the role of people’s assumptions about the stability versus malleability of intelligence (Dweck, 1999), and in the broader literature on epistemic beliefs (Hofer & Pintrich, 2002) and teacher beliefs (Fives & Buehl, 2012). The importance of purpose and goals in action has been demonstrated extensively in the motivational literature through research on constructs such as life goals (Cantor et al., 2002), career goals (Gati & Asher, 2001), purpose (Damon, 2008), achievement goal orientations (Butler, 2007), social goals (Wentzel, 1996), and content goals (Locke & Latham, 2002). The centrality of self-perceptions and self-definitions in action has been supported by a large body of literature spanning constructs such as self-efficacy (Bandura, 1997; Klassen, Durksen & Tze, 2014), self-concept (Hattie, 2014), and social identity and self-categorization (Turner & Reynolds, 2011). Finally, perceived action possibilities—a person’s perceptions of the available options for action in a particular situation—
has been highlighted in research concerning people’s strategic knowledge (e.g., learning or instructional strategies), behavioral intentions (Fishbein & Ajzen, 2011), and self-regulation (Boekaerts, Pintrich & Zeidner, 2000).

Whereas several frameworks have postulated the interaction of two or even three variables representing these different components (e.g., Bandura, 1997; Dweck, 2006; Zimmerman, 2008), the DSMRI makes a unique contribution in three ways. First, it incorporates all four components into a single, coherent, systemic, meta-theoretical model (Overton, 2013). Second, it conceptualizes each component as a category of constructs rather than as a single variable. Third, it applies assumptions of complexity science for conceptualizing these four components as constituting a complex dynamic system (van Geert, 2003); specifically, the interdependence of the four components, and hence the irreducibility of teacher identity and motivation to any distinct component; the continuous, non-linear, simultaneous, reciprocal, and indeterminate relations among the components, and hence the dynamic, non-linear, and at time chaotic nature of teacher identity and motivation; and finally, the reciprocal contextual-components relations that render the continuous emergence of the teacher role identity and motivation system highly contextualized.

Figure 1 presents a schematic of the DSMRI that reflects the complex dynamic nature of the RI through the reciprocal interrelations among the four components (depicted by reciprocal arrows between each pair of components) and the central location of teacher action, which conveys that the relations of each component to teacher motivated action cannot be considered independently of other system components. Figure 1 also presents the assumptions that the RI system is domain-specific (e.g., science), and that it is constructed within a socio-cultural context but also influenced by the teacher’s personal dispositions.

The DSMRI highlights three aspects of the teacher’s RI: content, structure, and process of formation. Any one of these three aspects of RI can vary between teachers and within a teacher over time. Variation in the content means that teachers differ in the amount, kind, and
complexity of the knowledge, beliefs, goals, emotions, self-perceptions, and action possibilities they hold for teaching. For example, teachers’ RI may reflect a more teacher-centered than student-centered configuration. A teacher with a teacher-centered RI may hold the epistemological belief that students learn knowledge best when it is presented to them, or that students are not capable of directing their own learning. She may adopt the goal of having students memorize information, and experience positive emotions of satisfaction and pride when she is able to cover all the material and when students do well on multiple-choice tests. She may construct the self-perception that she is very knowledgeable in the subject matter, and hence, she may value lecturing as the most appropriate pedagogical action for achieving her goal. In light of her beliefs, goals, and self-perceptions, she may not consider student-driven inquiry an action possibility. By contrast, a teacher with a student-centered RI may hold the epistemological belief that students learn knowledge by constructing it themselves. She may adopt the goal of having students engage actively in constructing such knowledge, and she may experience positive emotions of satisfaction and pride when students engage in and produce meaningful personal projects. She may construct the self-perception that she is attentive to students’ interests and needs, and hence, she may value problem-based inquiry as the most appropriate pedagogical action in light of her goals, beliefs and self-perceptions.

Importantly, variability in the content of RI manifests not only in differences in a particular construct (e.g., teachers being high versus low on beliefs about the malleability of students’ intelligence; high versus low on teaching self-efficacy), but also in the salience of different constructs in the components (e.g., teachers experiencing salience of assumptions about the malleability of students’ intelligence versus about the characteristics of knowledge in the subject matter; salience of self-perceptions of efficacy versus self-perceptions of personal interests). Thus, the DSMRI conceptualizes each component as harboring multiple constructs and dimensions, the salience of which may be different for different teachers at different times and in response to different situations. Such variation in the content of teachers’ RI can explain
why teachers evaluate PD subject area content as more or less relevant and compatible with who they are as teachers, and why they may be more or less motivated to integrate this content into their practice. For example, teachers are more likely to endorse a new practice as a viable action possibility and enact it in their practice when they have knowledge of it and perceive it to correspond with their unique system of beliefs, purpose and goals, self-perceptions and self-definitions, and other actions they consider central to who they are as teachers.

Variation in the RI structure means that teachers differ in the degree of harmony within the content of each component, the degree of alignment between the components, and the degree of integration between the teacher RI and other central RIs of the person. For example, whereas one teacher may construe various goals associated with student learning, classroom assessment, and standardized testing to complement each other, another teacher may find them to be in conflict and feel tension because of their association with different beliefs about learning, self-perceived values, or incompatible strategies (Boekaerts, 2010). Whereas one teacher may feel alignment between his beliefs about the role of students’ active engagement in their learning, goals of developing students’ interest in science, and self-efficacy for inquiry instruction, another teacher with similar beliefs and goals but with low self-efficacy for inquiry instruction may sense misalignment between the components and experience tension within her RI. Finally, whereas one teacher may experience integration and supportive concordance between the various RI components in teaching and the parallel components in parenting, another teacher may experience components in these two RIs to be unrelated (e.g., goals for students’ learning as unrelated to goals of learning for the teacher’s own children), or even to contradict each other (e.g., perceiving oneself as committed to fairness at home but as negligent about fairness at school).

Thus, structural differences in teachers’ RI may manifest in variability in the sense of coherence and commitment that the teachers feel towards their vocation, predisposing them to remain in or leave the profession to a lesser or greater degree. A teacher with a more aligned and
integrated RI structure would experience a sense of identification with the vocation and clarity with regard to goals and courses of action. In comparison, a teacher with more fragmented or conflicted RI structure would experience uncertainty, ambiguity, or tension with regard to certain goals and practices and would be motivated to resolve these tensions. Thus, variation in the structure of teachers’ RI would predispose them to exhibit more or less contextual and pedagogical discontentment (Southerland et al., 2011), be more or less open to change promoted by a PD program, or achieve change through different sequences of events (Clarke & Hollingsworth, 2002). Science teachers with a RI structure that is aligned and integrated would be more committed to their current practice and more resistant to change messages than would science teachers whose RI structure is more fragmented or conflicted. However, when the more aligned teacher’s RI system is perturbed through a challenge to one of its structural elements (e.g., creating misalignment between beliefs, goals, and practices through challenging the validity of a certain belief), a transformation is more likely to reverberate throughout the RI system and lead to sustainable change in action than would occur in a more fragmented teacher’s RI.

Variation in the process of RI formation means that teachers may differ in the breadth (number of RI components), depth (magnitude of deliberation within a component), affective intensity, and method of their identity construction process. Following assumptions of complex dynamic systems (CDS), the DSMRI conceptualizes the foundational process of RI formation—i.e., change in content of the four RI components, the nature of their structural interrelations, and the relations of the teacher RI with other central RIs (e.g., parent, employee)—as continuously emerging while being framed and shaped by the socio-cultural context (i.e., the particular subject-matter, cultural norms, values, practices, and social interactions) (Kaplan, 2014a).

Whereas the diversity of teachers’ personal histories results in an infinite number of idiosyncratic teacher RIs, the processes of emergence do seem to lead to the formation of certain general types of RIs—higher order profiles of relatively aligned beliefs, goals, self-perceptions,
and perceived action possibilities—within which, despite noteworthy differences, the individual RIs nevertheless share much content and structure (e.g., different permutations of student-centered RIs). Drawing from CDS, the DSMRI aspires to self-organization (Kunnen & van Geert, 2012)—that is, to a state of increased harmony, alignment, and integration—in the prevalence of cultural constellations of beliefs, goals, self-perceptions, and actions (e.g., a student-centered RI profile, a teacher-centered RI profile) that constitute “attractors” and “repellors” towards which, and away from, the RI is moving (Kunnen & van Geert, 2012). In the RI’s non-linear, dynamic trajectory towards increased harmony and alignment, logical connections between components within these cultural constellations (e.g., connections between the belief that students learn through active engagement, the goal of students’ active engagement, and the instructional strategy of student inquiry) provide positive feedback loops, meaning that activation of one component triggers the others and attracts the RI system towards a particular category of RIs (e.g., a student-centered RI). In turn, culturally-illogical connections (e.g., a connection between the belief that students’ learn through active engagement and the instructional practice of lecturing) provide negative feedback loops, with activation of one component (e.g. the beliefs) deactivating others (e.g. suppressing the practices) and repelling the RI system away from a particular category of RIs (e.g., a teacher-centered RI). Variation in RI formation across socio-cultural contexts may be based, in part, in the relative prevalence of such attractors and repellors as well as the weighting or salience of each component.

However, variation in RI formation processes also manifests differences between individuals within the same socio-cultural context—for example, in the initial state of the content and structure of the RI systems and in personal dispositions (e.g., open-mindedness, need for cognition, self-worth concerns, creativity, achievement orientation, future orientation). Different initial RI states and personal dispositions could lead to more or less resistance to change, in general or in a particular direction. Moreover, depending on the initial state of the system (e.g., fragmented RI versus strongly aligned teacher-centered RI), a strong environmental event (e.g.,
demonstration of effective self-directed inquiry) may promote an RI change process towards increased organization (i.e., fragmentation towards increased alignment of student-centered RI) or towards entropy (i.e., initial teacher-centered RI alignment towards misalignment) (Kunnen & van Geert, 2012).

Furthermore, our research on the identity formation of students and teachers highlights the contribution of individuals’ deliberate engagement in reflections on and exploration of identity-relevant questions to their sense of self and decision-making about action (Kaplan et al., 2014). In the DSMRI, such individual’s volitional identity exploration is integrated with the social-cultural context through the understanding that any identity exploration is inevitably shaped and mediated by social-cultural meanings and practices (Penuel & Wertch, 1995). However, the DSMRI assigns an important role to the teacher’s agency in initiating and guiding the RI formation process through the volitional engagement in identity exploration (Flum & Kaplan, 2006). Accordingly, variability in the process of RI formation also involves differences in the level of the individual teacher’s agency in identity formation, with some individuals engaging in active exploration of beliefs, goals, self-perceptions and definitions, and action possibilities, other individuals constructing these components and their interrelations primarily through adopting those that are emphasized in the environment or through following the normative example of significant others, and still others avoiding engaging in identity construction altogether (Berzonsky, 2011). Thus, variation in identity processes can manifest in differences in the breadth, specificity, and depth of the identity exploration. Some individuals may focus on exploring a particular component (e.g., contemplating a certain belief, or reflecting on the adequacy of a particular goal, or on a particular relation of a goal and action possibilities) and others may engage in a more comprehensive identity exploration process (e.g., an overall exploration of the four components and their relations, or of components across central RIs around a central personal dilemma) (Luyckx, Goossens, Soenens & Beyers, 2006). These processes may be cognitively and emotionally intense or conducted in a more cursory or
superficial manner. Finally, variation in the identity construction process can manifest in different modes of exploration and construction, with individuals engaging in some or many of a variety of actions, including personal reflection through writing or meditation, social conversations, and experimentation (Vangrik, Kaplan & Flum, 2011).

Conceptualizing the RI as a complex dynamic system allows the integration of the strengths of the current approaches to teacher RI while compensating for their limitations. The DSMRI reflects the holistic, contextualized, dynamic, varied, and rich nature of RI, and at the same time, anchors it in central constructs from the established motivational and self literatures. The DSMRI is a meta-theoretical framework: it specifies a set of conceptual anchors and principles of operation that provide guides for systematic measurement, investigation, and intervention in teachers’ RI (Kaplan, 2014a). It does not a priori specify the particular content, structure, or process that would manifest in the RIs of particular individuals in a particular group of teachers in a particular setting. However, researchers can utilize the DSMRI to develop and test theories concerned with such specifics of content, structure, and process among individuals or groups of teachers of different characteristics and in different contexts. The model offers tremendous potential for prompting role identity exploration during teacher education and professional development. PD designers can utilize the DSMRI to evaluate the specific content and structure of the participating teachers, design activities that aim to facilitate particular identity formation processes perceived to be conducive to the goals of the PD, and measure and evaluate the effectiveness of these activities in achieving these goals.

The DSMRI holds that change in RI manifests patterns of complex dynamic systems: it is non-linear, non-deterministic, highly contextualized, and can exhibit chaotic characteristics such as sudden increases or decreases in order and complexity (van Geert, 2003). This stands in contrast to the prevalent linear and deterministic assumptions regarding teacher motivation and change that guide the current approach to PD design (Garner & Kaplan, 2013). In a well-cited critique, Guskey (2002) characterized the prevalent assumption about teacher change in the
context of PD as a linear progression from change in teachers’ attitudes and beliefs to specific changes in classroom behavior and practices to improved student learning. Guskey countered that teachers’ change follows their experience of success in the classroom rather than the other way around, and proposed an alternative sequence, leading from change in teachers’ classroom practice to change in student learning outcomes to change in teachers’ beliefs and attitudes. In contrast to both, the DSMRI guides PD designers to anticipate the process of teacher change on the basis of the initial content and structure of the teachers’ RIs, the circumstances of their work environment, and the experiences in the PD that may trigger identity exploration and construction processes. When conceptualized as a complex dynamic system, change in the RI can be initiated by triggering any component that is salient to the participating teachers. For example, novice teachers might be more concerned with learning science content in relation to pedagogical action possibilities, whereas expert teachers may be more concerned with their purpose and goals for teaching (Birenbaum & Rosenau, 2006). Teachers who work with students with disabilities may be sensitive to ontological and epistemological beliefs about students’ ability to learn (Jordan & Stanovich, 2003), whereas teachers from minority background may be concerned with self-perceptions and self-definitions (Clark & Flores, 2001).

Knowledge of the teachers’ RI and its characteristics is of utmost importance to the teacher educator, PD designer and facilitator. Evaluating the content and structure of the participating teachers’ RI on the basis of the DSMRI assumptions would allow the designers and educators evidence-based insight into possible effective strategies for making the program relevant to teachers’ identities and for triggering identity processes that may promote constructive teacher change. Importantly, anticipating non-linearity, non-determinism, and chaotic changes in the RIs should guide educators, designers, facilitators, and evaluators to adopt dynamic formative assessments that continuously evaluate as well as inform the program design and adapt it to the changing developmental characteristics of the participating teachers (Garner & Kaplan, 2013). Knowledge of the DSMRI is also important for teachers themselves. The DSMRI
provides a powerful conceptual tool for promoting the teachers’ agency in developing their own professional RIs. For example, guiding teachers in mapping their own RI and considering the interrelations among its components in relation to a new practice can provide the teachers with a powerful scaffold for a systematic identity exploration process (e.g., “What are your goals for your students? How do your current practices promote your goals? Why do you believe that such practices promote these goals? How might the new practice relate to your goals?”). In our experience in designing, facilitating, and evaluating science teacher PD, we have found the DSMRI to be particularly effective for promoting constructive identity exploration processes around teacher-generated professional dilemmas. The systematic exploration of RI content and structure (i.e., reflecting on the content and the harmony or conflict between beliefs, goals, self-perceptions and definitions, and action possibilities, the alignment and misalignment of the components, and the integration of the RI with other RIs) has been generative of self-understandings and decision-making. Project deliverables will include examples of such insights and breakthroughs.

**An illustrative brief case study**

As an illustration of how the DSMRI can be used to investigate and guide interventions and evaluation of teacher PD, we present here a shortened case study of one participating teacher, Patrick (a pseudonym), a 48 year old veteran high school physics teacher, who was interviewed prior to, during, and after participating in an eight day intensive summer PD institute (Hathcock, Kaplan, Garner & Davidson, 2013). The research questions that guided the interview protocol and the DSMRI-based analysis were: (1) How has the participant’s incoming RI frame his motivation for the PD, and his response to particular PD design features? And (2) What changes did the PD experiences spur in his RI? The case study illustrates how a PD approach that aims at RI transformation through focusing on the participants’ reflection on their PD experiences promotes the dynamic change of the RI. Upon beginning the PD, Patrick’s teacher RI reflected relative alignment between self-perceptions and epistemological beliefs. Patrick held
strong commitment to teaching physics with self-definitions of science teaching as his “destiny,” which also aligned with his overall perceived career goals and action possibilities: “I’m not coming out of that classroom…I am today where I will be when I retire.” This self-definition was aligned with his epistemological belief that “physics is all around us” and his self-perceptions as someone fascinated by physics and interested in understanding how things work. As often is the case, Patrick’s epistemological beliefs about student learning were integrated with his own self-perceptions as a former physics student (a past RI) for who physics did not come easy: “I’m not one of those students, physics majors, where physics came easy…for me to get a B or a C I had to work real hard.” Accordingly, his epistemological beliefs about students’ learning physics were that: “…anybody can learn anything if they want to, if they’re interested and they stick with it. You don’t have to be intellectually gifted, you have to be curious, you’ve got to be open-minded and willing to apply yourself and not quit.” However, Patrick’s incoming RI also manifested misalignment between these epistemological beliefs, self-perceptions, and his goals for his students and instructional action possibilities that involved much work for him in creating teacher-centered assignments rather than engaging his students’ curiosity and effort: “[I do] a lot of work outside the classroom and at home [to] create an activity that will pull in the concepts. What kind of worksheet can I give them… I am constantly trying to create in-class activities on paper that will help them make connections.”

In his mid-PD interview, Patrick’s participant RI reflected a strong salience of the experience of the PD’s problem-based scientific inquiry. On the one hand, his experience of “information overload” during the interdisciplinary field scientific inquiry triggered exploration of self-definition as a science teacher versus a scientist; but on the other hand, his self-definition as a curious scientifically-minded person aligned with his enthusiastic embrace and positive emotions during this inquiry: “I really enjoyed looking at the wells…I find that very fascinating…it’s amazing how you can go from one layer to the next and easily see it and identify how you describe it…What the different colors mean.” Again, as commonly happens,
positive emotions ensue from insights about integration of different RIs, in this case between the participant’s RI and a former child RI: “...as a kid where I grew up, I was always playing in red dirt, and I never understood what the red meant versus the clay and so, I’ve really enjoyed the geological stuff.” Importantly, Patrick’s attempt at integrating his participant RI and science teacher RI did not occur immediately. Only a couple of days after the field inquiry, when experiencing frustration with the PD instructor’s instructions about analyzing the data, he began to explore his epistemological beliefs about his own students: “It was fascinating that I wanted to start here, which seemed more logical to me, and [the instructor] wanted to start over here, which seemed more logical for him... And, um, while all this was going on, I’m asking myself, how often does this happen to my students? You know, how often am I saying things to them and it’s just blah, blah, blah, thinking I’ll figure it out once he’s through blah blahing.” This exploration of epistemological beliefs aligned with exploration of perceived action possibilities: “How often is it that I may give them a data table and it not work for them because it’s not their data table?...I need to let them do it all from the ground up, maybe.” In this mid-PD interview, Patrick reported on change from certain teacher-centered epistemological beliefs to more student-centered beliefs, which provided a positive feedback loop to change in perceived action possibilities: “I’ve always kind of looked at my students and...my attitude is, OK, you’re a clean slate...we’re just going to start from the beginning and I’m going to introduce everything to you as though it’s the first time you’ve ever really heard it... I think I need to get away from that and I think my pre-assessments need to be real world questions. I think, you know, describe, or try to explain what’s happening here, and see how they respond to those types of questions...I haven’t normally thought that way.”

This process of exploration and move towards more aligned student-centered teacher RI manifested in Patrick’s post-PD interview, in which he aligned these epistemological beliefs with goals that included students developing their own problem solving strategies and working on more authentic, real world experiences: “Using their knowledge for them to begin to make
decisions...they need to build on what experiences they have. They need to be able to, I think, synthesize... using their experiences, background knowledge, to complete a task or assignment or something in my class.” These goals manifest as a negative feedback loop to his previous teacher-centered action possibilities: “I’m not interested in really repeating lock-step what I did last year. I refer back to what I did last year, modify, bring in something new...I want to be more of a risk taker now. Try new things...I ask myself, how can I model or actually...practice NOS [Nature of Science] in the classroom....from the very beginning.”

A Dynamic Systems Simulation of the DSMRI

The application of the DSMRI as a guide for PD design, facilitation, and evaluation and as a framework for researching teacher RI requires comprehension and endorsement of teacher RI as a complex dynamic system (CDS). Such application also requires the utilization of innovative modeling and analytical methods that are different from the traditional quantitative techniques that rely on assumptions of linearity and stability of relations among constructs (e.g., Hierarchical Linear Modeling, Structural Equation Modeling). Traditional analytical techniques are limited in their ability to capture, demonstrate, and test the complex dynamic phenomena resulting from multiple interdependent system elements (Axelrod & Tesfatsion, 2005). Moreover, most often, traditional quantitative techniques aggregate individuals’ phenomena to group-based variance analyses and make assumptions about identity of processes at the group and individual units-of-analysis that may not be warranted (Hamaker, 2012). In comparison, the DSMRI highlights the individual teacher unit-of-analysis, and emphasizes attention both to individuals’ RI trajectories as well as to the collective patterns of RI change, not losing sight of the individuals within the pattern.

In order to promote comprehension of the conception of teacher RI as complex and dynamic we developed a simulation that demonstrates its CDS characteristics. Furthermore, the simulation affords experimenting and testing hypotheses about the teacher’s RI complex characteristics and mechanisms of change. For developing the simulation tool, we turn to
quantitative dynamic modeling techniques that have become the viable and appropriate strategy for simulating complex phenomena (Guastello & Gregson, 2011). Quantitative dynamic systems modeling is an algorithm-based representation of a system and its components. It depicts change in the values of and coupling among components as these reciprocally and dynamically influence each other over time. Such modeling has been deemed particularly appropriate for representing and studying psychological and socially-situated psychological systems that are composed of interacting elements and that exhibit emergent properties—that is, when the system’s output cannot be reduced to the simple aggregate of its components (Axelrod & Tesfatsion, 2005).

Dynamic systems modeling involves translating the conceptual model into equations and formulas, calibrating the values of interrelations among elements to simulate conceptually viable cases, and validating the model (Kunnen, 2012b). Our (still developing) simulation tool of the meta-theoretical DSMRI can be used by researchers, teacher educators, and PD designers and evaluators for experimenting and investigating the RI phenomena most relevant in their unique contexts. The interface translates the DSMRI assumptions into equations, but allows calibration and validation of the particular content, structure, and process of participants’ RIs to be guided by the interests of the researchers, PD designers or evaluators, characteristics of the participating teachers, and the PD circumstances. Thus, the simulation is a tool for simulating the RI system formation and change as well as the effect and duration of interventions in one or more model components.

The simulation of the DSMRI provides a simplified quantitative demonstration of the dynamic, non-reducible, and non-linear nature of RI change that also reveals aspects of its regularities and laws of operation (e.g., self-organization; positive and negative feedback loops). The simulation allows modeling of a four-variable dynamic system representing each of the four components in the DSMRI, and the investigation of theoretical hypotheses about the effect of different types of interventions aiming at RI change (e.g., interjecting a certain degree of change in the beliefs component) at different phases of PD among teachers with different RI
characteristics. For example, the simulation allows the user to compare simulations of the effect of different interventions (e.g., intervening in beliefs versus in self-perceptions) on the change of the RI, and the effect of manipulating assumptions about the stability of the components depending on the participating teachers’ characteristics (e.g., when working with pre-service teachers versus veteran teachers) and on the PD context (e.g., when policy is changing versus remains stable). The simulation also allows the user to modify the direction and magnitude of reciprocal influences among components in the model to allow for the inclusion of variables of interest presumed to provide positive and negative feedback loops. The user is able to simulate hypotheses concerning strength of different relations between components, such as simulating the hypothesis that action possibilities have a stronger influence on beliefs than vice versa (cf. Guskey, 2002). Such modifications allow researchers and PD designers and evaluators to simulate anticipated change of RI among different types of teachers and under different PD circumstances.

Figure 2(a)-(d) presents screen shots of the current version of the DSMRI dynamic simulation model (code written in MATLAB). Contextual effects and an intervention are not presented in the Figure. Figure 2(a) presents the Graphical User Interface (GUI) that includes the scheme of the four components in the DSMRI. This GUI provides the opportunity to modify parameters that characterize the components and their interrelations, which can be derived from theoretical assumptions and from relations found within existing empirical research on the relations of the different constructs of interest to the researchers or PD designers or evaluators (e.g., research findings about the relations of teacher achievement goals, teaching self-efficacy, and use of inquiry-based instructional strategies). The GUI also allows modifying assumptions about the components’ stability (reflected in the Figure in the percentage within each component) and the magnitudes of the reciprocal influences among the components (reflected in the Figure in the colored arrows between components).
Figure 2(b) presents the dynamic change in the four model components across 20 longitudinal measurements in one simulated teacher. For the purposes of this presentation, the four components were represented by four variables with values ranging from 1-5. The initial values in the simulation (represented for this teacher on the left-side Y-axis) were random. For this demonstration, arbitrary specifications of stability of the components were set at 80% for beliefs, 60% for goals, 50% for self-perceptions, and 40% for action possibilities. Reciprocal interrelations of all components were set at +.05. As the RI system progressed through time, the mutual positive influences and relative stability of the components resulted with different change trajectories of the components, manifesting slow convergence to lower levels. The simulation demonstrates the dynamic systems principles of component interdependence and positive feedback loops, non-linear change, and self-organization. When performed for several simulated teachers with different initial values of the components, the simulation demonstrates how the same PD environment could lead to very different RI developmental trajectories. In this way the
simulation challenges the linear and deterministic assumptions about teacher change and elegantly illustrates an alternative approach.

Figure 2(c) presents the line trajectories of 100 simulated teachers across the 20 iterations, with the top graph presenting the trajectories of the sum of the four variables, and the four graphs below presenting the trajectories of the self-perceptions, goals, beliefs, and action possibilities variables, respectively. This Figure demonstrates the diversity in the trajectories of both the distinct components and their overall sum, allowing an insight into the nature of the relations between change in individual components and the dynamic system as a whole. For example, this Figure demonstrates a large variability in the trajectories of the individual components, with trajectories that begin in different initial values ending in any of the end values. In comparison, the trajectories of the sum of the components are more predictable, with trajectories that begin with low initial values end in similarly low or lower values, and trajectories that begin in high initial values end in similarly high or higher values, demonstrating the positive feedback loops among the parameters (clear converging patterns would indicate attractors). The simulation also allows the user to select one line of interest (e.g., an outlier) in this graph for more detailed examination of an individual case (showing the trajectories of its four components as appearing in Figure 2(b)).

Finally, Figure 2(d) presents the aggregated results of the 100 simulated teachers. The top graph presents a plot of the initial sums by the end sums of the four RI components, and depicts a non-linear curve of relations between initial and end states of the RI. This graph demonstrates how the change in RI may be different for teachers with different initial RI states. In addition, the graph suggests that different initial RI states are predictive of different dispersions of end-states, illustrating more indeterminate change in some initial values of the RI system. The bottom graphs in the Figure represent the distribution of initial and end sums of the components across the 100 simulated cases (left two graphs), the distribution line of the end states of each of the
four components across the 100 simulated cases (second to right graph), and the rate of change of each component across the 100 simulated cases (far right graph).

This simulation provides a tool for experimenting with the effects of different influences on the magnitude and patterns of RI change of simulated teachers with different initial RI values (e.g., the effect of changing the magnitude of the relation between goals and action possibilities through a PD activity that asks teachers to explain how their practices promote their goals). It also allows simulation of interventions into each of the components and their relations. Future developments will allow manipulation of multiple inner-elements in the components, and modification of extra-system characteristics reflecting different contexts and teacher characteristics. Output of these simulations could be compared with researchers’ and evaluators’ data from existing PD and research projects for calibration, validation, and theory building, and for informing PD design.

**Conclusion**

Any teacher education and PD program (or any other educational program for that matter), explicitly or implicitly, concerns two RIs: the participant RI and the professional/practitioner RI. Whether the educational program aims at pre-service or veteran teachers, is conducted in school or off-site, and employs lectures, modeling, or collaborative inquiry, the goal is to instigate processes of change in the participant RI that can be transferred to (or, integrated with) the professional teacher RI. When PD is conducted in out-of-class settings, transfer between the two RIs requires scaffolding. The DSMRI provides a conceptual tool for measuring the two RIs and their change in the context of teacher PD, investigating processes underlying successful and unsuccessful change and transfer between the two RIs, and intervening to promote such transfer through dynamic formative evaluation that focuses on the particular components and on specific interrelations that are salient to the participating teachers at particular phases of the PD. The DSMRI provides an example of the theoretical, empirical, and practical merits of conceptualizing teachers’ role-identity and motivation as a dynamic
system over perspectives that view and operationalize motivational processes as comprised of distinct variables that are related in linear ways.
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