CAUSAL BELIEFS IN EDUCATIONAL LEADERSHIP AND IMPLICATIONS FOR PROBLEM SOLVING

by

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ABSTRACT OF THE DISSERTATION

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This exploratory study investigated the impact of causal beliefs on how educational leaders explain and solve a complex problem (the mathematics achievement gap). In the first part of the study, individuals' causal beliefs were examined from a systems perspective and patterns of causal understanding, ranging from less to more systemic, were defined. Causal understanding was defined as a function of beliefs about causal agency, breadth of causation, system levels and connectedness among levels, and some system archetypes. In the second part of the study, variations in problem solving as a function of individuals' different levels of causal understanding were examined. The study sample involved educational leaders (district leaders and school principals) and teachers (no leadership position). Data collection employed a structured interview protocol, allowing for verbal and pictorial representation of thought. Data analysis involved the use of quantitative and qualitative methods. Qualitative analyses defined major categories and themes of answers as well as different levels of systematicity in participants' causal beliefs, which in turn served to determine different patterns of causal understanding (from less to more systemic). Quantitative analyses employed causal beliefs and patterns of causal understanding as independent variables to investigate implications for problem solving. In terms of causal beliefs, findings from this study corroborated much of what has been documented in the science education literature regarding individuals' failure to understand causality in a system, suggesting that major barriers to systemic causal understanding may be pervasive across different age groups and fields of knowledge and experience. In terms of problem solving, causal thinking patterns were correlated with types of solutions and ways to involve others. More systems-oriented causal thinking was associated with system change and empowering ways to involve others. Other findings also described (a) individuals' dispositions to change their mental models when faced with contradiction and (b) which pedagogical changes individuals believed were necessary to improve math achievement. These descriptions supported discussions on how individuals' beliefs and problem-orientations might create self-reinforcing loops that worsen the problem and prevent productive system change. Implications for instruction and educational leadership training were discussed.

DEDICATION

I dedicate this dissertation to five very special people without whom this could never be finished: my husband, my mom, my dad, my sister Gabi, and my daughter Isabela. To my beloved husband Alfredo because he always encouraged me to finish it, never complaining about my bad moods and absences. To my dearest mom, Mary, for her never-ending support, faith, and friendship while I spent months and months just working on this dissertation. To my dad who sponsored all my mom's trips to the US and always cheered up for me! To my sister Gabi because thanks to her great sense of humor and companionship I was able to collect the largest part of my data. And, finally, to my daughter Isabela who although is still very young to know what a PhD means, has illuminated my days with her beautiful spirit, making me believe that it is worthwhile to try making this world a better place to live.

Finally, I want to thank my adviser, Dr. Clark A. Chinn, for the great mentor he was during all my years of study, teaching me about the importance of thinking and acting like a true scientist, never forgetting about the ideals that have made us choose to be, above all, educators.

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CHAPTER ONE

Introduction

Thinking of education as a complex social system is fundamental to understanding educational problems so that meaningful changes can be promoted (Kaput et al., 1999; Fullan, 2001). Education is a complex system shaped by multiple factors that bear multiple, interdependent interactions within different levels of the system hierarchy (Kaput et al., 1999). The whole system is affected by contextual factors, local goals, and short-term results (Firestone, 1989). The relevance of examining education itself from a complex systems perspective has been advocated by several researchers involved in systemic reform efforts sponsored by the National Science Foundation (NSF) and the Department of State (cf., Kaput et al., 1999).

Systems thinking is crucial to understanding complexity. Systems thinking enables individuals to perceive underlying interrelationships and frame problems holistically rather than in terms of isolated events (Senge, 1990; Sterman, 2002). There seem to be two major views of systems thinking. One view, which I will call the agent-based view, explains complex phenomena as the observable outcome of simple interactions that happen at the micro-levels of the system. In this view, macro-level patterns *emerge* as the results of micro-level interactions (Chi, 2005; Jacobson & Wilensky, 2006; Maroulis & Wilensky, 2005; Resnick, 1994; Resnick & Wilensky, 1997). Understanding emergence requires viewing causality in a system as the product of decentralized influences and not as the influence of a centralized controller (Resnick, 1994, 1996). That is, a complex pattern can arise from simple rules that determine micro-level agents' behaving coherently at the macro level, without the need of "lead or seed" (Resnick, 1994). This agent-based view of systems thinking might be particularly useful in the study of what Lesh (2006) called "simply complex systems," that is, systems that are complex at the macroscopic level, but their constituent parts obey fairly simple functional rules. Examples of such systems are in biology (termites and ant colonies, fish and bird flocking), chemistry (diffusion), physics (quantum mechanics), and economics (the stock market), to name a few. In each of these cases, fairly simple interactions among the individual constituent parts leads to complex patterns of behavior at the level of the system. The applicability of the agent-based view of systems thinking in the social world is as yet uncertain (Stewart, 2001).

Another view of systems thinking, which I call holistic, explains individual behaviors at as the result of the system design (Bar-Yam, 1997; Forrester, 1961, 1998; Senge, 1990; Sterman, 2000). The system design is determined by the macro-level rules such as the sociocultural context and policies of incentives and resource allocation. In this regard, policy makers have a direct impact in establishing the design of the system by determining: (a) who and what gets rewarded and why, (b) how much and in which ways resources are allocated and towards which goals, (c) and which ending goals the system ultimately pursues. For instance, if school leaders and teachers are told that teaching needs to be student-centered, but the system ultimately rewards test achievement, which incentives might teachers have to pursue student-centered teaching if they can get students to achieve high test scores with a more traditional, skill-and-drill teaching approach? These macro-level rules based on the way system is designed define the affordances and constraints to which individuals will adapt and within which they will navigate. Authors who study change and reform in social systems, such as the educational system, argue that it is not possible to understand local problems without understanding how the system as a whole influences the behavior of the parts (e.g., Anyon, 1997; Fullan, 2001; Lieberman, 1995). The holistic view of systems thinking seems more appropriate to study social systems. This is because in the social world, systems are often "deeply complex," that is, "neither the systems-as-a-whole nor their constituent parts obey simple functional rules" (Lesh, 2006, p.47). This study employs a holistic view of system thinking, focusing on the role of higher level rules (policies, resources, and social context) in affecting the behavior of lower levels of the system.

Individuals have difficulty in dealing with complexity and a tendency to oversimplify it (Feltovich, Spiro, & Coulson, 1997; Ross, 1977). Cognitive studies conducted with students in science education have shown that systemic thinking is difficult to learn (Chi, 2005; Jacobson & Wilensky, 2006). Although these studies generally deal with agent-based systems (whose applicability to social systems is uncertain), they investigate causal beliefs that might also impact the understanding of complex social systems. For instance, systems thinking in science entails causal beliefs that incorporate multiple causal factors, deep underlying mechanisms, non-directional causal interactions, conflicting interests and goals among the different levels of the system, and causes and effects not always closely related in time (Chi, 2005; Grotzer, 2003; Grotzer & Bell Basca, 2003; Resnick, 1996; Wilensky & Resnick, 1999). These same causal beliefs also influence the understanding of complex social systems (Forrester, 1961; Sterman, 2000). Therefore, even though this study follows a holistic view of systems thinking, one of its goals is to investigate whether the cognitive difficulties documented in the science literature (which often follows a agent-based view of systems thinking) also happen when individuals think about and solve complex social issues (following a holistic view of systems thinking).

The social problem explored in this study concerns the improvement of mathematics achievement in urban districts. This problem is systemically complex because it involves multiple variables (including students, teachers, school leadership, parents, community, district, government, resources, and school capacity), which are connected in multilayered relationships that generate complex patterns (e.g., teacher burnout, achievement gap, low teacher and student motivation). In this study, I investigate how district leaders, school principals, and teachers – selected from the New Jersey Math and Science Partnership (NJ MSP) – think about and deal with this math achievement gap problem in their daily practices. I examine the extent to which these groups think about the problem in a systemic fashion and how this in turn affects the way in which they go about solving the problem. The study examines what types of solutions less and more systemic-prone thinkers propose, how they involve others in the problem-solving processes, whether they are willing to revise their mental models of the problem when faced with contradictions, how long they think it would take for improvements to be noted, and which pedagogical reforms in math teaching they suggest.

The study is designed to address two main research gaps in the systemic thinking literature. The first gap concerns the lack of evidence that systemic thinking promotes better problem solving. There are several prescriptive models on how to solve problems using a systemic framework (e.g., Keating, Kauffman, & Dryer, 2001; Senge, 1998, 1990). However, these models lack valid evidence showing whether such systemic frameworks necessarily lead to better problem solving; that is, solutions that benefit the whole system, not only the isolated parts (Cavaleri & Sterman, 1997; Doyle 1997). As Doyle (1997) noted, most of the research conducted to evaluate the impact of systemic thinking interventions in organizations has relied on retrospective self-evaluations (i.e., participants review their experience and describe how the intervention has altered their thinking), which entails a serious potential for subject bias. One area that this study investigates is whether systemic thinking improves problem solving. The study investigates systemic thinking in educational leaders, exploring how this type of thinking affects how they solve a complex problem.

The second gap to be addressed in this study is how ideas from the systems thinking literature can be applied to the social world, particularly in a complex social reality such as the school system. In family therapy and counseling research, systemic thinking has been applied to the behavior of individuals in family, marriage, and other intimate relationships (Rolland & Walsh, 1994), but it is not clear whether the findings from this research can be applied to larger, more complex social systems, such as the educational system. Overall, most studies on systems thinking have been conducted in science and science education.

Few studies have employed a cognitive lens to study educational leadership. Spillane, Reiser, and Reimer (2002) showed that the goals and content of educational reforms could be misinterpreted depending on individuals' different knowledge background and experiences. Nelson (1997) studied how administrators' views about teaching and learning affected their approach to school-related issues such as parents' concerns and teacher professional development. Leithwood and his colleagues (Leithwood et al., 1999; Leithwood & Steinbach, 1995) showed that educational leaders with transformational values often employed problem-solving strategies similar to those documented in the expert-novice literature. All these studies demonstrate that cognition (i.e., values, knowledge, views, etc.) can deeply affect individuals' understanding of reforms, policy implementation, and problem solving. However, such studies are few and, although they acknowledge the role of cognition in leadership thinking, they have not delved deeply into the content of thinking (Stein & Spillane, 2005). By systematically applying cognitive science techniques to the study of educational leaders' thinking, deepening its content, this study has the potential to offer a novel contribution to the growing area of educational leaders' cognition.

This study has two major goals. The first is to examine the causal beliefs and patterns of causal understanding of educational leaders and teachers when they explain a complex education problem (i.e., the math achievement gap). The second is to examine the impact of such beliefs and causal understanding on the way that education practitioners go about solving the problem. The study explores similarities and differences in the way different participants of the study think – district supervisors, school principals, and teachers. These between-group comparisons provide information about role-based differences in thinking and deeply enrich the growing area of research on leader cognition in education.

In the literature review that follows, I discuss the relevant literature in leadership and in systemic thinking. I first review studies that deal with cognitive aspects of leadership. These aspects include values, views, understanding, and knowledge. Most of this research has examined behaviors and content-free cognitive processes, leaving the cognitive content of thinking largely unexamined. I suggest that beliefs, particularly causal beliefs, are part of what comprises the content of thinking that is worthy of investigation. To support my argument, I subsequently review the cognitive literature on the role of beliefs in thinking (mostly conducted with students), showing that beliefs impact thinking in several ways. In particular, this study investigates whether evidence found in studies with students might also apply to studies with educational leaders. As this study examines causal beliefs from a systems perspective, I review the systems thinking literature in a separate section. Much of this research has been conducted in science education, mostly employing middle-school students. My overall argument is that a similar line of research employing practitioners (rather than students) and investigating systemic thinking in the social world is needed.

CHAPTER TWO

Literature Review

Individuals are active sense-makers and constructors of their own understanding (Greeno, Collins, & Resnick, 1996; Piaget, 1970). The ways in which they make sense of the world and solve problems are strongly influenced by their cognitive repertoire of preexisting knowledge, beliefs, and views of the world (Bransford, Brown, & Cocking, 1999; Donovan, Bransford, & Pellegrino, 1999; Greeno et al., 1996). These cognitive repertoires work as mental systems that select, shape, and create expectations, and give meaning to our experiences (Piaget, 1970; Moshman, 1982; Rumelhart, 1980).

Although researchers have learned about the role of cognition in teaching and learning by focusing on teacher and student thinking, educational leaders' thinking is territory that remains largely unexplored. Several authors have emphasized the need for research on thinking and cognition in educational leaders, since they deeply affect the way leaders interpret and implement policies, reforms, school actions, professional development initiatives, and instruction (Firestone, Fitz, & Broadfoot, 1999; Leithwood & Steinbach, 1995; Spillane, Reiser, & Reimer, 2002; Stein & Spillane, 2005). My study aims to address this research gap by investigating the role of cognition in leaders' thinking.

The Role of Beliefs in Leadership Thinking

The literature on the influence of beliefs in non-educational settings, particularly business leaders' behaviors, is extensive. This literature is often viewed as highly relevant in offering empirical insights to the research on educational leaders' beliefs (Raun and Leithwood, 1993). Classical theories about the influence of beliefs in organizational leadership behaviors include McGregor's Theory X and Y (McGregor, 1960) and Burn's (1978) and Bass' (1985) theories about transformational and transactional leadership. McGregor's Theory X and Y is based on the role that leaders' beliefs about human nature has on the way leaders act. Theory X consists of beliefs

that the average person: (a) is lazy and will avoid work if possible, (b) wishes to avoid responsibility, (c) has relatively little ambition, and (d) prefers to be directed. Leaders whose beliefs are consistent with Theory X are likely to coerce, control, direct, or even threaten followers with punishment in order to get them to achieve organizational goals (McGregor, 1960). On the contrary, Theory Y consists of beliefs that the average person has the capacity to exercise a high degree of ingenuity and creativity in the solution of problems and is willing to learn not only to accept responsibility but also to seek it. Theory Y interprets individuals' avoidance of responsibility as being a general consequence of experiences, not an intrinsic human characteristic (McGregor, 1960). Leaders whose beliefs are consistent with Theory Y are likely to be more democratic and respectful of others' individuality and capacities. Theory Y leaders may also tend to be transformational in the sense that they inspire their followers to attain goals by appealing to lofty ideals and moral values and by engendering a degree of trust, admiration, respect, and loyalty from their followers (Bass, 1985; Burns 1978). In contrast, transactional leaders tend to apply contingent rewards and punishments as a way to impose authority and control and to push their followers to identify and attain goals (Bass, 1985; Burns 1978).

Ideas from the transformational leadership literature started appearing in writings about education in the late 1980s (Leithwood, Jantzi, & Steinbach, 1999). Among the varying interpretations of the concept of transformation leadership, the most thorough model of transformational leadership in schools has been provided by Leithwood and his colleagues (Leithwood, 1992; Leithwood, 1994; Leithwood, Jantzi, & Steinbach, 1999). Transformational leadership in schools has been seen as a means of providing intellectual directions, introducing practices, and shaping the school culture, while empowering and supporting teachers to become partners in decision making (Leithwood, 1994). Although much research on transformational leadership in schools has focused on leaders' behaviors, for the scope of this research it is relevant to mention the work on the effects of transformational beliefs on certain cognitive processes.

Leadership researchers interested in applying cognitive science to the study of leadership have examined the problem-solving process of transformation leaders. Leithwood et al. (1999) described many problem-solving characteristics of transformational leaders, showing that transformational leaders seem to act in ways similar to those of experts in other non-administrative fields, such as physics (Chi, Glaser, & Farr, 1988) and writing (Bereiter & Scardamalia, 1986). For instance, in terms of problem interpretation, transformational school leaders generally devote more time and effort to understanding and formulating problems and are more inclined to view problems as part of the school's mission. Transformational leaders also show a greater tendency to plan for how to deal with possible constraints in their daily practices. Transformational school leaders often think about solution process in greater detail, develop explicit plans for solving problems, collect comprehensive information relevant to understanding the problem at hand, and carefully monitor their progress (Leithwood et al., 1999).

Leithwood and Steinbach (1995) investigated the role of professional and basic human values on superintendents' problem solving. Values are a kind of belief; they have a strong affective investment and are internalized to guide behavior (Nespor, 1987; Pajares, 1992; Rokeach, 1968). However, the authors looked at the types of beliefs and how often they occurred during problem solving rather than looking at how beliefs themselves influence problem solving (which is one of the goals of this study). Although Leithwood and Steinbach (1995) acknowledged the role of values and beliefs in guiding thinking, they did not explicitly investigate that issue in their research. Rather, they examined factors that might have influenced the development of certain values and beliefs among educational leaders, choosing to focus on leaders' level of expertise as an important factor guiding value development. In this sense, values and beliefs were treated again as dependent variables and their effects on the content of leadership thinking were not examined.

The impact of leadership beliefs on problem solving has mostly focused on problem-solving processes rather than on the cognitive content of problem solving. These problem-solving processes involve cognitive strategies that individuals use to regulate, monitor, categorize, organize, plan, and ultimately solve problems. Although problem-solving processes are important in problem solving, they are content-free, and this limits a deeper understanding of how individuals explain and solve problems. Two individuals can use similar strategies to categorize a particular problem, but their conceptualization of the problem and the ways in which they interpret and make sense of the problem can be quite distinct. For example, school principals may conceptualize the issue of low-test scores as a problem of teacher preparation. However, how each school principal understands teacher preparation and thinks about ways to improve it may differ to a great extent. In order to capture such differences it is necessary to investigate the content of thinking, that is, the reason why individuals think and choose to solve problems in a particular way. To date, very few studies in educational leadership have pursued this task. The very few that did will be now be reviewed.

The Content of Educational Leaders' Thinking and Its Effects on Leadership Practice

Educational leadership effectiveness has mostly been studied from a "process-product" perspective (Stein & Spillane, 2005); that is, through examining relationships between observable behaviors of leaders and student outcomes, generally in a descontextualized and atheoretical manner. Subsequently, another line of research, following a "mediational paradigm" (terminology used by Stein & Spillane, 2005), looked at "how principals influence student learning by shaping the school environment" (p.16). Whereas the bulk of the research on leadership effectiveness has focused on behaviors, few studies have been devoted to examining thinking. In addition, when thinking is examined, the focus lies mostly on cognitive processes, detached from the content of thinking (as discussed the previous section).

Investigating the content of leadership thinking seems a promising line of research towards understanding differences in leadership effectiveness. The content of thinking may include knowledge, views, understandings, and beliefs about subject matter, learning, and students. According to the few researchers committed to this important line of research, the content of thinking may influence teaching, how reform is interpreted, and how policies are implemented (Firestone et al., 1999; Nelson, 1997; Nestor-Baker & Hoy, 2001; Spillane, 2000a).

Nestor-Baker and Hoy (2001) argued that the content of thinking is shaped by tacit knowledge, or the knowledge acquired through experience that allows individuals to "adapt, select, and shape their environments in ways that enable them to achieve their goals" (p.86). Tacit knowledge might be crucial to the development of professional expertise and to goal-oriented problem solving (Nestor-Baker & Hoy, 2001). Spillane (2000a) investigated district leaders' understanding of the math education reform in the state of Michigan and how their understanding affected their views of the reform and of policy implementation. He found that district leaders' interpretation of the math reform were relatively superficial, based on instructional features (*form-focused* interpretation) such as the use of manipulatives, hands-on learning, or cooperative learning. Very few leaders viewed math reform as involving changes in the epistemological and basic pedagogical functions of instruction (*function-focused* view). These form-focused interpretations were typically associated with piecemeal changes in the school system:

"Thirty-nine of the 65 district leaders who expressed form-focused understandings of the reforms understood the reforms as an assemblage of instructional, motivational, and classroom management tools rather than a coherent pedagogy or instructional philosophy designed to support more integrated changes in mathematics education" (Spillane, 2000a, p.162). With this study, Spillane (2000a) demonstrated that leaders' different understandings of reform have a profound impact on how they interpret and implement changes in the system.

Nelson (1997) discussed the influence of administrators' views of the nature of math, learning, teaching, and school culture on their interpretations of parents' concerns, their understanding of the nature of professional development for teachers, and their thoughts about how new ideas are disseminated in a school or district. For instance, administrators with a view of math as hierarchical, with higher-order skills built on basic ones, often agreed with parents that facts and algorithms should be emphasized before conceptual learning. They also interpreted mathematics education reform as a matter of acquiring new techniques and skills, and so professional development for teacher should aim at furnishing such skills and providing practice. On the other hand, administrators with a view of math as a system of ideas that develop over time were more concerned with conceptual learning and with educating parents about the nature of children's thinking. They also interpreted math reform as a long-term process that required changes in beliefs, knowledge, and practice, so that professional development for teachers should focus on conceptual change.

Research on teacher thinking has also demonstrated that teachers' beliefs about the subject matter, teaching and learning, and about the students themselves also affect the way they interpret reforms. It has been often documented that teachers have a limited understanding about the epistemological meaning of the mathematics reform. For example, most teachers think that math reform is limited merely to the use of new instructional procedures such as small groups and manipulatives, with little (if any) changes to the old vision of math teaching as showing, memorizing, and calculating (Simon & Tzur, 1999; Schorr & Firestone, 2001; Spillane & Zeuli, 1999).

An important research question that has not yet been fully addressed is why leaders and teachers have different views and understandings of the reform in the first place. In order to implement changes successfully, individuals need to improve their understanding of reforms and of effective teaching and learning. But how might such improvements be achieved? One important step is to identify why individuals may come to develop certain types of understandings and views. For example, why do some leaders have a more form-focused rather than function-focused understanding of the math reform? This study is grounded in the premise that such differences in understanding might be related to certain causal beliefs that people may have. One of the goals of this study, which is the exploration of educational leaders' causal beliefs and how such beliefs affect problem solving, is an important step towards unraveling why leaders might think and act in a particular way. This study will contribute to this line of inquiry by examining whether more systems-oriented causal understanding may help leaders solve problems in a better way.

The Role of Knowledge in Thinking

In the cognitive science literature, expert-novice studies have consistently documented the effects of knowledge on thinking (Chi, Glaser, & Farr, 1988; VanLehn, 1990; Voss & Post, 1988). Knowledge that is elaborated, organized, and well practiced, improves memory, encoding, and problem solving (Anderson, 1993; Chi, Glaser, & Rees, 1982; VanLehn, 1990). When compared to novices, experts have stronger self-monitoring skills, superior analytical skills for representing problems, and a capacity to perceive much larger meaningful patterns in their domain (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Farr, 1988). They also represent problems using more abstract categories as opposed to using superficial features (Chi et al., 1981; Voss et al., 1983). Experts spend more time analyzing problems, trying to simplify the task, making plans, and monitoring their progress (Gagné, Yekovich, & Yekovich, 1993). In historical problem solving, experts employ heuristics such as sourcing, corroboration, and contextualization that improve problem representation and argumentation (Wineburg, 1991). In expert-expert studies conducted in the field of science, it was found that experts possess not only domain-specific knowledge but also many domain-general skills such as being able to select relevant variables, design appropriate and relevant experiments to test a given theory, and keep general settings constant across experiments (Schunn & Anderson, 1999). When compared to novices, experts often possess a greater understanding about the functional and mechanistic properties of the system (Hmelo-Silver & Pfeffer, 2004) and use the ontological language of complex systems rather than linear, deterministic language when solving complex problems (Jacobson, 2001). Therefore, acquiring relevant knowledge about the various components of the system is an important step towards achieving systems thinking. Finally, research that has examined the role of knowledge in political problem solving found that experts often develop their representations in problem solving by building in a great deal of domain-specific knowledge. In comparison to non-experts, experts build more complex and richer arguments structured in the form of supportive operators and reasoning structures in the problem solving process (Voss et al., 1983).

Although research on the role of expertise in educational leaders' problem solving is only beginning, it has demonstrated that expert educational leaders have many behaviors and problem-solving processes similar to those of the experts in other fields. In a series of studies with school principals and district leaders, Leithwood and Steinbach (1993, 1995) found that experts displayed many of the cognitive processes previously documented in the cognitive literature. Expert educational administrators spent more time and effort on interpreting, understanding, and planning how to solve the problem and provided more details about their solutions to the problem. They also displayed a higher degree of metacognitive control exercised over problem solving. There were also differences in the cognitive processes of principals and superintendents. For instance, superintendents usually spent more time interpreting the problem, used more values to guide their problem solving, and were more straightforward in the solution processes (Leithwood & Steinbach, 1995).

Unlike other research on expert-novice differences (e.g., Chi et al., 1981), research on educational leadership expertise has not yet examined how experts differ from non-experts in terms of the content of their thinking (i.e., their beliefs, schemata, worldviews, nature of their knowledge, etc.). Another limitation of this literature is that it defines expertise in terms of effectiveness, which is an abstract criterion often subject to bias. What makes one person more "effective" than someone else? To answer this question, individuals often rely on the most visible and salient aspects of individuals' actions (Kahneman & Tversky, 1996). In this sense, outcomes of actions are generally more visible than the processes behind them, but they are not necessarily the more informative features of leadership competence. Outcomes can be good or bad, not necessarily because of leaders' competence or lack of it, but also because of random or contextual factors that may not always be salient and that cannot always be reasonably anticipated or avoided by leaders. However, individuals have the tendency to rate the quality of the decisions or the competence of the decision maker as better when outcomes are favorable than when they are unfavorable – a phenomenon named *outcome bias* – ignoring all other factors that are equally or even more relevant to judging the true quality of the decision (Baron & Hershey, 1988). In this sense, it is problematic to define leadership expertise in terms of school or district outcomes if the tendency toward outcomes bias is not sufficiently controlled for.

Unlike Leithwood's and Steinbach's (1995) research, this study will not attempt to classify leaders based on their level of expertise. It would be very difficult to find a criterion that classifies which leaders are more expert than others. The effectiveness criterion has the potential for outcome bias, as discussed above. The classical literature on expertise classifies experts based on accumulation of knowledge, which is a rationale simpler to follow when the population against which experts are compared involves novices. In the case of this study, however, there will be no novices. The participants will be real practitioners who have been in their field for some time. It would be controversial to classify one as being more expert than another using any rationale found in the expert-novice literature. Therefore, this study suggests a different way of looking at the role of knowledge in leadership thinking. It will not assume that participants are necessarily experts, but the study will take advantage of the varying types of knowledge and experiences that are the result of leaders' different roles to explore how these role-based differences affect thinking.

How Different Leadership Roles Affect Thinking

The hypothesis that different leadership roles may impact thinking is drawn from a sociocultural view of cognition. Sociocultural views of cognition emphasize the role that the social context has in developing and shaping individuals' knowledge and beliefs (Vygotsky, 1986). Individuals construct their knowledge and beliefs through social interactions with other members of their community of practice (Lave & Wenger, 1991). These interactions allow individuals to appropriate cultural tools, negotiate socially constructed meaning for these tools, and transform their knowledge through social participation (Cole & Engeström, 1993; Rogoff, 1995). As individuals transform their ideas and negotiate meanings by participating in their communities of practice, knowledge changes and gets distributed among the different participants of the community (Cole & Engeström, 1993).

According to Stein and Nelson (2003), leadership content knowledge follows a systemic model of nested learning communities (classroom, school, and district levels), with size and kinds of knowledge as well as epistemology changing as a function of the different parts of the system that a person occupies. Within this model, as we move to higher levels of the system (away from the classroom), there is an increasing requirement for leaders to understand how individuals at every organizational level learn (Stein & Nelson, 2003).

Teachers, administrators, parents, and government have important roles in influencing the educational system. Teachers influence the system by directly affecting how students learn and by making schools more or less of a learning community (Fullan, 2001). When teachers have low self-esteem, are uncertain of their practice, and do not participate in goal-setting activities, schools become impoverished learning communities (Fullan, 2001). School principals strongly influence school capacity, which comprises the teachers' knowledge and skills, the professional community, the program coherence, and the technical resources at the school (Fullan, 2001). Like effective principals help teachers' work to improve, effective district leaders impact the work of school leaders through investments in professional development, continuous improvement in the learning environments of students and educators, development of district-wide identity, changes in the culture of schools, and the monitoring of the improvement process (Fullan, 2001). Finally, the government, at a macro level, influences all of the other variables by dictating policies that profoundly affect the subsequent levels of the system. Governments are essential to achieving large-scale reform, as they are a major force for transformation; "governments can push *accountability*, *provide incentives* (pressure and supports), and/or foster *capacity-building*" (Fullan, 2001, p.220).

This study will explore similarities and differences in the thinking of individuals in different positions in the educational system (classroom, school, and district). The social contexts in which individuals are situated constrain leaders' cognition, structure work practices, innovations, and the implementations process (Spillane et al., 2002). By examining individuals with different leadership roles, this research has the potential to offer novel insights into how these different social contexts in which individuals are embedded might influence thinking and problem solving.

Conclusion

The literature reviewed above has shown that a cognitive approach to the study of educational leadership can offer important insights into understanding educational practice. For instance, it is possible to understand why some leaders are more democratic in their decisions and meticulous in their problem-solving processes by examining some of their values (whether they are more transformational or transactional). By investigating how leaders view learning and come to understand educational policies, it is possible to explain why some leaders deal with school issues and implement educational changes in different ways. Leaders who excel in their fields might have specific behaviors and ways of solving problems that distinguish them from less successful leaders. However, they certainly have more than that. They have a way to perceive, interpret, and understand the world that is unique, and only a thorough examination of their thinking can unravel it.

The literature on leadership cognition has mostly focused on the impact of beliefs on leadership style, behaviors, and, more recently, on problem-solving processes. However, there still remains much to be studied in terms of what and how other cognitions affect leaders' understanding and their educational practices. For instance, as the following literature review will show, cognitive science research has shown that beliefs play a crucial role in thinking. In particular, causal beliefs (or beliefs about how causality operates in a particular event) seem to be closely related to individuals' ability to think more or less systemically. Much of the research on the role of beliefs in thinking has been conducted with students in the field of science education. There is a need for a line of research investigating real-world practitioners' reasoning about the social world. It is unknown at present whether these cognitive theories about beliefs and thinking in science also apply to the thinking of educational leaders.

Beliefs and Thinking

The purpose of this literature review is to show that core beliefs – named ontological, epistemological, and causal beliefs – play a crucial role in thinking. In particular, causal beliefs can be viewed as defining the ways in which thinking is or is not systemic. I first review the literature on the role of beliefs in thinking, and then I talk more specifically about the role of causal beliefs in systemic thinking. I conclude by showing that there is a gap in the literature concerning the role of causal beliefs in the thinking of individuals dealing with social world problems, outside experimental conditions.

Role of Beliefs in Thinking

Cognitive and developmental psychologists have investigated the role of prior beliefs in interpreting and explaining situations. Belief is an ill-defined construct, with no universally accepted definition (Abelson, 1979; Pajares, 1992). Beliefs are generally viewed as being deeply rooted in personal experiences (Abelson, 1979; Nestor, 1987). They often lie beyond individual control or knowledge and rely more heavily on affective and evaluative components than does knowledge (Nestor, 1987). Individuals who hold a belief may not be aware of alternative ways of thinking and they may create a situation that differs from the reality (Abelson, 1979; Nestor, 1987). Although some authors see beliefs as a relatively stable construct (e.g., Nestor, 1987), others see beliefs as less stable than knowledge and contextually dependent upon the problems (diSessa, Elby, &

Hammer, 2002). From a systems dynamics perspective, "beliefs are stocks that characterize your mental states. Your beliefs persist over time, generating inertia and continuity on your attitudes and behavior" (Sterman, 2000, p.195).

Prior beliefs underlie and constrain the mental models or representations of specific problems that individuals construct while reasoning about them (Vosniadou & Brewer, 1992, 1994). For instance, children's prior beliefs that the earth's ground is flat can explain why they develop mental models of the earth as a hollow sphere in which the earth is seen as a sphere but people live on a flat ground inside the sphere (Vosniadou & Brewer, 1992). Such an interpretation of the earth's shape seems to fit into children's everyday view of the earth as flat ground. This shows that certain beliefs can constrain and even alter how one interprets the reality they see.

Prior beliefs affect individuals' interpretation of new information and disposition to engage in conceptual change. Individuals often hold prior beliefs that are so deeply entrenched that they discount discrepant information in ways that enable them to maintain their preexisting beliefs (Chinn & Brewer, 1993). The resistance to change might arise in part from the fact that prior beliefs are often consistent with individuals' everyday experiences, which are generally more intuitive and less abstract than commonly accepted scientific theories (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Certain beliefs might also be hard to change if they serve strong personal goals (Kunda, 1987). When individuals are able to construct reasonable justifications for their preferred conclusions based on already existing beliefs, they may feel less motivated to examine other relevant alternative theories that may equally effectively explain a particular case (Kunda, 1987, 1990).

Beliefs affect thinking and how individuals construct explanations and frame problems about specific situations. For instance, Samarapungavan and Wiers (1997) argued that beliefs about causation and properties of things determine certain explanatory frameworks that impact children's explanations about speciation-related phenomena and "constrain the kinds of solutions that are proposed to problems of speciation" (p.167). The authors argued that such explanatory frameworks function like paradigms in the history of science (Kuhn, 1962) that "serve to circumscribe a domain of phenomena, focus explanation on certain types of problems, and constrain the kinds of explanatory mechanisms considered" (Samarapungavan & Wiers, 1997, p.167).

Core beliefs that have been shown to impact cognition include ontological, epistemological, and causal beliefs. Ontological beliefs are related to how individuals understand the nature and properties of the things in the world (Chi, Slotta, & deLeeuw, 1994). When individuals' ontological beliefs are inconsistent with the ontology of new conceptions to be learned, they make inappropriate attributions of properties and processes (Chi et al., 1994; DaCosta, Chernobilsky, & Hmelo-Silver, 2007). For example, the mistaken belief that energy is a substance rather than a process might lead individuals to view energy as something that can be touched, weighed, and smelled; these are characteristics of substances, not processes (Chi et al., 1994). To provide an example from education, a teacher who believes that the classroom discourse is an outcome rather than a process might think that discourse can be controlled and defined by the teacher rather than co-constructed with the students in an ongoing, unbounded fashion (DaCosta et al., 2007).

Epistemological beliefs are individuals' belief of what knowledge is and how it is acquired. Productive epistemological beliefs include the ideas that knowledge is disputable rather than black and white and that it is a set of interrelated ideas rather than isolated facts (Hofer & Pintrich, 1997; Schommer, 1994). Students who have immature epistemological beliefs about the purpose of science, the nature of scientific knowledge, and the notion of scientific facts are less likely to acquire an integrated understanding of particular science concepts and to change their preexisting conceptions (Qian & Alvermann, 2000).

Finally, causal beliefs refer to how individuals believe cause and effect operates in a certain event. These types of beliefs directly affect individuals' explanations about why a phenomenon has happened in a particular way. This study seeks to capture the tacit aspect of how individuals make sense of causality. Individuals may have a general scheme for causality – for example, elements that covary with an effect may be a cause (Cheng, 1997) – but why they see some specific events as having greater causal power than others is an arbitrary, personal judgment. Studies on causal induction (Cheng, 1997; Ahn, Kalish, Median, & Gelman, 1995) have often dealt with simple and nonsystemic contexts, asking about causality in a highly structured format and experimental design. For this reason, these studies have not addressed how individuals select causes and effects out of a large pool of possible representations. These studies do not explain, for example, individual differences in causal attribution; why individuals choose certain causal explanations instead of others or why they weigh information differently during causal induction.

This study occurs in real environments (outside experimental designs) and uses open-ended questions geared towards capturing the many different ways in which individuals make sense of causality. As a consequence, this study has the potential to help explain why individuals' views of causality diverge from one another and from reality. As this study will focus on the role of causal beliefs in cognition, this topic is more carefully discussed in the next section.

Causal Beliefs and Systems Thinking

The philosopher Emmanuel Kant argued more than two centuries ago that human beings structure the world around them using very specific rules (Kant, trans. 1996). Causality involves one set of rules. Indeed, finding explanations for why something has occurred in a particular way is a common human activity. For instance, when someone says that "students misbehave because their motivation is low," this person is attributing the cause of student misbehavior to low motivation. If a person argues that "schools face difficulties to implement constructive curricula because too much emphasis is placed on testing," this person is attributing the cause of schools' difficulties to testing. No matter how simple or complex a phenomenon is, causal explanations are a pervasive cognitive activity among human beings.

Although events generally have multiple possible causal explanations, some causal explanations are better than others; that is, they are more accurate and better connected to available evidence. Sometimes people attribute the cause of an event to variables that are not in fact causal. On other occasions, causality may involve many factors and interactions that individuals fail to consider. The question, then, is why individuals' causal explanations vary so much. Causal beliefs are one of the possible answers for this question.

Causal beliefs are beliefs about how causality operates in an event; that is, about who or what causes an event and how causality happens. These causal beliefs involve causal agency, breadth and depth of causation, and causal direction. The way individuals perceive causality in a complex event may help explain why systems thinking is so difficult to attain (Chi, 2005; Grotzer, 2003; Grotzer & Bell Basca, 2003; Sterman, 2002).

Individuals may believe that "who" or "what" causes an event (causal agency) is *centralized* into a single factor. Beliefs that causality is centralized are problematic to understanding systems complexity, regardless of whether systems thinking follows a more holistic or agent-based view (DaCosta & Chinn, 2004; Resnick, 1996). In complex systems, causality involves multiple factors and their respective interactions. In a more agent-based view of systems thinking, micro-level agents follow often inherently simple rules that determine coherent behaviors at the macro level (Jacobson & Wilensky, 2006; Maroulis & Wilensky, 2005; Resnick, 1994). What appears to be controlled or determined by a "leader" is actually caused by multiple decentralized interactions. In a more holistic view, the design of the system determine which properties, traits, and problems become more salient and which behaviors are the most fitted (Forrester, 1961, 1998). Again, attributing causality to the dispositions of a particular leader ignores the fact that leadership itself (i.e., who the leaders are and how they look like) is determined by the affordances and constraints of the system. Non-systemic thinkers often centralize causality in local, individual causes and disregard any causes in the surrounding social field (Ross, 1977).

Individuals often have a tendency to attribute causality to personal rather than to contextual factors (Cheng, 1997; Ross, 1977). This tendency is what Ross (1977) named the fundamental attribution error (FAE), or the extent to which internal dispositions of an individual alone are regarded as sufficient causes of one's behavior. In other words, individuals have a tendency to explain other people's behavior as a function of internal dispositions (i.e., personality, motivations, skills, etc), ignoring how contextual factors might be influencing that behavior. For example, it is often easier to attribute policy implementation failure to leaders' lack of capacity or to self-interested goals than to attribute it to contextual factors (Spillane et al., 2002). Yet policy implementation often fails for reasons that are much more complex than the simple culpability of individuals, reasons that are the product of the multiple interactions that take place among the distinct factors and levels of influence within the same system (Firestone, 1989).

Causal beliefs affect the quality of individuals' explanations. When events involve complex causal rules so that they cannot be explained in terms of a single cause or a straightforward causal relationship, beliefs about causality that assume simplistic causality are likely to generate poor causal explanations. For instance, in explaining why a particular school district faces the problem of high dropout rates, which is a problem with complex causality, individuals with simplistic causal beliefs are likely to generate explanations centralized on an individual cause (e.g., "students don't care about education so they simply drop out" or "teachers fail to engage students"), disregarding contextual factors (e.g., school culture, socioeconomic reality).

Simplistic causal beliefs might lead individuals to stereotype reality. Stereotypes are simplistic and imprecise descriptions of the reality. By relying on stereotypes, individuals oversimplify the reality by attributing fault to an individual rather than taking alternative perspectives and considering variables that are much more relevant for understanding a particular event (Kemmelmeier and Winter, 2000; Voss, Wiley, Kennet, Schooler, & Silfies, 1998).

In conclusion, causal beliefs can help define thinking that is more or less systemic. For thinking to be systemic, individuals need causal beliefs that correspond to a view that events are caused by multiple causes, nonlinear effects, and constraint-based rules that emerge from the system as whole (Bar-Yam, 1997; Forrester, 1961, 1998; Sterman, 2002). It is important that individuals take into account not only relevant variables involved in the situation, but that they also understand how these variables are related to each other and play out in the overall scenario. In this systemic view, every action within a system feeds back to shape the context, and overall effects might take time to arise upon causation (Sterman, 2002).

Overall Conclusion

The cognitive science literature shows that beliefs have an effect not only on how individuals acquire knowledge and choose to solve problems, but also on the types of thinking that unfold while they solve problems. This study focuses on the role of causal beliefs in thinking. Studies of science students' systemic thinking have demonstrated that causal beliefs help define whether thinking is more or less systemic and systemic thinking, in turn, impacts the way in which students reason about complexity. Research has also shown that systemic thinking is a difficult ability to acquire, in part because it requires changes in individuals' everyday causal beliefs. Most studies on systemic thinking have been conducted in science showing that systemic thinking is necessary for students to understand certain complex phenomena, such as traffic jams and colony-type behaviors. It is unclear, however, whether the theories developed in the science education literature apply to how individuals make sense of complexity in social contexts. In this sense, research on the specifics of systemic thinking in the social world is greatly needed.

CHAPTER THREE

Goals of the Study and Main Hypotheses

This study has two main goals. The first was to examine, from a systems perspective, educators' (leaders and teachers) causal beliefs regarding a complex educational problem (i.e., the math achievement gap). The second goal was to investigate how different levels of causal understanding, as defined by causal beliefs, affect problem solving.

First Goal of the Study: Examining Causal Beliefs

The study examines what types of causes (causal agency) and how many causes (breadth of causation) educators believe explain the problem of the math achievement gap. It also examines educators' causal explanations in terms of whether different levels of the system (particularly, the higher levels, such as district- and federal-related policies) are included in their explanations and whether connections among the levels of the system are coherent.

Causal direction is also investigated, but some considerations are necessary. It is controversial to define what exactly constitutes a systems-oriented causal direction. Advocates of agent-based modeling argue that complex macro-level patterns emerge from single agents following simple rules at the micro-levels of the system (e.g., Jacobson & Wilensky, 2006; Maroulis & Wilensky, 2005). In this regard, systemic causal direction is seen as bottom-up. In the context of this study, which deals with a social system and follows a holistic view of system thinking, systems-oriented causal direction is seen as top-down, that is, it should incorporate higher-level causes towards extending the explanation of issues initially associated with local levels. In this sense, analysis of causal direction should explain low-level issues as a function of higher-levels that either afford or constraint the behavior of low-level variables.

Causal beliefs are examined through the analysis of participants' verbal responses and pictorial representations. The characterization of individuals' causal beliefs will allow for patterns of causal understanding to be determined, ranging from a less systemic to a more systemic orientation. For the second research goal, these patterns of causal understanding are employed as an independent variable to investigate variations in problem solving.

The Second Goal of the Study: Examining Problem Solving as a Function of Individuals' Causal Beliefs

The second goal of the study is to evaluate how individuals with different levels of systematicity in causal understanding solve a complex problem. In this study, differences in problem solving are assessed in terms of (a) what types of actions individuals propose and (b) how they involve people in the problem-solving process and deal with possible resistance. Three other issues are also explored to determine whether they bear any significant relationships with causal understanding and problem solving. One issue is how individuals deal with contradiction: If their proposed solutions did not produce any improvement, how would they explain it? Would they be willing to change their initial mental models? The second issue concerns the individuals' perception of the time that it takes for their proposed solutions to produce improvement. And the third issue concerns which pedagogical changes they think would be necessary to improve math achievement.

Analyzing the solutions that participants give to the problem may carry a value judgment in terms of which solution might be better than the other. Value judgments are controversial because they depend on the perspective adopted to judge. Although many perspectives can be taken to evaluate a solution, this study takes a systems-oriented one. One of the main purposes of the educational system is to help children learn and achieve in school. Considering the problem of this study (how to improve/solve the math achievement gap), there is an implicit notion that the current system is not operating well (otherwise, there would be no gap). If the system is not operating well, then it is logical to assume that changes are needed. Therefore, systems-oriented solutions should be geared towards change.

It is hypothesized that individuals with a more systemic causal understanding of the problem will be more likely to propose actions that impact the system in a broader manner, producing more meaningful changes. Individuals with non-systemic causal understanding will tend to focus on actions to fix, improve, or control isolated parts of the system, while seeking to maintain the current system. This is because it is easier to maintain a system than to change it; changing the system requires an understanding about system archetypes, such as feedback loops and delays. The improvement of math teaching in schools requires a systemic change (Fullan, 2001). A systemic view of the educational system takes into account that any action in one part of the system tends to produce a wide range of reactions, either to reinforce the current system or to self-correct it (a phenomenon called feedback loop). Variables are nested, forming a multilayered web of relationships. When educational reforms are not implemented following a systemic approach, efforts tend to worsen the very problems they tried to solve. For example, Rubin (2003) showed that when detracking practices are implemented at a superficial level, without reconceptualizing the overall school context and taking into account the social world of the students in detracked classes, these practices tend to reinforce the very inequalities that they seek to address.

Less or more systemic causal understanding might also affect how individuals involve others in the problem-solving process and deal with possible resistance. Less systemic causal understanding might be associated with a top-down manner of dealing with others, imposing policies rather than involving people in the planning and implementation processes. In these terms, individuals less prone to systemic thinking might act as transactional leaders, focusing on supervision, rules, implementation and reinforcement. Moreover, as individuals less prone to systemic thinking might be more likely to engage in the fundamental attribution error (i.e., emphasizing individual dispositions and traits, while disregarding the role that the context plays on behaviors), they might have a tendency to blame and criticize others for resistance. On the other hand, systemic causal understanding might be associated with approaches that develop and empower local leaders so that meaningful changes are likely to occur through a professional learning community (Firestone, 1989; Firestone et al., 1999; Fullan, 2001).

Another hypothesis is that systemic causal understanding might be associated with being more open to contradictory information (such as the proposed solutions producing no improvement) and willingness to revise initial mental models of the problem. Sterman (2002) argues that an important characteristic of systemic thinking is the disposition to view unexpected events as informative of one's mental model of the system. Unexpected events might serve as a source of anomalous data that encourages individuals to review their preconceived ideas about the system (Chinn and Brewer, 1993). Individuals with more systemic causal understanding might interpret unexpected events as providing crucial information on the limitations of their mental models. As a consequence, they might rethink and change their mental models to reflect a more thorough description of the reality. On the other hand, non-systemic causal understanding might be associated with interpreting unexpected events as something uncontrollable, such as bad luck or a side effect (Sterman, 2002). If this is true, individuals less prone to systemic thinking would not substantially change their mental models, and they would be likely to consider unexpected events as invalid sources of information.

Another interesting issue to investigate is whether causal understanding would be associated with different views of how long an action takes to produce effects in the system. One hypothesis is that more systems-oriented thinkers may view the time for an effect to emerge as difficult to predict, because cause and effect are not closely related in time. Upon causation, effects might not be immediately available because causal direction in a system is multiple and nested. The causes of a certain effect may be far back in time and may come from an entirely different part of the system. Moreover, "the complex system will present what appears to be a cause that is close in time and space, but that apparent cause in [sic] only a coincident [sic] symptom of the real cause" (Forrester, personal communication, September 28, 2006). Another important consideration is that effects might not be proportional to an action; even a small change at the micro level can have a significant impact at the macro level (Forrester, 1961, 1971).

Finally, another important issue is whether different causal beliefs impact individuals' views of the pedagogical changes necessary to improve math achievement;

namely, whether they would view pedagogical changes as a matter of form or a matter of function. According to Spillane (2000a), form-focused understanding refers to the understanding of instruction focused on forms such as learning activities, students' work, instructional materials, and grouping arrangements; whereas functional understandings refer to what counts as learning and knowing mathematics. Only functional understandings focus on the epistemological functions of math education so that real educational change can take place. In the context of this study, it is possible to argue that the tendency for individuals to view math reform in terms of piecemeal, form-focused changes might be related to poor systems-oriented causal understanding. For instance, less systemic-prone thinkers may have difficulty understanding change as a holistic, in depth process because they lack a systemic conceptualization of the problem. On the other hand, systemic thinkers might be more able to understand the importance of changing more than just the surface level of the system. For meaningful change to occur, they might see it necessary to review the deep-seated epistemology that operates in the system and promotes certain types of mindset and behaviors that reflect on instructional practices.

Overall Rationale for the Study

The schema presented in Figure 1 summarizes the main rationale supporting the two research goals of the study; that individuals' causal beliefs underlie systems thinking and directly affects problem solving. Examining individuals' causal thinking reveals a lot about their ability to think systemically. The rationale in Figure 1 is drawn from the literature on systems dynamics that defines systems thinking as comprising the understanding of stocks, flows, and system archetypes (Bar-Yam, 1997; Forrester, 1961;

Sterman, 2000, 2002; Sweeney & Sterman, 2000). Although this study is not about individuals' understanding of systems dynamics, this literature supports the relevance of examining causal beliefs, as such beliefs deeply affect one's ability to engage in systems thinking (as the previous literature review discussed).

System archetypes are the responses that the system generates when it is affected by an action (e.g., feedback loops and delays). As Sterman (2000) explained the idea of feedback loop, "our attempts to stabilize the system may destabilized it; [o]ur decisions may provoke reactions by others seeking to restore the balance we upset (p.5); "the results of our actions define the situation we face in the future" (p. 10). Stocks "characterize the state of the system and generate the information upon which decisions and actions are based" (Sterman, 2000, p.192). Flows "are the rate at which these system states change" (Sterman, 2000, p.198). For every situation in which there is a delay between an input and an output, there will be a stock; that is, the "difference between the input and output accumulates in a stock" (Sterman, 2000, p.196). Stocks are the signal of disequilibrium in a system. From a systems dynamics perspective, the mathematics achievement gap can be considered a stock generated by the delay between an input of decisions to improve achievement (such as instruction, curriculum, professional development) and the output of what the students have actually learned during the process. There are other issues associated with urban areas (low-income population, insufficient school buildings, parental involvement, etc.) that flow into the system, worsening and widening the gap at a certain rate. The achievement gap is the demonstration that the educational system is in disequilibrium. Several actions to solve the problem cause the system to respond (feedback) either in a way that reinforces the problem (positive feedback loop) or in a way that corrects the problem (negative feedback loop).

To understand the concepts of system stock, flow, and feedback, one needs to develop a mental model of a complex system. This mental model should include “beliefs about the networks of causes and effects that describe how a system operates, along with the boundary of the model (which variables are included and which are excluded) and the time horizon we consider relevant” (Sterman, 2000, p.16). Therefore, the examination of causal beliefs about agency, breadth, depth, and causal direction will be highly informative of individuals’ disposition to develop an adequate mental model of complex systems (Grotzer, 2003).

In conclusion, the rationale for the study is based on the close interaction between causal beliefs and their effects on causal thinking and individuals’ ability to think in a systemic fashion (as Figure 1 illustrates). The argument of this study is that the examination of causal beliefs and causal thinking tells whether individuals might have a tendency to think more or less systematically. In other words, individuals might display causal beliefs that make them more or less prone to systems thinking.

CHAPTER FOUR

Method

Based on the two research goals of the study, four major research questions are addressed. First, from a systems perspective, which types of causal beliefs do educators hold when explaining a complex educational problem? Second, how might these causal beliefs help define patterns of causal understanding? Third, how might these causal beliefs and patterns of causal understanding affect problem solving? Fourth, what are the major differences in terms of causal beliefs and problem solving when individuals with different positions in the system (supervisors, principals, and teachers) are compared?

The nature of this study is exploratory. There is no previous research on educators addressing causal beliefs and content of problem solving that could have served as the grounding theory to this study and helped focus the questions on the interview protocol. The hypotheses of this study are drawn largely from the science education literature. Therefore, the major concern of this study is to explore and identify potential variables and issues that could be more deeply investigated in later research.

The use of an open-ended questionnaire seemed adequate as an exploratory instrument. It allowed for participants to develop a very particular mental model of the situation, not necessarily biased towards more acceptable interpretations and explanations of causality (Vosniadou et al., 2004). This way, a wide variety of causal beliefs and ways to solve the problems could be captured. Another benefit of letting individuals talk more spontaneously about the problem was that it allowed for implicit beliefs and views of math education, and even urban education, to emerge. As Patton (1990) explains, "open-ended question allows the person being interviewed to select from among that person's full repertoire of possible responses.…[it] permits persons being interviewed to take whatever direction and use whatever words they want in order to represent what they have to say (p.296-297).”

The wording and order in which questions were asked were kept standardized as much as possible (following the interview protocol). There were some instances, however, in which participants answered a particular question with ideas that addressed later questions. For example, several participants mixed causal analyses with the solutions to the problem. In this case, they preferred to focus on the things that they have done to solve the problem rather than on the causal understanding that had guided their actions. In such cases, the interview had to be adjusted to maintain the flow of participants’ reasoning. As a consequence, it was not always possible to keep to the planned order of the questions.

Data analysis involved a mix of qualitative and quantitative methods. Qualitative analyses identified major themes and categories of answers as well as ranges of systematicity in causal understanding as a function of causal beliefs. Quantitative analyses examined variations in problem solving as a function of individuals’ different levels of causal understanding and relationships between causal beliefs and problem solving, view of time and contradictory events (such as no improvement), and pedagogical changes. All coding schemes were developed in an ordinal scale to facilitate quantitative analyses such as ANOVA, Spearman correlation, and linear regressions, following the example of other analyses conducted in cognitive science research (e.g., Brem & Rips, 2000).

Data Collection

Sample

The sample was composed of educational leaders (district supervisors, principals, and teachers), with varying levels of experience in dealing with the math achievement gap problem. All were associated with the Math and Science Partnership (MSP), a project aimed at helping school districts increase the math and science achievement of students.

The sample included eight district leaders (curriculum supervisors), seven elementary school principals, and nine elementary teachers. For a more homogeneous sample and to avoid introducing uncontrolled factors, the sample was drawn from urban elementary schools within similar districts. All individuals were from low-achieving districts where math achievement was a problem.

All but three supervisors were selected from the 12 partner districts comprising the New Jersey MSP (NJ-MSP) The other three supervisors were not from the MSP project, but from a district similar in terms of the problems faced by the oMSP districts. The districts that participated in the NJ-MSP were characterized as small- and medium-sized urban districts with poor, high-minority, and low achieving student populations. The partners' schools enrolled over 78,000 students, of whom 61% were minority and 51% lived in poverty.

Recruitment. In the fall of 2005, just after finishing the pilot, the MSP project came to an end. Because the participants to be recruited for this study were linked to the MSP, the early ending of the project caused two serious recruitment problems. First, many of the people initially planned to be recruited were no longer available. Second, among those who were available, many did not have time (or perhaps interest) for the interview. Because there were no longer any financial or political incentives to persuade individuals to participate in the interviews, the best incentive was to assure participants that the interview would not exceed 20 minutes. Some individuals (two supervisors, in particular) agreed to participate in ten-minute interviews only.

The most difficult individuals to recruit were school principals. All seven who participated in the study needed to be contacted at least three times. In most cases, neither e-mail nor telephone contact worked. The best way of reaching the principals proved to be turning up at the school on a day when the principal was in (as confirmed by the school secretary) and asking to talk to the principal in person. Contrary to what I expected, the supervisors were not as difficult to contact. None replied to my first e-mail, but all agreed to participate in the study during a telephone call following the e-mail. The teachers were the easiest to contact because I was able to take advantage of the good relationships I developed with some elementary teachers during the time I worked for the MSP as a graduate assistant.

Participants' background. The three leadership roles investigated in this study varied in terms of knowledge, experience, and power in the educational system (see Table 2 for demographic information). Supervisors had an average of 8.7 years of administrative experience (SD = 5.9 yrs.) and 22.5 years of teaching experience (SD = 9.7 yrs.). Principals had an average of 6.6 years of administrative experience (SD = 5.6) and 18.7 years of teaching experience (SD = 9.3 yrs.). Finally, teachers had an average of 15 years of teaching experience (SD = 7.9 yrs). All supervisors and principals had a Master's degree compared to only two teachers. Two out of the seven principals and two out of the eight supervisors also had a Ph.D or Ed.D degree.

Piloting

A pilot preceded formal data collection to explore potential issues in the proposed questionnaire. One issue was whether the open-endedness of some of the questions would be problematic in the sense that it could constrain the collection of relevant data. The use of vignette type of questions was suggested as a possible way of compensating for the potentially problematic open-ended questions. Another important issue was establishing the amount of time needed to conduct the interview. Finally, it was necessary to examine the clarity and validity of the questions, to ensure that they captured the intended constructs.

The individuals contacted for the pilot were not linked to the MSP because the number of potential MSP individuals for the formal interview was too restricted to be used for the pilot. Three principals (two from suburban elementary schools, the other from an urban middle school) and two experienced teachers (from two suburban elementary schools) were interviewed for the pilot. Supervisors were not interviewed for the pilot. Given the limited number of individuals in that position who could be potentially contacted for the interview, the supervisors were saved for the formal interviews.

Three questions in particular caught the attention of the dissertation committee as being potentially too open-ended: (a) question about the major causes for the math achievement gap (1^{st}-order causation), (b) question about the causes that lead to the aforementioned causes (2^{nd}-order causation), and (c) question on how to solve the problem (problem solving). For the pilot, three vignette questions (extracted and adapted from a study being conducted by Dr. James Spillane) were added to the questionnaire as a potential way to narrow down the participants' answers. The vignette questions were chosen on the basis of: (a) whether they were related to math education (because the research sample were MSP participants and the problem of the study was about math achievement), and (b) whether they were relevant to supervisors, principals, and teachers (ie., whether they involved educational issues rather than administrative issues only). The vignette questions added to the pilot were:

Vignette #1. Four years ago, a new math program was adopted at your school. The math program was chosen because independent research had shown it to work. Over the past few years, math scores on standardized tests have not improved significantly. The math scores of poor students have decreased slightly. Many of your best teachers are convinced that the new mathematics program is excellent and should be kept. But other teachers are frustrated. A few teachers tell you that they think that the math program is at fault. Others admit that they are starting to use "whatever works," rather than following the math program. How would you address this situation?

Vignette #2. While reviewing the lesson plans of one of your best teachers, you realize she has not been teaching mathematics based on the philosophy of your building. Instead, she uses a "drill and skill" style of teaching. Teachers in your school know to use manipulatives and other strategies to reach students. However, this otherwise proficient teacher has not complied. How would you explain this situation [question added, not in the original vignette] and what steps would you take to bring this teacher on board?

Vignette #3. As you review your school's math test scores, you realize they are significantly lower than the district average. Your teachers, however, explain to you they are working extremely hard to meet the math needs of their students. When you visit their classroom, you see teachers working very hard. However, you do not see evidence of effective teaching strategies that will better serve the students' needs. You also do not see the spirit of the district's math initiative being implemented in your teachers' classrooms. As the new principal, how will you address this situation?

After asking all the questions in the proposed pilot questionnaire (including that asking for a pictorial representation of the variables involved in the math achievement gap and their relationships to explain the problem), the three vignette questions were added to the questionnaire. The average interview time was 40 minutes (with a maximum of 90 minutes for one principal, and a minimum of 25 minutes for one teacher. On the basis of this information and the fact that the formal interview could not exceed 20 minutes, the questionnaire had to be revised.

According to the participants of the pilot, all questions were clear and easy to follow with the exception of two questions. One was the question that asked for the third-order causation of the problem ("What factors might explain the causes of the causes of the math achievement gap." Most participants were somewhat puzzled, thinking that I was looking for more in depth economic or sociological explanations of the causes that they had already mentioned; because of this, the question took up a considerable amount of the interview time (with only marginally interesting outcomes).

Another problematic question was the one that asked whether the participants could foresee any other impacts that their solutions might have on the school and/or district. Most participants found the question confusing and were tempted to answer very superficially that their actions would impact everything (either directly or indirectly). Therefore, this question was removed from the questionnaire. The question asking for the pictorial representation of the participants' ideas could have been removed, considering that it took the greatest amount of time to answer (on average 7-10 minutes); however, the richness and uniqueness of the responses made this question one of the most interesting of the whole questionnaire and, therefore, it became a must in the formal questionnaire.

The vignettes proved to be problematic in capturing the causal analysis, a crucial component of the study. In their respective problem statements, the three vignettes pointed out the potential causes of the problems, limiting the scope of causal analysis that participants could have provided spontaneously. In the first vignette, the potential causes were the math program and teacher behavior, which were signaled as possibly inadequate. In the second vignette, the potential causes were resistance on the part of some teachers to use new teaching methods (such as manipulatives). The second vignette was also somewhat redundant to an earlier question that asked how participants would deal with resistance to implement their decisions. Finally, the third vignette dealt with similar causes, such as the resistance to implement new teaching strategies. As a consequence, answers to those questions had a more problem-solving focus than a causal understanding one.

In addition, there were some implicit ideas embedded in the vignette questions (that is, that certain teaching strategies would be more suitable to teaching math than others, such as "drill and skill" and that the use of manipulatives should be followed by teachers). These implicit ideas limited the possibility of testing whether participants would spontaneously consider such ideas in both their causal analyses and problem solving. For example, in the second vignette, there was an implicit idea that "drill and skill" might not be an adequate form of instruction, which could have lead participants to argue for or against this type of strategy in more open questions (for example, about the causes of the math achievement gap). Indeed, two teachers defended the very idea that students were not scoring high in the math tests because instruction lacked "drill and skill." There were also participants who questioned whether the math program itself was adequate, something that was less likely to occur had the problem statement affirmed that the math program was shown by research to work.

Therefore, given the limited interview duration and the fact that the vignette questions seemed less effective in capturing in depth causal thinking (a crucial goal of the study), they were not included in the final questionnaire. Should more time have be available for the interview, a revised version of the vignette questions would have been included, as they could have served as means to triangulate participants' answers to the more general problem-solving question on how to solve the math achievement gap.

The Final Interview Protocol

After the pilot, the final interview protocol was established with the constraint that the interview not exceeded 20 minutes (see Table 1 for the questions and a detailed rationale for each question). Throughout the interview, participants were encouraged to talk freely about the problem of the math achievement gap. The major goals of the questions were to capture participants' implicit causal beliefs and the implications of these beliefs for problem solving. To this end, the interview protocol included questions in two major categories. One category of questions assessed causal beliefs, and the other category examined implications for problem solving.

The final interview protocol had a total of nine questions, including the pictorial representation of participants' causal thinking. Questions 1, 2, and 5 assessed participants' causal beliefs and questions 3 and 7 examined implications for problem solving. Question 5 was a follow-up question regarding causal understanding asked after participants' offered their solutions to the problem. The goal of the question was to examine whether new ideas about causality would emerge if participants were asked to think somewhat harder about the problem. The question also gave participants the opportunity to consider causation more seriously, particularly those who rushed through the first two questions without much consideration.

Question 4 examined participants' views about how long they believed it would take to see improvement after their solutions were implemented. Question 6 assessed how participants would deal with a situation that contradicted their expectations: How they would explain no improvement even after their actions to solve the problem were implemented. Question 8 assessed participants' views of the pedagogical changes needed in the classroom to solve the problem. Question 9 asked for a pictorial representation of the variables involved in the problem and their relationships to explain the problem. This part of the interview process was inspired by the work of Vosniadou and Brewer (1992) with middle-school students. In their study, they asked students to draw pictures of the earth and show where humans would live in their pictures. This task was very successful in capturing students' implicit beliefs about the shape of the earth, which would not be illustrated by verbal means alone. For example, some students said that the earth was round, but in their pictures they drew the earth as a hollow sphere where people lived on a flat ground inside the sphere, clarifying their interpretation of what they meant by the earth being round. I believe a similar type of question in this study could help clarify most causal beliefs that would have otherwise needed to be inferred from participants' answers. This question was expected to bear close relationship with questions related to causation.

The Interview Process

All interviews were recorded after receiving the participants' consent. Participants were briefly informed about the purpose of the interview and asked to sign the IRB consent form. During the introduction, no reference was made to the ideas of causal beliefs and systems thinking, to keep answers unbiased.

With the exception of one supervisor, participants expected that the interview would not last more than 20 minutes, and this concern was taken seriously. For one interview, I was informed half way through the interview that the participant (a teacher) had no more time to answer any questions (even though only 10 minutes of the interviewed had passed). In this case, two questions were not answered, but the data from this teacher were not removed from the study and answers to previous questions were included in the analysis.

In the dissertation proposal, it was noted that the interview would include follow-up questions. However, when faced with the time constraint of the interview, it was decided that there would be only one follow-up question (question 5). Overall, the interviews ran smoothly. The interviews with teachers were a little more complicated because the interviews took place during the teachers' prep time, with the teachers doing other things at the same time with students coming into the classroom and occasionally interrupting the interview.

Field notes were also collected and described the following: (a) physical installations, (b) how the interview process ran, (c) interviewees' attitudes towards the interview (particularly, if unusual), (d) unexpected incidents, and, if available and applicable, (e) how interviewees related to peers and subordinates. It is important to note, however, that the amount of rich material that could be collected through field notes was reduced given the limited duration of the interview.

At the end of the interview, participants were debriefed about the goals of the project in more detail and their e-mail addresses were collected so that they could be sent the final report. They were asked to fill out a very short demographic questionnaire with questions about their education background and years of experience. A thank-you note and a small chocolate bag were offered in appreciation for their help.

Data Analysis

All interviews were transcribed, resulting in a 300-page document to be analyzed. The nine interview questions were divided into six major categories for coding: (a) causal analyses (which included an analysis of the pictorial representation of causes), (b) solution to the problem, (c) how to involve others, (d) how long to see improvement, (e) explaining no improvement, and (f) pedagogical changes. Each major category had its own coding scheme, which is described separately.

Causal Analysis

Four of the nine questions investigated participants' thinking about causality: questions 1, 2, 5, and the pictorial representation of causal thinking. The four questions were analyzed in terms of causal agency, breadth of causation, depth of causation (levels of the system), and connection between first- and second-order causation.

Causal agency and breadth of causation. This first analysis sought to identify causal agency in participants' responses (i.e., to whom or to what causation was attributed), the breadth of causation (i.e., the total number of causes mentioned), and which level of the educational system causal agency was attributed to. The education system was divided into a hierarchy, beginning at the level of the individual and ending at the level of the larger professional and policy context. The *individual* level involved issues related to personal dispositions or traits, individual cognition, motivation, views, mentality, values, and so on. This level is most relevant to students, teachers, and parents. The next level was the *school context*, which involved issues related to instruction, classroom dynamics, content of instruction and testing, and teacher and student relationships. The third level, *district*, comprised all the issues related to decisions and resources (such as financial and personnel) influenced by the district administration. The fourth level involved the *larger policy and professional context* or the issues related to major economic, social, and policy factors affecting education. The final level, *urban life*, was closely related to the district level. This level concerned the main issues attributed to urban areas such as high mobility, violence, and urban areas being less attractive to teachers. This level was ranked as below or above the district level depending on the type of argument used when referring to urban-level causes. If urban-level causes were mentioned to explain individual-level problems, then urban level was ranked lower than district level. If urban-level causes were mentioned to explain district-level problems, then urban level was ranked higher than district level. Table 3 shows all the possible answers given in the study, classified by each of these five levels of the education system. The definition of these levels was based on relevant policy literature that defines levels of the education system according to different administrative views of the educational system (Kaput et al., 1999; Knapp et al., 2003), sociocultural approaches that analyze major issues in urban education (Anyon, 1997, 2005), and system-based views of educational reform (Elmore, 1990; Fullan, 2001; Lieberman, 1995; Massell & Fuhrman, 1994).

Each participant's answers for questions 1, 2, and 5 were carefully analyzed to identify the different ideas about the causes of the math achievement gap. Next, the causes were classified within their respective levels of the system, using the classification guide described in Table 3. As shown in Table 5, the classification of all causes mentioned within their respective system levels became the starting point for most of the causal understanding analyses. An independent coder, hired from a prestigious university in Sao Paulo and able to read in English, was trained to check for reliability. The coder was blind to the groups of the study. The coder and I independently selected all the causes that participants mentioned and classified each cause in its respective level of the system. Interrater agreement on cause identification was 88.4%. Interrater agreement on classifying the causes according to system level was 95.6%. The end result of the selection of causes and their respective classification in the levels of the system is shown in Table 5. Disagreements were resolved through discussion.

Levels of the system and connection among levels (LC). In this second analysis, I examined the relationship between second- and first-order causal explanations: (a) whether higher levels were included as explanations extended and (b) whether the connection among the levels that were mentioned was adequate.

The decision as to what to consider low and high levels of the system was based on the logic of which levels might affect the others within the educational system. Even though debatable, relevant policy literature on educational reform discusses that the school context is influenced by decisions and resources at the district level, which, in turn, is affected by decisions and resources coming from the federal educational level (Fullan, 2001; Knapp et al., 2003). Therefore, both the district and the larger professional and policy context were considered high levels of the system (with the latter higher than the former). These high levels together influence individuals within the school (students, teachers, and parents). Consequently, the individual and the instruction levels were considered low levels of the system. As for the urban life level, some considerations are necessary. Individuals are not influenced by the educational system only. They, as well as the educational system itself, are influenced by the economic and social reality that affects suburban and urban areas differently. At the same time that the reality of urban areas (high mobility, violence, single-parent homes, etc.) affects the educational system (particularly, schools and districts) in ways that generates educational problems, the politics of how federal and state resources get allocated as a function of social classes differences also “overwhelm education efforts to reform the schools” (Anyon, 1997, p.55). Moreover, the inefficiency of the educational system to provide quality and meaningful schooling to urban children only deepens the social and economics problems of urban areas (Anyon, 1997; Fine, 1991). Therefore, because urban life both affects and is affected by the whole educational system, it was considered either a low or high level of the system depending on the way it was discussed. If participants referred to urban life to justify individuals’ (students or parents) behavior or attitude towards schooling, it was considered low level; if they referred to urban life to help explain the idiosyncrasies of urban education, it was considered high level.

A coding scheme was developed to score the extent to which causal explanations presented (a) as many levels of the system as possible (with an emphasis on the higher levels) and (b) a logical connection (flow) among the causes that were mentioned and their respective levels of the system. This score was named the *LC* score and was associated with depth of causation. Participants received a score of 1 if their first- and second-order causal explanations only included causes related to the individual level of the system. For example, Supervisor F (see Table 4) first attributed the math achievement gap to an individual-level cause: The fact that "[children are not] exposed to the types of toys they need to extend their experiences so that they come to school with prior knowledge." When asked to explain the causes for the students' lacking prior knowledge (second-order causation), this supervisor said:

> …a lot of the parents themselves lack education. These are usually parents that haven't finished school themselves and that education isn't a priority for them….[they do not] realize the emphasis of how important it is going to be for their children to get a better education.

Again, second-order causal attribution was focused on an individual-level cause (i.e., parents do not value education). This causal explanation emphasized individual-level causes, without considering causes at upper levels of the system.

Participants received a score of 2 if their first-and second-order causal explanations were focused on local levels (still local explanations, but not solely focused on the individual level). For example, Teacher H (see Table 4) first attributed the causes for the math achievement gap to two local factors: (a) inadequate prior knowledge in math (individual level of the system) and (b) inadequate instruction (instruction level). As the teacher explained, "[children] are not exposed to baby math.…children's ability of concrete numbers is not there….teachers don't take enough time to understand that that [making math real and concrete to children] is very important." Next, for the second-order causal explanation, the teacher focused on two instructional causes: (a) the curriculum assumes skills and knowledge that children do not possess and (b) the fact that math is not integrated with other lessons, as the following excerpt shows:

> Trailblazers [the curriculum] leaves a lot of it into the children, they assume that the children coming into first grade understand the concept of numbers up to anything and they don't. Not these kids….[and after giving a very long example of how she integrates math with other lessons, she concluded] it was a math lesson integrated with the reading lesson. Do you know what I'm saying? And integrated with the language lesson.

The teacher's reasoning started on individual- and instructional-level causes and then focused on the instructional level. There was an attempt to get away from individual-related causes, expanding to other levels, but the explanation was still focused on local levels of the system.

Explanations received a score of 3 if they included upper levels of the system in their explanations, particularly if they expanded to upper levels of the system in second-order explanations, but still lacked a logical connection among the levels of the system in their first and second explanations (as when causal explanations were scattered across the levels of the system, lacking a flow). For example, Teacher I (see Table 4) first mentioned that the causes for the math achievement gap were: (a) too much curriculum change (district level), (b) the fact that children have inadequate language and cognitive development (individual level), and (c) lack of staff stability (district level). In her own words:

> We've changed curriculums every two or three years here.…finding I guess the right curriculum and actually giving it time to work is one of the biggest disadvantages….These kids also in terms of family life and concepts that they come with….they're not necessarily mature in their thinking, in their speaking....one of the biggest problems with the district…even any urban district, is stability….we might get more testing personnel and then two, three years later, they'll change the supervisors…

For the second-order causal explanation, the teacher focused on two district-level variables: (a) the availability of money to buy and change curriculums and (b) pressure to improve test achievement. As the teacher explained, "I think we have more money to spend on these curriculums. I think there's more fear because of low test scores and where we stand on these curriculums." As the example shows, the argumentation seems somewhat circular: Low tests scores are explained by too much change in the curriculum, but "the fear of low test scores" also motivates change in the curriculums. The explanation is mostly focused on the district level and it is unclear what the logical connection is between the children's characteristics (immaturity), recurrent changes in the curriculum, availability of money (should it be a problem?), and how all these create the achievement gap. On the other hand, this reasoning was superior to that scoring 1 and 2 because it included upper-level variables in the discussion.

Finally, a score of 4 was assigned to causal explanations that included a wide range of levels, with a focus on upper levels of the system, and keeping a logical connection among these levels. For example, Supervisor H (see Table 4) initially gave four different causes for the math achievement gap, each at different levels of the system: (a) special education population (individual level), (b) overcrowding (district level), (c) lack of certified math teachers (larger policy and professional level), and (d) economic status of the family (urban life level). In the supervisor own words:

> …a lot of factors [cause the math achievement gap]…the economic status of the family contributes. We have overcrowding in our classrooms. That contributes....We often cannot find certified math teachers.…we have a lot of children who are either special ed. but more, we have many, many who are English language learners.

Note that this explanation was not solely focused on one level of the system, but attempted to consider a wider range of levels. In her second-order causal analysis, Supervisor H was able to enrich the explanation, keeping variables and levels well-connected. For example, the supervisor mentioned lack of resources (larger policy level) and excessive population (urban life level) to explain the causes for overcrowding:

> We have a number of our school buildings are over 100 years old. We are land poor, so there's not a lot of resources to put new school buildings…taking away a classroom [to put a computer lab or a technology center] means those children have to go someplace...it's just a lot of children. The schools were not built for as many children…

The supervisor reasoned that the lack of certified teachers may be caused by teachers' misperceptions about teaching (individual level) in an urban district:

> I think there is a perception that somehow teaching in a suburban district is better. I think it's a misperception. I think those of us who choose to work in an urban district would not trade that experience for anything else....I do think mainly it's probably lack of the money and the thought that it's more glamorous or more rewarding or safe, whatever, in a suburban district. That misconception.

As the excerpts above shows, this supervisor was able to include practically all the levels of the system in the analysis (except for the instructional level), generating rich and coherent reasoning.

It is important to recall that causes related to urban life were considered local explanations if they were intended to explain students' and parents' attitudes towards school (as a function of urban home life). With the exception of two supervisors, all causal explanations focused on urban life followed that logic and, therefore, were considered local explanations. With this coding, it was possible to take into consideration depth of causal analysis (i.e., whether several levels of the system, particularly upper levels, were included in the analysis), connection among these levels (i.e., whether logically coherent), and, to a less extent, direction of causation (i.e., whether causal explanations were expanded to include upper or lower levels).

Participants' complete answers were examined for analysis. Interrater agreement for assigning LC scores was 95.8%. Disagreements were resolved through discussion.

Pictorial representation. The findings of the causal analysis (i.e., participants' ideas related to the different levels, causal direction, and connections among variables and levels) were inferred from participants' answers to the verbal interview questions. Participants' pictorial representations of their causal understanding served to provide a visualization of some of what was inferred from the verbal interview questions. By asking participants to graphically represent causes and how those causes were related to one another to explain the problem (and later on comparing the different answers), it was possible to visualize five dimensions of causal beliefs among participants' answers: (a) number of variables involved, (b) how variables related to one another, (c) whether the idea of level was present, (d) whether levels were arranged within some system hierarchy, and finally (e) whether other, more specific systemic beliefs were displayed (e.g., beliefs about feedback loops, delays, and other types of system effects). Table 6 shows how the pictorial representations were coded based on these five dimensions. Note that coding of participants' pictorial representations was based on the picture itself and on participants' verbal explanations of the pictures after they finished them (which not all participants did). The coding did not draw on answers to earlier questions.

Representations ranged from non-causal (score of 1) to systemic-oriented (score of 7). *Non-causal* representations (n = 4) had a score of 1. These representations did not show any causal connection among variables. Their goal was just to illustrate (through words and drawings) an ideal solution to the problem (similar to a plan), leaving implicit which causal variables and relationships might have supported that ideal plan (see Figure 2 for an example).

Simple causation representations (n = 7) were assigned a score of 2. In these representations, individuals attempted to draw a list of causes that might explain the problem, but failed to represent relationships among these variables in a meaningful way. The representation looked more like a "shopping" or "to-do" list of which causes should be taken into consideration to solve the problem (see Figure 3 for an example).

Causal chain representations (n = 4) received a score of 3. In these representations, individuals attempted to establish relationships between variables, but in a more simplistic way. Causal relationships were a one-way, linear sequence (see Figure 4 for an example). In this example, the participant even referred to the representation as a "zipper," which reinforces the idea of things being in a sequence, as a chain.

Reciprocal representations (n = 2) received a score of 4. In these representations, individuals were able to show variables connected in a less linear way as two-way and/or multiple interactions (see Figure 5 for an example).

Simple level representations (n = 4) received a score of 5. In these representations, individuals placed variables within levels of the system, sometimes showing some simple interconnections between them (see Figure 6 for an example). However, simple level representations showed neither levels in a hierarchical fashion nor complex interconnections among levels. On the other hand, *complex level* representations (n = 2) showed a hierarchy between levels and complex connections among these levels (see Figure 7 for an example). They were assigned a score of 6.

Finally, there was only one representation that encompassed most of what might be considered a systemic understanding of causation. This *system-effects* representation (n = 1) not only incorporated several causes in a coherent set of relationships but also displayed an understanding of “feedback loops” (i.e., the idea that any attempt to change the system would create pressure in certain parts of the system, leading the system to a response that alters the system itself). The graphical representation (see Figure 8) shows that in the long-run, the system tends to improve despite all the resistance (pushing the system back) that might happen along the way. As the participant explained it “[there is a] gradual change with new materials, staff development and then obstacles, such as teachers' beliefs, low expectations, that pushes things back and this cycle repeats many times but always in the next level….There's a positive inclination in the whole process but it takes a long time.” For including ideas that were more systemic than any other representation, it achieved the highest score (7) of all representations.

Interrater agreement for coding pictorial representations was 87.5%. Disagreements were resolved through discussion.

Solution to the Problem

This analysis looked at how participants solved the problem of the math achievement gap. Major themes of answers were identified and compared to themes that emerged during participants' causal analyses. An ordinal coding scheme was developed to score participants' solutions to the problem. Solutions that proposed changes to the system were scored higher than solutions that did not propose changes. This was based on the rationale that if the system is not operating well (hence generating an achievement gap), then it is logical to assume that changes are needed. Systems-oriented solutions should be geared towards change. See Table 7 for a description of the coding.

Solutions that were focused on *system maintenance* (n = 14) were assigned a score of 1. In this type of solution, there seemed to be an implicit notion that the system is well-planned, but does not work properly because of inadequate implementation. In this case, it is thought that implementation can be improved by better communication, supervision, alignment among policies and practice, or additional resources. For example, Principal D suggested that a way to solve the problem was for "the administrators…to be aware of the curriculum frameworks and [to] let the teachers know that it is important also to concentrate on the math." In this answer, the concern with supervision and communication is salient. Another focus of system maintenance solutions was on increasing resources, such as hiring more staff, adding new buildings, and providing more workshops for teachers. For example, some participants mentioned providing more workshops for teachers not as a vehicle of change, but as a way to reinforce pre-established ideas, as the following excerpt from Principal G shows:

> …so encouraging that [teachers attending professional development] and participating in those team meetings. Attending them on my behalf and administration attending them….[because] sometimes it's not just enough to dictate what it is you need to be doing. It needs to be modeled. And not once. It needs to be reinforced. And so that people can develop a comfort level.

Other participants suggested instructional improvements, such as having more field trips or adding music and arts classes because they help with math concepts. Nevertheless, these instructional improvements were not associated with any epistemological changes in teaching and instruction. The concern was only with the format of instruction.

Some participants did propose changes, but they were either focused on instruction or policy. These solutions were considered *local* (n = 5) because instructional or policy changes alone are not enough to change the system as a whole. These solutions received a score of 2. An example of instructional change comes from Teacher A who suggested that “administrators need to devote more time in the school day to math. They need to have smaller, manageable class sizes…hire more teachers…you have to teach them a different way….using small groups….[Students] need a tutoring program after school.” Teacher D focused on a policy change: “A lot of teachers are, don’t deserve the job that they are given. And when they get tenure, it’s impossible to get rid of them….administrators, they have to, they have to work a little harder to keep the good teachers.” In both examples, changes were in isolated parts of the system. The literature on systemic reform shows that broad changes are very unlikely to occur as the result of local initiatives (Schorr & Firestone, 2001).

In order to be considered broad and have the potential to lead the system to meaningful change, policy instruments need to be coordinated with instructional changes (Schorr & Firestone, 2001). Individuals who suggested solutions that involved instructional and policy changes had their answers classified as *broad* (n = 5) and were given a score of 3. The following excerpt is from Supervisor H, which contemplated broader changes:

> There are many, many actions that should be taken....There are a lot of things our kids need, all of which are beyond our, my control and our control for the most part. What is within our control is what we do….we have lengthened the instructional period for mathematics in the elementary schools. We provided math coaches this year in all the elementary schools.…We've developed a plan hopefully to ensure that we are providing differentiated instruction as well as on grade-level instruction for our students….We're trying to identify those teachers who are best [sic] math teachers and have them teaching only math.…We're having math centers in our elementary school classrooms….have some money budgeted this year so that we can buy materials for those centers. And we're providing ongoing training to our teachers….We're also trying to increase the number of math certified teachers…

As the excerpt shows, this solution included instructional (e.g., differentiated instruction, more time for math) and policy changes (e.g., new budget for math centers, ways to increase the number of certified teachers). The coordination of changes in instruction and policy at the same time is more likely to produce broader changes in the system than working on each change separately.

The interrater agreement for coding solutions was 91.7%. Disagreements were resolved through discussion.

Involving Others

After proposing their solutions, how would participants involve others and deal with possible resistance? Answers to this question were scored according to the coding scheme described in Table 8. Scores increased as a function of whether individuals were treated as active participants in the process of change (not only in the implementation of the process, but also in the planning of the process). Low scores were assigned to answers that assumed individuals were passive receptors of decisions coming from the top.

Some participants suggested involving others by imposing solutions through supervision and behavior modification. These types of solutions were categorized as *imposing* (n = 9) and received a score of 1. For example, some explanations suggesting that teacher workshops be adopted seemed to point to behavior modification. As Teacher D explained: "What would I do if somebody didn't want to change? That's tough, because you can't fire them. They got tenure. You can set up workshops for them. Give some training on how to manage a class in that format." Principal F defined his leadership role as "getting people to do what they normally wouldn't want to do" and resistance to change as "more of an outlier typically from the building…than the norm." Teacher E suggested dealing with resistance by "get[ting] hard line…[because] if you want to stay in the school, then you will have to do what it is we know we've seen work to raise test scores." Teacher E continued saying that if people do not behave as expected, she "would probably open [her] own school...and then hire exactly who [she] wanted." Similarly, Teacher G suggested that "those that don't want to, that doesn't [sic] motivate…got to move someplace where it will work.…[because] maybe the old people need to move out to let some new fresh ideas come in." As the examples show, in imposing approaches, resistance is either ignored or treated with energy as a way to discourage it.

Other participants suggested *persuasive* means (n = 6) to involve people through information and explanation. This type of solution received a score of 2. For example, Teacher B suggested involving people "by showing them data from schools that were similar to where [they] were.…[by showing] examples of how a particular program can work." Principal E suggested "explain[ing] the benefits of it [the changes]…the reasons why it's needed." The implicit belief in these examples seemed to be that individuals might change if they had more information. The persuasive approach was considered as a more sophisticated response than the imposing approach because it viewed individuals as less passive; at least, individuals were seen as active to process information, reason, and eventually change their minds. A persuasive approach would focus on persuasion and reinforcement to overcome resistance, as the following excerpt from principal B shows: "They have to see that this is productive, otherwise they're not going to change...and you keep reinforcing." Overall, it could be argued that both the imposing and the persuasive approaches resemble some of the characteristics associated with transactional leadership.

Some participants (n = 3) suggested ideas that involved some level of dialogue and participation among individuals, such as contributing ideas in grade-level meetings or discussions. Encouraging individuals to engage in dialogue supposes more interaction among people (therefore, assuming individuals as more active) than imposing changes or persuading individuals to change. However, such a level of participation was considered *peripheral* because it was limited to implementing and validating pre-established ideas. At the same time that individuals were encouraged to participate, they also had to show results to "deserve" such participation. This type of solution was given a score of 3. The following excerpt from Principal C illustrates this type of approach:

> We told the teachers after they had their training and we brought it in, that they had to give up their old books…they all had to get to know the skinnies and the flats…teachers in the district who fell in love with it and saw how great it was, helped their colleagues…it was teachers doing it…I give them carte blanche, but if the results are not there, then I always tell them, if you can't work here, there are, there's the opportunity for a voluntary transfer or to another district.

As the example above shows, participation happened with teachers helping other teachers and being given a "carte blanche." However, "if the results are not there," participation is withdrawn.

All three approaches discussed so far – imposing, persuasive, and peripheral participation – seemed to limit individuals' participation to a passive role; that is, individuals were supposed to accept and implement pre-established ideas. Participation was associated with helping implementation and showing expected results. On the contrary, the *empowerment* approach (score of 4) gives individuals a more active role in the process, as individuals were seen as vehicles of change, rather than simply executors. Following this approach, some participants (n = 5) suggested ways to empower individuals, as the following two examples from Supervisor B and Principal G, respectively, shows: "What I need to do is not have my particular ideas implemented, but to get a new teacher and to have them find their own voice…"; "you bring them in with an expertise…you're empowering them with something." Supervisor B emphasized the importance of empowerment as a mean to develop local leadership:

> I'll take a couple of teachers and just sort of implement with them. See how those kids do….So then I picked up a couple of more people and then that's hopefully to get the ball rolling….The important part was to try to get some of those teachers to funnel and to do work and staff development for other [sic], to build their leadership.…[Have] teachers realize how powerful they are, how much knowledgeable and smart they are.

To an extent, the empowering approach resembles the characteristics of transformation leadership. Leaders should inspire and serve as role models to motivate individuals to value and support the change, rather than impose it. By developing and empowering the local leaders, change can happen at the various parts of the system, becoming a compounded process more likely to generate meaningful system change.

Interrater agreement for the coding was 87.0% (we disagreed on 3 out of 23). Disagreements were resolved through discussion.

How Long to See Improvement

In this part of the analysis, answers were coded in terms of how long individuals believed it would take for results to be seen after implementation (see Table 9 for a description of the coding). An individual with a systems-oriented view of time should see time as something difficult to predict because it is "an emergent property of the whole system as its many feedback loops interact simultaneously" (Sterman, 2000, p.197). Therefore, scores increased as a function of whether participants viewed the time to see results as affected by unpredictable, uncontrollable variables and subjected to system resistance. The highest scores considered unpredictable variables and system resistance.

The least systems-oriented view of time, named *accelerated* (score of 1), viewed time to achieve results as a function of intensity of work. That is, if individuals work hard and intensively to implement decisions, results will show up quickly. This view ignored system resistance due to feedback loops, delays, and the effect of unexpected, uncontrolled variables that might emerge during the process of change. As an example, Teacher A suggested that "it [results] takes a year, you know, to really get going with implementing it and it's like a learning curve with the teachers and the students and then the second year, you kind of understand it and you know how to do it." According to this teacher, learning happens quickly (one year) and it seems to be enough to produce results by the following year. Another example, coming from Principal D, also shows the similar view that learning can be fast and results immediate: "One year to train and by the second year we should be able to grasp, have the knowledge and to be able to teach it." Overall, individuals who followed this approach (n = 10) seemed to view change as a predictable process, that if followed intensively should produce results quickly.

Still non-systemic, the *slow and continuous* view of time (score of 2) interpreted results as less immediate due to individuals' internal resistance to change. Resistance in this case was not attributed to system effects such as feedback loops or delays, but to dispositions inherent to individuals, such as individuals' being resistant to change or slow to learn. This approach lacks the view that the system itself, the way it operates, might create resistance. Individuals who followed this approach (n = 7) considered results as a steady, continuous process that tended to increase as a function of individuals' changing through learning or experience. This learning process was viewed as a slow but steady and predictable process. There was an implicit idea of proportionality, such as the more *x*, the more *y*. As Principal F explained, "you're not going to change society overnight….you need these teachers to understand where these students are coming from a little more.….the more understanding these teachers have, the more you're going to close this gap." Another example coming from Supervisor E illustrates the idea of continuity and predictability: "I think the new program with the coaches and so forth should help.…if we stay in the right direction, we're going to be there."

Some participants (n = 3) viewed time to results as *incremental* (score of 3). In this type of view, improvements to the system were seen as incremental because growth was not proportional to a fixed variable (such as the passage of time). This view considers the role that unanticipated variables might play out in the system, slowing the process of change. Change was seen not as a steady, predictable process, as the following excerpt from Principal G shows:

> It does take time….the hard part comes in where, for instance, I see in the middle school grades, especially, in our particular population, because of the way the curriculum adoption has occurred, there's been a slower process to integrate this into the upper grades....a lot of our population as well are Hispanic and they come from other countries and they will come here at any grade level.

In the excerpt above example, it is possible to note the concern with variables that are difficult to predict (i.e., the foreign student population could come in at any grade level). There is also a view of time as not immediate, but dependent on unpredictable variables that slow the process through compounded effects (i.e., as these variables are integrated into the model, they generate issues that are added to the previous ones). Still, this view lacked the idea of system resistance and sustainability of change.

In the *system growth* view (score of 4), there was a concern about sustainability of change and system resistance, two ideas that have not appeared in other types of responses. The notion of system resistance appears in this explanation from Supervisor B:

> I think you have to wait a long time [to see major improvements]...we call them implementation gulch [sic]. You know you drop down for a while. Which sometimes happens with test scores or people and that happens when people leave in and out.

The concern with sustainability of change can be seen in the following excerpt from Principal A:

> I think anytime there is a change, and that's based on pure research and statistics, because it's a process…to study, to see the gains, to see if the changes that were implemented were viable and workable…I gotta [sic] see it maintained or extended the next year and the next year.

The few individuals who followed this approach (n = 3) viewed change as unpredictable, incremental, and affected by system resistance (i.e., feedback loops and effects of unpredictable variables). Because of feedback loops, previous improvements might not be sustainable, and the process of change might become very slow. Change was seen as a never-ending process in which variables not initially anticipated played out and interfered with the process.

Interrater agreement for coding how long to see improvement was 91.2% (we disagreed on two out of 23). Disagreements were resolved through discussion.

Explaining No Improvements

This analysis examined how participants explained why it might be that no improvement occurs. It was a goal of the study to examine whether systems-oriented causal thinking would approach unexpected results differently from less systemic ones. The coding scheme for this analysis drew in part on the work of Chinn and Brewer (1993) on individuals' responses to anomalous data. To a certain extent, the lack of improvement in response to an implemented solution could be considered an anomalous outcome, particularly considering that participants proposed solutions that they strongly believed would produce positive results.

The most common response that participants gave in the study seemed to fit three of the eight categories proposed by Chinn and Brewer (1993): rejecting data, reinterpreting data, and changing theories in response to the data. Nevertheless, different descriptions and interpretations of participants' responses needed to be developed as a function of the type of problem in the study and the types of arguments that participants employed.

In this coding scheme (see Table 10), scores increased the more participants approached the idea of revising or re-thinking their initial views of the problem. Participants who decided to *reject* the possibility of no improvement (n = 6) scored the lowest (score of 1). These participants reacted to the question by saying things such as: "There will be [improvement]!"; "[n]ot going to happen"; or "I truly don't know." They did not accept the challenge of thinking about a contradiction and preferred to assume improvement as certain or unlikely.

Some individuals attributed the possibility of no improvement to malfunctioning parts of the system: either people or the process of implementation (n = 14). Individuals who blamed people for no improvement (n = 10) were assigned a score of 2. The following are examples of answers in this category: “Kids may not be familiar with certain concepts”; “maybe teachers need extra help”; or “[we need to] make sure students are not developmentally challenged.” Individuals who blamed the implementation process (n = 4) were assigned a score of 3. Example of these answers are: “So you have to look at all the different variables and from there, try to pinpoint and narrow what may have gone wrong because sometimes it could be in the delivery” or “[there might be] problems with leadership, with the implementation of even a terrific program.” Answers that blamed the implementation process were considered more systemic than answers that blamed people because they attempted to take into consideration the role of environment, whereas answers that blamed people seemed closely associated with the fundamental attribution error (Ross, 1977). Nevertheless, neither of these types of answers contemplated questioning or reviewing initial assumptions and mental models of the problem, which were assumed as adequate.

A few participants (n = 4) suggested reviewing their initial assumptions, as the following excerpt from Supervisor G shows: “[If no improvement is seen], it would be a matter of going back to the drawing board….So I would have to say that whatever we are offering in the pre-K program and the kindergarten program is not sufficient enough to address the skills that are lacking.” These answers (assigned a score of 4) seem to consider the possibility that their initial assumptions and model about the problem might be mistaken, incomplete, or subjected to unpredictable variability. Epistemologically speaking, these answers seem to assume that mental models of the system are not definitive and that they may constantly change as new information is fed into the system, which in turn requires revision.

Interrater agreement for the coding of explaining no improvement was 91.7%. Disagreements were resolved through discussion.

Pedagogical Changes

This final analysis examined participants' answers about which pedagogical changes they would pursue in order to improve math achievement. The focus of the analysis was descriptive, examining three dimensions of pedagogical changes: (a) materials, (b) class format, and (c) instructional goals.

The first part of the analysis is descriptive. It shows which pedagogical changes were suggested and how these suggestions varied across the three groups (supervisors, principals, and teachers). Answers were initially categorized following Spillane's (2000a) classification of whether pedagogical changes were form-focused or function-focused. The second part of the analysis examined participants' reasons for adopting certain instructional changes. Combining the types of pedagogical changes that were suggested with the reasons provided to adopt them helped capture contradictions and inconsistencies in individuals' thinking that betrayed the real view of mathematics teaching and learning that individuals might have.

CHAPTER FIVE

Results and Discussion

There were two major goals in this study. The first was to examine participants' causal beliefs about the math achievement gap problem and explore the existence of causal thinking patterns that might explain some of the variations in problem solving. As causal thinking was analyzed from a systems perspective, causal thinking patterns ranged from a less systemic to a more systemic orientation. The second goal was to examine variations in problem solving as a function of the different levels of systematicity in causal thinking. I interleave results and discussion to facilitate reading. Relevant but unexpected and not initially hypothesized issues that emerged during the data analysis are also explored and discussed in this section.

First Research Goal: Examining Causal Beliefs

These initial results show the major types of causal beliefs that individuals displayed, ranging from less systemic to more systemic. The following were examined by analyzing verbal and pictorial responses: Beliefs about causal agency, breadth of causation, depth of causation (defined as levels included in the analysis and connection among these levels), and system hierarchy.

Causal Beliefs

Causal agency and breadth of causation. Participants focused their initial (first-order) casual explanations (i.e., causal agency or what causes the problem) mostly on low-level factors: Individual and school levels (See Table 5). All principals focused their first-order causal explanations on the individual and school levels. For example, Principal D focused on teacher competence and teaching:

> I think that many of the teachers have not taken the courses that would be necessary to be able to teach math….I have seen a lot of teacher that are not prepared to, that don't have the content knowledge to teach that subject matter….I think that many, many teachers try to concentrate more on the language arts and some of the other subjects…They [teachers] have to receive training. Overall training in teaching math, better ways to teach it. Try to use manipulatives, higher-order thinking skills so that they can remember what they do and so on. It's not a simple subject (Principal D).

Principal D focused on two low-level factors of the system : (a) lack of teacher preparation, which is an individual-level cause, and (b) inadequate teaching format (lack of manipulatives and higher-order thinking skills), which is a school-level cause. Overall, the majority of first-order explanations focused on individual factors (i.e., students' lacking prior knowledge or necessary math skills), such the following two excerpts illustrate:

> The largest [cause for the math achievement gap], from my observations and I've been a principal for ten years, is the lack of experiential knowledge with the kids coming in [sic]….Let me give you an example. I say some family from a suburban district is going on vacations to let's say California. OK, they're flying and the parents explain, [sic] we're going 6,000 miles across the country. And some parents will even go on to explain that we're traveling 500 miles per hour, what have you [sic]. Or even driving to Ohio, OK? They can understand that it takes a certain amount of time. They can understand looking at, and maybe some parents will explain mile markers, etc. So they start to have a built-in concept of length combined with time, OK? And urban kids sometimes, like I said because of generally economic barriers don't have those opportunities (Principal F).

In the example above, the first-order causal explanation is focused on the individual: Students lack experiential knowledge. Principal E goes along the same lines: "I think part of the problem is that some of our teachers may lack the knowledge necessary to teach mathematics." In this case, Principal E focused on an individual aspect of teachers: their lacking knowledge to teach mathematics.

Teachers also focused their first-order causal explanations on low-level causes. Eight out of 9 teachers also focused their first-order causal explanations on the individual (mostly) and school contexts. The following example is a typical causal explanation, focused on students and instruction provided by a teacher:

> …the math program that they had, Investigations in math, was not a very good math program. It didn't teach enough like computations. It didn't have enough computational math…They were trying to get the students to think on a deeper level but they missed kind of the basics of math…I also think that some of the, some of the achievement gaps are, I think it's when you take a test, I noticed that my students that aren't [sic] good readers…they can't read the questions (Teacher A).

Three supervisors out of 8 focused their first-order causal explanations on the individual level, particularly on the intrinsic characteristics of urban students, as these two short excerpts, from Supervisors A and G, respectively, illustrate: "…the last thing on most of those youngsters' mind is mathematics. All right? They're worried about what's going to happen to them when they get home"; or "Students come to school…not prepared for math courses…" In these two examples, the two intrinsic characteristics that supervisors focused were: (a) that students have things other than mathematics in their head and (b) that students do not come prepared for math courses. It seems that from the supervisors' perspective, schooling is only a small part of the lives of urban students.

Two supervisors focused on teaching (i.e., school level), as the following illustrates: "I think that in our schools, the problem is not using a hands-on approach with the students. And sometimes not understanding that you have to go back to the concrete and work with the concrete…"(Supervisor D). The other three supervisors provided causal explanations that included higher levels of the system, such as the district and the larger policy context, which teachers and principals failed to do. The following is an example of a first-order causal explanation, coming from Supervisor H, who contemplated a wide range of system levels:

> Probably a lot of factors [to explain the math achievement gap]. We probably just, the lack of education, the economic status of the family contribute. We have overcrowding in our classrooms. That contributes. Probably not enough additional support after school, and pre-school. That hurts. We often cannot find certified math teachers, especially for the upper grades…We have a lot of children who are either special ed but more [sic]. We have many, many who are English language learners. English is not their primary language. Some of my students come to us from countries where they've received absolutely no schooling at all. So it, we're playing catch-up.

In this example, Supervisor H considered several factors that could explain the math achievement gap: (a) the "economic status of the family" (urban-life level), (b) "overcrowding classrooms" (district level), (c) lack of "support after school" (district level), (d) lack of "certified math teachers" (larger professional context), and (e) children's having language barriers and lacking schooling (individual level).

In explanations for second-order causation, principals and supervisors tended to expand their causal explanations to higher levels of the system. Four principals and four supervisors expanded their second-order causal explanations towards higher levels of the system (i.e., district and the policy context). Take as an example Principal D, who focused his first-order causal explanation on teacher competence (as shown in an excerpt above). When asked about the possible causes for teacher's lacking training and preferring to concentrate on language arts, he answered:

> Most of the real good workshops that I have attended and that I have seen teachers attend usually come after the person became a teacher. I don't know why….But I don't think that's happening during regular training of a teacher…we were doing better and better, much better into the language arts curriculum. And they had the specific curriculum, there were monitors coming in, observing how you taught language and evaluating and giving us feedback and so on and so forth. That wasn't happening with math. So I guess that's one of the reasons that people tend to concentrate more on language arts.

As the excerpt shows, in his second-order explanation he included issues related to the professional context (i.e., how graduate schools of education are helping form teachers before they come to school) and issues related to district administration (i.e., language arts seem to receive much more resources and support from the district than math).

Principal F, who focused his first-order causal explanation on the individual level (i.e., students lack experiential knowledge), argued that the economic life of the urban family was the second-order reason to explain lack of experiential knowledge:

> The largest [cause for the math achievement gap], from my observations and I've been a principal for ten years, is the lack of experiential knowledge with the kids coming in [sic]….Let me give you an example. I say some family from a suburban district is going on vacations to let's say California. OK, they're flying and the parents explain, [sic] we're going 6,000 miles across the country. And some parents will even go on to explain that we're traveling 500 miles per hour, what have you [sic]. Or even driving to Ohio, OK? They can understand that it takes a certain amount of time. They can understand looking at, and maybe some parents will explain mile markers, etc. So they start to have a built-in concept of length combined with time, OK? And urban kids sometimes, like I said because of generally economic barriers don't have those opportunities...
>
> Principal E followed the same logic:
>
> I think part of the problem is that some of our teachers may lack the knowledge necessary to teach mathematics. And another area I think could be that the home environment didn't instill any math knowledge with the kids at an early age….So they come lacking some of those experiences. And I think that's the gap in the beginning. And then the teachers aren't sure of how to fill those gaps...

Supervisor D is another example of someone who focused on teaching in her initial causal explanation (i.e., lack of more hands-on, concrete learning experiences) and expanded to the district level in her second-order causal explanation. When asked about what causes a lack of hands-on experiences in the classroom, she answered: "I think to a certain extent in some of the districts…it's the resources. I think that in many if the schools, the classes have become overcrowded….it's very hard to have enough materials in your math classes to support hands-on activities."

Contrarily to the examples showed, some supervisors and principals still continued to focus their causal explanations on lower-levels of the system. Supervisor F, who focused her first causal explanation on the fact that students did not come to school with adequate prior knowledge on mathematics (i.e., an individual-level factor), attributed the second-order causality to parents' attitude towards schooling (still an individual-level factor):

> …a lot of the parents themselves lack education. These are usually parents that haven't finished school themselves and that education isn't a priority for them. Because in their generation, they were able to get by without it. And I don't think that they realize the emphasis of how important it is going to be for their children to get a better education.

The majority of the second-order explanations that teachers provided were still focused on lower-level causes. Six (out of 9) teachers still focused their explanations on the individual and school contexts (see Table 5). Take again as an example Teacher A, whose first-order causal explanation focused on students (i.e., students are not good readers) and teaching (i.e., the curriculum lacks basic math skills). When asked the causes for why students were not good readers, she still focused on individual-level factors (in particular, parents' mentality) as the following shows:

> I think they're poor reader because…they…a lot of…I know I saw [sic] this professor, he was a Nigerian educator and he said that a lot of lower income people have a, he called it a beer mug mentality. He thinks that schools, they think school does not start until five year old. Until they get to school. That's when you start learning. And they think that when they start kindergarten, the beer mug comes in at where, they think when they go to school, that the teacher opens the top of their head up, like a beer mug, and pours the, pours the knowledge in their head and closes it up and then they know it. It doesn't work like that.

In explanations of why the problem of the math achievement gap was difficult, roughly half of the principals and supervisors focused their causal explanations on higher levels of the system (while the other half focused on lower levels). On the other hand, contrary to the previous pattern of causal explanations, the majority of teachers (6 out 9) focused their causal explanations on higher levels of the system (rather than on lower levels). Still using Teacher A as an example, whereas she focused her first- and second-order explanation on low-level factors, she mentioned issues related to urban districts when asked to explain why the math achievement gap was difficult to solve:

> I think that it seems like when you come from a lower income population that a lot of times you know it's a single parent household and like just informally, a lot of times I see students that come from a two parent household in this school, they do better....a lot of students that come from one parent households that are not doing well, it's hard for that parent to spend time....it's hard for them to monitor because they're doing with other issues. And they need help. It's not enough. Support systems. You know, it's not places for the kids to go. You know they only have so many spaces in after school programs for example. And they don't have enough places in the community....They should have more community programs that parents could take their children and get them academic support, academic help, academic enrichment. They don't have that... they don't enough programs in the school itself. And then there's no community place.

As the excerpt shows, two factors related to urban-life levels that she mentioned were: (a) the "single parent household" and (b) lack of "places for kids to go" in the community. However, it is important to note that teachers never mentioned larger policy-context variables in their answers to the three questions. Nevertheless, the fact that most participants focused their answers about why the problem has been hard to solve on higher levels of the system (see Table 5) suggests that asking participants to think about causation in different ways (and with different types of questions) may encourage them to enrich and expand their initial causal explanations.

Overall, the most cited first-order causal explanations that supervisors provided were (in order of most common occurrence): (a) students' lack of prior/experiential knowledge on math (all supervisors mentioned it) and (b) inadequate teacher preparation/competence. The most cited second-order causal explanations for the most cited initial explanations were: (a) parental involvement and attitude towards school (e.g., parents do not value education, so they do not provide support to extend kids' experiences on math) and (b) teacher education programs (fail to prepare teachers adequately).

The most cited first-order causal explanation that principals provided was inadequate instruction (too much focus on memorization, lack of curriculum alignment, or lack of skill reinforcement). The most cited second-order explanation for that first-order explanation focused on teacher competence/preparation.

Finally, the most cited first-order explanation that teachers provided concerned students' dispositions (i.e., lacking basic skills, having language deficiencies, and listening and reading problems). The two most cited second-order explanations for those students' dispositions were: (a) parental involvement and parental attitudes (i.e., parents support learning or think education is the sole responsibility of schools) and (b) inadequate curricula (lack of drill and skill and more computation or curricula that requires knowledge and skills that students do not have). Note that teachers and principals seemed to differ in their views of what good instruction might be. Whereas principals criticized the fact that instruction was inadequate because of an excessive focus on memorization, teachers criticized the curriculum for not enough emphasis on drill and skills and basic math facts.

Table 4 shows a sample of the main first- and second-order causal explanations that participants provided. The mean number of causes (breadth of causation) for supervisors, principals, and teachers was 6.75, 5.71, and 6.22 (SDs = 1.75, 1.38, and 1.72, respectively). These differences were not statistically significant ($F(2)<1$).

Levels of the system and connection among levels (LC). After describing participants' first- and second-order explanations, the next step was to examine: (a) whether those causal explanations included as many levels as possible and (b) whether these levels were well-connected.

As the excerpts in the previous section illustrated, teachers often focused on local levels of the system: students' characteristics, parents' mentality and the curriculum. Most principals and supervisors initially focused on local levels of the system but then expanded to higher levels in their second-order causal explanations. For instance, most principals focused their first-order causal explanations on inadequate instruction (which was classified as a school-context variable) but then expanded to the role of teacher education programs and teaching training in adequately preparing future instructors. This shows that some of the principals attempted to expand their causal explanations to higher levels.

Similarly, some supervisors also expanded their second-order explanations to higher levels of the system (see as an example Supervisor D, whose excerpts are shown in the previous section). Some of them emphasized teaching and instruction in their first-order causal explanation and then expanded to the role of teacher education programs and district administration (i.e., access to resources, pre-K education, etc.).

On the other hand, teachers were the most focused on local-level variables. As it can be seen among the most cited causal explanations, teachers concentrated mostly on students and instruction: initially on students' characteristics (individual) and then on the characteristics of the curriculum (instruction-related).

Overall, although some supervisors (n=4) and principals (n=3) expanded their causal explanations to higher levels, the majority of participants (n=15) still concentrated their analysis on local levels of the system. Among those who expanded their causal explanations to higher levels of the system, 6 participants (2 principals, 2 supervisors, and 2 teachers) crafted second-order explanations that lacked coherence with their first-order explanation. An example comes from Supervisor D whose causal connections were not very coherent:

> [first-order causal explanation]…the problem is not using a hands-on approach with the students. And sometimes not understanding that you have to go back to the concrete and work with the concrete to build up to the abstract with the students.…[second-order explanation] I think to a certain extent in some of the districts, it's the training in the upper grades that the teachers have…it's the resources. I think that in many of the schools, the classes have become overcrowded. They no longer have math <inaudible>, and if you don't, you have to teach in four different classes, it's very hard to have enough materials in your math classes to support hands-on activities. It requires time to prepare for the children. And when, and your movement, you don't always have the time to, nor the ability to leave your things in a particular room.

As the excerpt shows, Supervisor D focused on a lack of hands-on learning experiences in her first-order causal explanation and then expanded to the role of district resources. However, in her second-order explanations, she mostly listed reasons, weakly relating these reasons among themselves. In addition, the first-order explanation ("not understanding that you have to go back to the concrete") does not seem to be supported by her second-order explanation. That is, her second-order explanation seems to be focused on infra-structure (lack of resources) for not having more hands-on learning, while her first-order explanation also talks about understanding of using hands-on approach.

Only three participants (two supervisors and one principal) were able to craft a systems-oriented causal explanation that included all the levels of the system connected in a coherent fashion. As an example, there is the case of Supervisor H who was able to provide a wide-range and well-connected causal account of the math achievement gap, as the following excerpt illustrates (I highlight the different levels mentioned):

> [first-order explanation] We probably just, the lack of education, the economic status of the family contribute [sic] [**urban-life level**]. We have overcrowding in our classrooms [**school level**]. That contributes. Probably not enough additional support after school, and pre-school [**district level**]. We often cannot find certified math teachers [**Larger policy and professional contexts**]….[second-order explanation for overcrowding] We have a number of our school building are over 100 years old.[**district level**] We are land poor, so there's not a lot of <inaudible> to put new school buildings. So in order for, in order to put a computer, if you want to put a computer lab or some kind of technology center in the building, taking away a classroom means those children have to go someplace…the schools were not built for as many children as we now have in the district…[**district level**][second-order explanation for lack of certified teacher] I think a lot of times teachers get paid more to teach in suburban districts [**Larger policy and professional contexts**]. I think there is a perception that somehow teaching in a suburban district is better [**individual level**]. I think it's a misperception…in some areas, it's maybe more challenging because we had to, some of our kids do have so many problems [**individual level**] because like, coming to a district, have no education…

Table 11 shows the complete distribution of scores across the three groups. As it can be seen from the table, 15 participants (4 principals, 4 supervisors, and 7 teachers) received scores of 1 or 2. One participant (Supervisor F, whose excerpts were shown in the previous section) focused his first- and second-order explanations solely on the individual level (scoring 1). Six participants attempted to expand their second-order causal explanations to higher levels, but they either focused on one level in particular or provided at most a fuzzy connection among levels.

Pictorial representation. The number of responses for the seven categories of representations across the three groups is shown in Table 6. The majority of representations displayed a very poor causal understanding of the system. Fifteen representations failed to express causal relationships in a systemic fashion. Causal relationships were shown as limited to a small number of interactions and were linear. Seventeen representations failed to convey an understanding of system levels, whereas 21 representations failed to convey an understanding of system hierarchy.

Causal thinking patterns

A combined causal-thinking score was generated for each participant by summing up LC scores and scores from pictorial representations. These two scores were summed because together they represented all the dimensions related to causal thinking that the study investigated. Whereas LC scores considered breadth, depth, and connection among levels (but had the limitation that items needed to be inferred from participants' answers), scores of pictorial representations captured a more concrete view of participants' causal understanding, including causal direction. The two scores were not significantly correlated, suggesting that the two scores might be complementary in examining individuals' causal understanding. For instance, some individuals may better explain their causal understanding verbally than in a drawing, or vice-versa. Summing both scores represented an opportunity to provide a more comprehensive summary score of participants' causal beliefs. The sum of LC scores and scores from the pictorial representation was called the *total causality* score. After scores were summed, the results were compared and contrasted against the data to check for coherence (i.e., make sure that final scores were really consistent with the overall level of causal understanding that participants demonstrated during the interview).

Four distinct ranges of causal thinking patterns became apparent by looking at participants' total causality scores. Range 1 (n = 8) comprised participants whose total causality scores were the lowest, between 3 and 4. These participants displayed the least systemic overall causal thinking; that is, their causal beliefs were generally focused on individuals, centralized in a few variables mostly in low levels, demonstrating a poor understanding of relationships between variables and levels. For this reason, this causal understanding pattern was called *non-systemic*. For example, Teacher H's drawing is shown in figure 2 and it depicts a non-causal account of how variables are related to explain the problem. In the drawing, the math achievement gap was represented by a "fish" that was only "caught" (or solved) when certain kinds of "bait" (i.e., music and arts education) was used. The teacher did not show in the first place the rationale to support the reasons why specifically that kind of "bait" was enough to support that solution. The following excerpt is Teacher H's immediate answer to the question "what do you think the major causes of the math achievement gap are in urban schools?":

> The best way of narrowing that gap between the children is to make math real for them. And when you make math something that is constantly happening throughout the day in every subject area, then math become relevant…Because you can't really teach math. I believe you have to experience math. And for it to become real…children need to visualize and to feel the numbers….And another thing is also in the urban districts and another point that I have to make is that when you go to suburbia, many of the children are exposed to music and they're exposed to different types of music. In that in the urban setting [sic], they're not. And I find that the musical intelligence and the math intelligence really goes hand in hand. And when you bring that extra component into it, the children do better….

As the excerpt shows, Teacher H believed so strongly that the major reason for the math achievement gap was the lack of more music and arts education that her entire discourse seemed to be based on circular argument: arguing that the cause for the problem was the very absence of her ideal solution.

The second range of total causality scores, between 5 and 6, were called *localized-linear* (n = 8) because causal thinking tended to involve mostly local levels of the system (with a slight tendency to include upper levels) and a linear understanding of causality. Moreover, causal understanding about levels, system hierarchy, and interrelationships were lacking. Take as an example principal C. Her drawing is depicted in figure 4 as a "zipper," clearly showing a linear and sequential understanding of causality. The localized component is shown through causal explanations focused on local levels of the system, as the following excerpt shows (levels of the system are highlighted to show they are local):

> [first-order causation] The students I feel need much more reinforcement than they're getting. The students learn the skill, they learn the concept but they don't have enough opportunities to apply it sometimes out of school [**school context**]. [Second-order causation: why does it lack reinforcement?] Everybody has a time problem…that some kids, they want everything [**individual level**]. They want to be on a sport, they want to be in extracurricular activities, and if the child doesn't want it, the parent forces it [**individual level**]. So there's more time being spent in social activities or skills that the students are going to eventually need that [sic] in terms of them coming back to check the work.

The next range of total causality scores, between 7 and 8, named *complex*, included participants who demonstrated a more complex understanding of causal relationships, which included variables within different levels of the system and non-linear causal relationships (n = 5). However, there was still a focus on low-level variables and no references to understanding system effects. Principal D is a good example of this type of thinking. His drawing is depicted in figure 5, showing more complex causal connections, which includes reciprocity (rather than mere linear connections). However, even though his diagram included some variables related to the district level, his verbal causal explanations were mostly focused on the individual (teacher competence) and teaching, as the following excerpt evidences (I highlight the emphasis on individual factors):

> I think one of the major causes [for the achievement gap] is the training of the teachers [**individual factor: teachers lack training**]. I think that many of the teachers have not taken the courses that would be necessary to be able to teach math at a higher level….I have seen a lot of teachers that are not prepared to, that don’t have the content knowledge to teach that subject matter [**individual factor: teachers lack knowledge**]….I think that many, many teachers try to concentrate more on the language arts and some of the other subjects [**individual factor: teachers concentrate on language arts**]….I found out that many teachers really weren’t really looking at that frameworks because almost everything that was on the test, on the New Jersey ASK or ESPA at that time was there. And they had also recommendations for softwares that the kids could use that it wasn’t being used….[Teacher need] try to use manipulatives, higher-order thinking skills so that they can remember what they do and so on. It’s not a simple subject….I think it’s important for the administrators to go to the class and to teach once in a while.

Finally, the highest range, named *systems-oriented* (n = 3), comprised total causality scores between 9 and 11. This range represented participants who displayed a sophisticated causal understanding, which included the idea of system hierarchy and non-linear causal relationships, as well as the consideration that upper levels of the system affect lower levels (i.e., system effects). One of the three participants who were assigned this score was Supervisor B who specifically incorporated the idea of feedback loop (an important system component) in her drawing depicted in figure 7. The “stair-like” diagram shows that the process of change is not continuous. The several indents represent the responses (feedback) of the system (such as resistance and delay) to restore the equilibrium to a new state upon actions to change.

Supervisor C is an example of a systems-oriented causal thinking. His drawing was not as sophisticated as supervisor B's (figure 7), but scored in the top 30% (i.e., it received a score of 5, meaning that it identified levels and displayed a non-linear causal account). However, his verbal causal account was much richer, contemplating several levels of system, as highlighted in the following excerpt:

> Major causes, obviously home life [**urban-life level**]. Preparedness, support, the natural correlation between I guess the economy, the amount of money a person has, or districts have [**district level**], and the people in that district [**individual level**]…By the time we figure out how to bring the scores up, the testing changes [**changes in the test: district level**]…what you did is you taught to the test. And you taught them how to answer the test questions correctly. And to some extent, that's true. But to the extent that you can bring up scores in an urban district as we did is still a credit to the teachers....once the teachers are trained, it's up to them [**school level**]….the score [in the test] is the bottom line. And that's what we're being judged by. That's what we're being trained to judge ourselves by unfortunately….kids spend maybe, maybe...and we're lucky if that...180 hours a year...on math to some extent...it's [school] really not going to change the life of a child as a whole….Teachers may have an impact in the kids' life...but by and large, I think many times we overestimate the effect that we're going to have....home life [**urban life**] I think is so much more important than the tiny bit of time [in school]....when I want to hire a teacher, I think the misperceptions and fear sometimes the racism from people [**individual level**] keep them from coming here [in an urban district].

The complete distribution of thinking patterns across the three groups is depicted in Table 18. The distribution was not statistically significant (according to the non-parametrical Chi-squared test), meaning that none of the three groups was representative of any particular thinking pattern. However, it is interesting to note that all the three systems-oriented individuals were supervisors.

Discussion

The several opportunities to reason about causation might have encouraged participants to consider higher levels of the system and enrich their views of causal agency, breadth, and levels of the system. From a cognitive perspective, it could be argued that encouraging individuals to think harder about causation might be beneficial to extend causal understanding. However, among the educators of this sample, there was still a strong focus on low-level causes and, particularly, on individual-related causes, which are mostly outside one's control.

The definition of the four thinking patterns drawn from the data (and not established beforehand) reveals important aspects about how educational leaders think about causality. First, participants think better about causes involved in the problem than about how these causes are linked within and between levels to explain the problem. Individuals had difficulty elaborating on and representing causal connections and, when they did it, they tended to focus more on linear relationships. This phenomenon has been documented a few times in the science education literature (e.g., Ben-Zvi Assaraf & Orion, 2005; Kali et al., 2003; Penner, 2000). Second, participants tend to focus their causal analyses on local levels of the system (cf., Chi, 2005; Feltovich et al., 1997; Forrester, 1971; Penner, 2000). When attempting to expand causal analyses to higher levels, systemic coherence among the levels of the system was poor. This might be explained by the fact that the concept of system hierarchy seemed absent from most causal representations (based on participants' drawing). Finally, the hypothesis that supervisors would be more sophisticated in their causal analyses in view of their position in the system did not hold true, as they did not differ much compared to the other two groups (as the distribution tables showed).

Second Research Goal: Examining Problem Solving

With causal beliefs analyzed and causal thinking patterns defined, this section examines how participants would solve the math achievement gap problem and involve others in their solutions; it also examines variations in problem solving as a function of the different causal thinking patterns. I also report how participants viewed time to achieve results, how they explained no improvements, and which pedagogical changes they proposed.

Problem Solving

Participants focused their solutions on different aspects of the system (see Table 12). Seven categories of answers were established to summarize participants' solutions. The category *curriculum* comprised solutions related to curriculum alignment, improvement, or change. In terms of curriculum alignment, Principal B suggested that "it [the curriculum] should be more aligned to standards-based….[so] that's also pushes the teachers to different things so I think the gap will start to decrease." In terms of curriculum improvement, Teacher C suggested "schools should be piloting a new program, hands-on, with more concrete life experience....if they [the children] don't have life experience, we're giving them life experience."

The category *instruction* involved all solutions related to the use of new instruction techniques (e.g., field trips, investigation, hands-on activities) or actions that could improve math teaching (e.g., more time for math, different materials, pacing, language adjustment). For example, in terms of instructional materials, a principal emphasized the importance of "making sure...that calculators are accessible….[that] we are well stocked with the manipulatives and the tools that the teachers can use to implement the objectives." In terms of new instruction techniques, Principal E suggested to introduce field trips as a way to:

> Create experience for kids…I allocated as much resources as I could to field trips. Get kids out of the school….back to the experiential knowledge [that urban kids

> lack]. How do you defeat that? Field trips and even doable exercises within the community. Post office, which was let's say eight blocks away. OK did about four or five days of study and about distance and length and feet….the kids actually walked it, counted, paced it out and got to the post office and the just walked back.

Principal G suggested instruction techniques that employ "cooperative learning [because] when students work with students, and they participate in this, on these hands on problem solving activities, I think they internalize it better." In a less constructivist line though, Teacher G suggested for instruction techniques that "the times tables, multiplication. All that. Fractions, all that stuff needs to be actually sent home every night and your child must study dah-dah-dah-dah." Along these lines, Teacher A suggested that "the more problems they [students] do, the more math they do, the more math activities, the more games they play, the more they'll start automatically, it'll make it automatic."

The category *teacher support* involved solutions related to coaching, lesson study groups, peer modeling, and teachers helping one another, among others, as highlighted in Principal G's answer,

> We [the school] are encouraging that teachers take part in more things like the **lesson study project**…To get involved in attending professional development that will have valuable hands-on experiences that they can take away with them. And you know basically I guess…**having teacher leaders**. The lesson study does that, but apart from the lesson study and being involved in that, it's also can be done through the **team meetings**, being **able to talk with each other** about the things that are working in their classroom.

The category *teacher training* involved solutions that proposed professional development and workshops for teachers, as when Principal E suggested: "I started [solving the problem by] taking workshops. A two-year program of how to, just to learn more standards-based math and what it should look like in a classroom." As another example, Principal A emphasized the importance of professional development (as shown in the excerpt):

> …just making sure that we are kept abreast of all the advances and **making workshops available to teachers**….Teachers can no longer work in isolation, so we have grade level meetings. We have our **own building workshops**. I have people who are pretty excited about math and trying to show the way things should be done.

The category more *staff and teachers* comprised solutions that suggested hiring more people to help with math teaching (differentiated instruction, tutoring, additional classes, etc). As Teacher A suggested, "schools should hire more teachers to work with students who need help and students who are above [average]."

Finally, the category *district policy and infrastructure* involved district-wise policies (e.g., incentives to teachers), curriculum (where and when to introduce it), physical facilities (buildings, classrooms) and programs (after-school programs, pre-k programs). For example, supervisor H explained: "I think there are many, many, many actions that should be taken that are way beyond me and out of my control. We need new schools, we need more staffing, better working conditions." Teacher D focused the solution on revising the ternureship policy:

> …a lot of good teachers get frustrated because they find themselves doing a lot of work of the other, that the other teachers aren't doing…. the laws of tenure, whatever it is, tenure's a good thing but they need to make easier to get rid of a teacher that's ternure [sic]….

For teacher B, an important policy decision to solve the problem would be to introduce the curriculum in early grades and to make sure that low-performing children have access to tutoring sessions:

> …if I was the superintendent , I would have started [the curriculum], introduced it in the kindergarten, and had something different for the upper grades. I would also make sure those children who were performing lower maybe got some type

> of tutoring session during the day so that they could come, firm up on the skills that they were lacking. And possibly an after school program.

Teachers focused solutions on instruction and infrastructure of the district (70.4% of all their solutions). Solutions related to instruction were (in order of most common occurrence): (a) more time to teach math; (b) differentiated instruction (including pacing and adjusted language); and (c) more materials (such as books). As for solutions related to district infrastructure, the most common solution proposed by teachers was after-school programs. Principals also emphasized instruction-related solutions (41% of all their solutions), with more references materials (e.g., manipulatives, calculators) and new instructional methods (e.g., field trips, investigation). Another focus of principals' solutions was teacher support (23% of all their solutions). Finally, supervisors proposed solutions that cut across instruction, teacher training, and district-wise infrastructure. The most common solution among supervisors was teacher training, followed by new instruction techniques, and then district-wise infrastructure (such as after-school programs and day care).

Teacher training was the most cited solution among supervisors (comprising 29% of all their proposed solutions), but not a single teacher mentioned it. Solutions related to building new facilities and creating after-school programs and day cares (pre-K education) were cited several times by teachers and supervisors (comprising 25.5% of all their proposed solutions), but principals never mentioned these. Finally, teacher support (such as lesson study groups, coaching) was the least popular solution among all solutions proposed by all groups (comprising 9.6% of proposed solutions; see Table 13).

Solutions were also coded in terms of their impact on the system. Recall the coding scheme described in the data analysis section (see Table 7). Table 14 shows the complete distribution of types of solutions across the three groups. The differences among the three groups of participants was statistically significant (χ^2 (4) =13.6, $p<.001$), meaning that there was a strong tendency for supervisors' proposing solutions that impacted the system more broadly than principals and teachers. Recall that in order to be considered broad a solution had to incorporate teaching and policy decisions, as Supervisor C suggested:

> Everyone should be rotating and then what you have is you have a staff of math teachers, where everyone knows the content…[examine] your course selection. What works, what doesn't work…right now we're evaluating our math program, if I were to do an adoption…I would see a great influx of money in books coming to my schools. On the other hand, our problem, the greatest problem in our district is too much change. With every new administration that comes in, and every reshuffling and organization that comes in…our recent curriculum study comes to mind…. So my inclination at this point would be to recommend if the teachers are happy with the books and I'm happy with the books, and the students appear to be happy….don't get this influx of books. Because after all, books alone don't teach our children. It's the teacher in the classroom….So the more I can get in and know my people and work with my people to change my people or improve my people, the longer range effects we're going to have.

In the example above, the supervisor was discussing the importance of coupling teaching resources (curriculum, books, teacher rotation) with a policy structure (decision to not change the curriculum, to work closely with teachers, and on how to spend money) that support teachers and their practices, aiming at the long run. Note that throughout his discourse, supervisor C adopted a critical attitude (even questioning whether curriculum change was necessary) towards evaluating the system, rather than simply focusing on implementing pre-established decisions.

Principals were the most focused on system maintenance, with six out of seven principals suggesting solutions focused on implementation and ways to make the system work as planned. For example, assuming the curriculum as being effective, principal G focused on how to implement it by preparing teachers: "…we are encouraging that teachers take part in more things like the lesson study project….it's not just enough to dictate what it is you need to be doing. It needs to be modeled. And not once. It needs to be reinforced." Similarly, principal A, also focusing on curriculum implementation, suggested to:

> …have math specialists who work with teachers on strategies and curriculum, knowledge of the curriculum that the district has adopted. Making sure for instance, something very simple, that calculators are accessible…that we are well stocked with manipulatives…that the rooms are set up in a friendly way…that the rubrics are being used consistently and throughout.

Six out of the 9 teachers also focused on system maintenance. Teacher B proposed to "keep the program…[because] it's a good program, as long as the teachers do use all the components." Another teacher focused explicitly on supervision to assure correct implementation: "If I were principal, I would be in the classrooms more so I could really get an idea of what's going on in the classroom…also as a principal, I would really need to know exactly what is my fourth grade teaching?"

Another important finding was a correlation between *solution type* and *causal thinking pattern* ($r_s = 0.60$, $p<0.01$). Recall that thinking patterns were classified according to an ordinal scale ranging from 1 to 4, which allowed for the computation of Spearman correlations. This high correlation suggests that an increasing systemic orientation in terms of causal understanding (such as *complex* and *systems-oriented*) was associated with solutions geared towards changing the system (in a local or broader manner).

Involving others in the solution and dealing with resistance. The distribution of scores for ways to involve others across the three groups (see Table 17) showed that teachers were either imposing or persuasive in their approach to involving others. Imposing and persuasive approaches were associated with several characteristics of transactional leaders. Transactional leaders tend to apply contingent rewards and punishments as a way to impose authority and control and to push their followers to identify and attain goals (Bass, 1985; Burns 1978). An example of an imposing approach coming from Teacher G is shown in the following excerpt:

> I think you have to constantly introduce it to people and let them see it. And those that don't want to, that doesn't motivate and move, you got to move them someplace….If you're not a motivator and you're not getting kids to work, it makes no sense in you having a hold on how to, what to do here. What to do with any kids in the area. Because I think that's the whole piece of you, you've got to begin to move and sometimes you've got to be out with the old, in with the new and sometimes maybe the old people need to move out.

In the excerpt, Teacher G's response to those who do not seem to work properly and comply with the changes was to "move them someplace." This is an imposing approach because she does not seem open to controversy.

Teacher I, who followed a persuasive approach, suggested: "…explaining to the teachers what it is that you want and what you expect….finding out who feels they need more training, more help, possibly assigning more tutors." Teacher H proposed:

> …hav[ing] workshops with other teachers in team meeting….you would need to have a speaker that would actually show data...I'm sure that there is data that shows when these programs are implemented, how much better students do academically…so I think that that would actually teach teachers.

As both examples show, these teachers seem to believe that communication and training (through workshops, team meetings) is enough to convince people to change their practice. With the exception of two principals, the principals treated people generally as executors of pre-established ideas or involved others only marginally (i.e., contingent on the presence of certain situations only) in the implementation of their ideas. For example, in principal D's view, opportunity for participation seemed contingent only to successful outcomes:

> They [teachers] are motivated, they want to do well. And if they see that you are open…you know, I mean if I think that something that they're doing is better than the way that I wanted to be done and it seems to be working, go ahead…And if they see that something is not working and you're doing your best to get it to the next level, they will follow the system and your instructions…and it should be able to get there.

Along the same lines, principal C also implied that participation was contingent on effective results: "I give them carte blanche, but if the results are not there, then I always tell them, if you can't work here, there are, there's the opportunity for a voluntary transfer or to another district."

Supervisors did not perform any better in terms of involving others. Only three suggested employing empowering and community-building approaches., as it is the case of what supervisor A suggested:

> …we need to be able to develop that community again among teachers so that it is reinforced when they finally get into the classroom….we need to be able to create a mentoring situation, a nurturing situation with our teachers so that the community, you got several nuclei circles of community that expand and include and expand and include…we need to be able to give support to the teachers in order to be able to continue to develop that kind of learning community that we want to develop.

There was a significant correlation between *causal thinking patterns* and how participants suggested involving others in the solution of the problem ($r_s = 0.46$, $p<.03$), meaning that individuals with an increasing systemic causal understanding were more likely to propose empowering ways to involve others.

How long to see results. Table 15 displays the distribution of scores for participants' explanations regarding time to see improvement. Most participants (n = 17), which includes all teachers, expected the time to see improvement to be either *accelerated* or *slow and continuous*, but neither view considered the possible effects of unplanned variables or the role of system effects (such as delays, feedback loops, system resistance) in affecting possible results. As an example of an accelerated view of time, Principal E strongly believed that the math achievement gap could be overcome through better instruction and teacher preparation: “If it was just poor instruction but the kids didn’t receive it all, then I would assume within a year you should be able to see results.” Another example of an accelerated view of time comes from teacher G who believed that if her ideas about emphasizing more drill and skill with students were implemented, results:

> …would definitely [be seen] by the next year. It shouldn’t take no more than about two years, one or two years to actually see it. You’re really going to see the effect when the first grades go to second grade and the second grades go to third grade…if they already have some foundation, you will definitely see a big difference…the following year.

An example of a slow-and-continuous view of time comes from Teacher I whose view seemed to imply that the time to see results was simply dependent on the implementation of a set of actions (disregarding the possible effects of system resistance):

> I don’t think results are always immediate…Do I think overall, there will be an increase within a year? But I think realistically over the course of three years we will see dramatic results. Where teachers can get to certain goals and directions [sic]. New teachers also need mentors. They need to know where to find resources. They need to have resources available to them. And they will also need the right training and direction.

Three participants (2 principals and 1 supervisor) expressed an incremental view of time. They considered change not as a predictable process because of the role that unanticipated variables might play out in the system (slowing down the process of change). As Principal B explained:

> …you're not going to see a miracle because you brought in a new book, OK, or you brought in this dynamic teacher. You know? It's based on incremental change and it's going to take a couple of years. And you know, depending upon the groups that you have…but you're metering out that, in small increments…

Finally, three participants (1 principal and 2 supervisors) conveyed a system-growth view of time, considering aspects such as system resistance and sustainability of change, as seen in Supervisor B's excerpt below:

> A real good, like a systems change takes at least five full years. I think that means five full years if you have all the energy going kind of in the same direction. It's a sustainability issue **[sustainability]**. That's really hard if you have a principal leaving, a new principal comes in, doesn't really like a program. Therefore here I am as a district person trying to say this thing, this principal's saying you know it's just the nature of trying to get everybody at least kind of on the same page [**system resistance**]. So and you have administrators going in and out and you have a leadership drain or a new person who's overwhelmed [**system resistance**]...

Explaining no improvements. The majority of participants (n = 20) did not revise their initial mental models of the problem when confronted with the possibility no improvement (see Table 16 for the distribution of scores). Six participants simply rejected the idea that their solutions would not produce results, as in the case of Teacher D: "If they have more counseling, kept [sic]the good teachers, get rid of the bad teachers, and updated the curriculum? [teacher repeated all his recommendations to solve the problem] I don't see what, I don't see what else could be wrong." As the excerpt shows, Teacher D seems puzzled before the idea that changes might not be achieved through his suggestions.

Ten participants attributed the failure to see results to individuals' dispositions. In particular, students' learning skills were the most cited reason among the individual-focused explanations for no improvement. As it can be noted in principal E's explanation: "Well we'd have to then look at the students and seeing what the student is really capable of doing and does our curriculum match what the state is expecting us to teach? ....I think we really have to look at the individuals that have taken the test and see why they didn't perform well." For Principal E, results might not have been achieved due to individuals' limitations. Along the lines, teacher E attributed "blame" to students' lack of language skills, as the following excerpt illustrates:

> Oh my goodness. Parents are helping. Principals are involved. Students are getting help at home. That's a biggie. That is a biggie, what that you know. What else?.... OK. What we have in an urban setting is language. Even if it's not an Hispanic [sic], a Hispanic area. Because I taught in [district X], where it was basically African-American. And the language was still lacking. These children come in with a deficit in listening vocabulary which affects their reading vocabulary. And then they sit down and they take this exam and there are still words that are used that they don't know because of where they're coming from. Because they're not exposed to this.

Still not revising their initial model, four participants explained no improvement by placing responsibility on the implementation process, as Supervisor B's explanation illustrates:

> Well I think when things go wrong in a district, it could be a couple of things. It could be a leadership, it could be people say they're making the changes and you could have a terrific standards-based program but implement it in a very traditional way. Where the teacher does all the talking and the kids never do the thinking and the work. The teacher's doing a lot of the work. So it could be that or the way something has been implemented.

Finally, four participants (1 principal, 2 supervisors, and 1 teacher) considered revising their initial mental model of the problem when confronted with the possibility of no improvement. Supervisor G's explanation illustrates this approach by considering the possibility of "going back to the drawing board":

> Let me just think about that one for a moment. Hypothetically, if that should happen and of course I certainly hope that it doesn't happen, it would be a matter of **going back to the drawing board** [highlighted added] and I think if I had to say, ask myself what would go wrong.... Because studies show that students don't really improve through remediation. Students improve through enrichment. So I

> would have to say that whatever we are offering in the pre-K program and the kindergarten program is not sufficient enough to address the skills that are lacking.

A high correlation between time to see improvement and explaining no improvements was observed (r_s =0.63, $p<0.01$), meaning that individuals with a more systemic view of time were more likely to revise their mental model of the problem.

Variations in problem solving as a function of thinking patterns. Causal thinking pattern was used as independent variable in a non-parametrical test analogous to analysis of variance (the Kruskal-Wallis test) to examine differences in solutions and ways to involve others across the four causal thinking patterns – (1) non-systemic, (2) localized-linear, (3) complex, and (4) systems-oriented. It is important to note that the Kruskal-Wallis test only examines differences in terms of mean ranks of samples (not the means or medians of the samples). In other words, it assumes ordinal rather than interval or continuous data.

For causal thinking pattern 1 (non-systemic) and 4 (systems-oriented), there were no variations in solutions proposed (see Table 19 for complete distribution of solution scores across the four thinking patterns). This means that all thinking classified as non-systemic provided *system maintenance* solutions. Similarly, all thinking classified as systems-oriented provided *broad* solutions. Individuals classified as localized-linear thinkers (thinking pattern 2) scored higher on average in the solutions proposed than individuals classified as complex thinkers (thinking pattern 3). Apparently, having localized-linear causal thinking was not necessarily detrimental to proposing changes to the system. Whereas 62.5% of the individuals classified as localized-linear thinkers proposed either local or broad changes to system, only 40% of the individuals classified as complex proposed local (but not broad) changes to the system. The non-parametrical Kruskal-Wallis test showed a statistically significant difference in terms of solutions: Ranks of scores for ways to solve the problem did differ among the four thinking patterns ($H(3)=10.32$, $p<0.02$).

Systems-oriented thinkers were more likely to involve others in an empowering way than localized-linear thinkers (see Table 19 for complete distribution of scores on ways to involve others across the four thinking patterns). Localized-linear thinkers (thinking pattern 2) scored the lowest on average in terms of how to involve others in the solution when compared to the other three thinking patterns (even worse than non-systemic thinkers). The non-parametrical Kruskal-Wallis test was marginally significant towards pointing statistical rank differences for ways to involve others across the four thinking patterns ($H(3)=7.64$, $p=0.054$).

There was no correlation between scores for types of solution and ways to involve others. This leads to an important conclusion that may be logically deducted on the basis of the quantitative analyses performed. If thinking patterns correlate with both solutions ($r_s = 0.60$, $p<0.01$) and ways to involve others ($r_s = 0.46$, $p<.03$), but solutions and ways to involve others are not correlated, then one possible explanation is that individuals were not systemically consistent in their problem solving. I refer to *systemic consistency* when both solutions and ways to involve others are systemic. This conclusion matches the data. In fact, among the individuals classified as localized-linear thinkers, 87.5% focused on the two low-score approaches to involving others (imposing and persuasive). At the same time, 62.5% of the localized-linear individuals proposed high-score solutions--that is, solutions that contemplated either local or broad changes. Individuals classified as complex thinkers had a higher average score than localized-linear thinkers on ways to involve others. However, complex thinkers scored lower on average than localized-linear thinkers on solution: Complex thinkers focused their solutions more on system maintenance. Only individuals classified as systems-oriented thinkers were systemically consistent in their responses. Individuals classified as non-systemic were also consistent in the sense that both their solutions and ways to involve others were non-systemic. This argument is summarized in Figure 9. The figure shows a matrix depicting problem-solving patterns across the four causal thinking patterns.

Discussion

The most significant finding to be noted concerning the solutions that participants proposed was the emphasis on ways to improve teaching. Supervisors, principals, and teachers did not always agree on the specifics of how to improve teaching; their solutions involved new instructional techniques, improvements in the curriculum, teacher training, and teacher support, among others. However, they all put pressure on teaching. An important question to ask is whether teaching as a cause of the math achievement gap really justified the extent of this problem-solving focus. In this study, participants did not seem to think teaching was the most important cause of the problem. Based on their answers, school-context causes (which included mostly instruction-related issues) were only mentioned 26% of the time (see Table 5).

The majority of solutions proposed (79.2%) were focused on system maintenance (58.3%) or local changes (20.9%). Principals were the most focused on system maintenance solutions. This finding suggests that either individuals prefer (intentionally or not) to avoid changes in the system or they believe that local initiatives will be sufficient to lead macro changes. Either mindset is likely to hinder meaningful changes in the system, as massive changes caused merely by local initiatives are very unlikely (Schorr & Firestone, 2001). The pragmatism observed in principals might be associated with the cognitive characteristics of routine experts (Hatano & Inagaki, 1986). As a function of their job profiles and duties, principals have to be efficient and technically proficient to make the system work (rather than questioning it). As a consequence, they become routine experts by developing a great repertoire of procedural knowledge more oriented to efficiency than to understanding the system. Nevertheless, routine experts may have difficulty dealing with changes or new ways to thinking about the problems they face. Contrary to routine experts, adaptive experts tend to act more flexibly when solving problems, modifying existing procedures or suggesting novel solutions to old problems (Hatano & Inagaki, 1986). An important hypothesis to explore is whether this pragmatism of teachers and principals might hinder meaningful questioning of, and changes in, the system.

Most of the variability in problem solving was a function of individuals' different levels of causal understanding (rather than group membership). In terms of variability in problem solving across groups, the only difference found was somewhat expected. Supervisors were found to propose solutions more focused on system change, whereas principals' and teachers' solutions prioritized system maintenance. In a sense, it seems that principals and teachers tended to question the system less and focus solutions more on pragmatic issues linked to implementation.

Causal thinking patterns were associated with types of solutions and of ways to involve others.A systemic causal understanding was associated with solutions oriented to change and with empowering ways to involve others. Similarly, non-systemic thinking was associated with non-systemic problem solving; that is, system maintenance and non-empowering ways to involve others. However, this same consistency was not observed in the other two types of causal thinking: complex and localized-linear (recall Figure 9). Complex causal thinking was associated with empowering ways to involve others, but not with system change. Localized-linear thinking was associated with system change, but not to empowering ways to involve others. This suggests the importance of examining a wide range of decision outcomes in order to identify how less systemic types of thinking fall short in terms of problem solving.

There were two major cognitive weaknesses demonstrated by the majority of participants in the study. One was the view of time to achieve results, which most participants (71%) considered as predictable and proportional. View of time to achieve results may be the most difficult construct for individuals to grasp in this study. From a systems perspective, time for effects to emerge upon causation is non-linear, non-proportional, and unpredictable (Forrester, 1961; Sterman, 2000). These are all counterintuitive ideas for most individuals. However, without a correct understanding of how time works in a complex system, systems thinking cannot be fully achieved. Another cognitive weakness that most individuals displayed (83.3%) was the failure to revise their mental models when faced with contradiction. Systemic thinkers should consider contradictions as crucial sources of information to improve system design, and most participants did not engage in such considerations.

Pedagogical Changes

In line with previous results (Simon & Tzur, 1999; Spillane, 2000a), most of the pedagogical changes suggested by participants emphasized materials and the format of instruction. Twenty-five percent of participants focused only on the format of instruction. Half of the participants (particularly teachers and principals) emphasized the use of technology and manipulatives in the classroom. The use of small groups and hands-on learning were the two favorite formats of instruction (suggested by 58.3% of participants).

When analyzing the reasons for adopting the different class formats, two major types of instructional goals seemed to emerge. The majority of participants (54.2%) seemed to be concerned with the goal of helping students to understand math—the *getting-it* approach. Other participants (20.8%) seemed to be concerned with the goal of helping students to think about math—the *thinking* approach. Finally, some participants (25%) did not seem to refer to any instructional goal at all, focusing on the format of instruction only. Below, I present data supporting these claims.

Participants who followed the getting-it approach demonstrated a concern with providing students with many different types of instructional strategies (e.g., field trips, investigations, manipulatives, differentiated instruction). However, a careful analysis of the reasons for employing these strategies revealed several contradictions and implicit forms of prejudice. For example, participants incorporated many of the constructivist terms and tools (e.g., manipulatives, small-group work, hands-on activities, discovery, exploration) in their dialogue. Nevertheless, when asked to explain why they recommended certain tools and instructional formats, participants' answers did not fit into the constructivist epistemology. As the following examples show, underneath a method of teaching superficially formatted as constructivist, often lay a very traditional theory of learning, emphasizing knowledge acquisition, retention, and test achievement. For instance, one teacher concerned about practice and repetition suggested that students should:

> play a lot of games…have a lot of manipulatives, hands-on, because they're small children…they have to, they have to have that because it's hard for a lot of them to get in their head….they should have more tests…more problems, whatever the problems are. They should do a lot of those. Probably more. They get more practice.

Along similar lines, one teacher who emphasized the need for students to retain the math facts explained that manipulatives and small-group work help students "enjoy mathematics and retain what they've learned….[because] if the child is having difficulty, they don't know their facts." The emphasis on "getting" math is also evident in this teacher's explanation about why to use concrete tools: "Give [concrete tools] to them and let them physically do it; and when they physically do it, they get it. So concrete is very obvious to me." Another teacher concerned with test achievement emphasized the importance of providing students with multiple ways to solve problems, because "if you just word it one way or show it to them one way, and it's different on the New Jersey ASK, all of a sudden they [students] don't know what [the question on the test] talking about [sic]." Note that multiple ways to solve a problem is not employed to generate deeper understanding, respect different learning styles, or even help students develop more cognitive flexibility. The goal is to help them do better on the test by acquiring the necessary knowledge. Reasons for why to use concrete tools were often associated with helping "visual" and "tactile" students. A principal explained that:

> Manipulatives are excellent for visual [sic] because again you have to think about the different learning styles. You know if some people are auditory and some people are visual and I mean so [sic] learning styles. We even had a workshop here several years ago because of the fact that we are a large African American school district. Two of my teachers took it. On learning styles of African Americans…

Along these lines, another teacher explained that “if they [students] get down to the tactile, they’re at the concrete level and they can actually see what’s going on…and a lot of our students, that’s the type of learners they are [concrete learners].” As it can be noted, associating the idea of concrete learning to different learning styles seems to betray an indirect form of stigmatization. Assuming that urban children are “visual” and, as such, they should be taught in a concrete way might carry the implicit notion that they are less capable of thinking abstractly (which is fundamental to mathematical thinking). This type of rationale seems to be a distortion of the meaning of multiple intelligences, used in this sense as an indirect way to stigmatize children. Comments such as “it's hard for a lot of them to get it in their heads,” “when they physically do it, they get it,” or even “if they get down to the tactile…they get it” betrayed not only the low expectations that teachers might have towards students but also a view that teaching should be trivialized in order for students to “get” math.

Teachers focused their answers either on the format of instruction (33.3%) or on the getting-it approach (66.7%). It is interesting to note that the very teachers who demonstrated an inadequate understanding of the constructivist epistemology applied to teaching (i.e., focusing merely on the format of teaching and the getting-it approach) were the exactly those who did not suggest teacher training as a solution for the math achievement gap. As the following excerpt illustrates, this teacher was so sure that her teaching was not a problem that she commented:

> And I don't think we really know why there is this gap because I couldn't teach any better no matter where I was. I truly believe I am doing a really great job. And I wouldn't teach someone from a non-Abbott, non-urban area any differently than I'm teaching now. The only difference I think I would find is that they would, their knowledge that they come [sic], would be greater than these children.

More than half of the principals (66.7%) also focused pedagogical changes on the getting-it approach, as illustrated in the following excerpt:

> I think it's very important number one that they [students] have to repeat themselves a lot….I think it's important that the problems are done in a certain manner. Following the same format….And hopefully if they see the operation that is needed to be able to solve that problem, then with easy number or with a problem that is relevant to them, they might be able to apply that knowledge to whatever is presented to them.

Supervisors did not perform any better either; 75% either focused on the format of instruction or on the getting-it approach. The emphasis on the format of instruction is evidenced in this supervisor's explanation:

> Well I think one of the main things is to get kids being active in math classes. Get them working with manipulatives….[because manipulatives] it's hands-on. And a lot of our students, that's the type of learner they are. There's different types of learning, obviously. And I believe that the majority of our kids will benefit from…

Supervisor F believed that the major reason for the improvement in math achievement was due to the fact that: "We've done extensive staff development for our teachers…pushed them from direct instruction to more of the constructivist approach…created student-centered classrooms." The emphasis on "we've done", "we've created", "we've pushed" seems to imply that the pedagogical changes towards a constructivist approach were more determined (or pushed through) than nurtured.

A few participants employed a *thinking* approach when discussing pedagogical changes. In their reasons for adopting more constructivist tools and methods, these participants demonstrated a concern about creating opportunities for students to think and explore, deemphasizing concerns with acquisition of knowledge and math achievement. The instructional format suggested for instruction seemed to match the constructivist epistemology of discovery and reasoning. For instance, a supervisor criticized the excessive focus on a “plethora of technical things out there” such as “hands-on activities as many technical things as we can bring into the classroom” because they do not help students “see how patterns form.” She continued saying that it is important that students “check out the patterns, build [their] own little models and…own little patterns, and draw [their] conclusions from there.” A concern with thinking is also expressed in the words of this principal who explained the importance of teachers’ asking questions that promote thinking:

> What’s different in the pedagogy today would be teachers asking some questions and saying well, well how do you know this? What proof do you have? What makes you think that? Could it be something else? Asking those kinds of questions, having kids construct their knowledge.

Only five out of the 24 participants in this study followed a thinking approach when proposing pedagogical changes to math teaching. Three were principals and two were supervisors.

Discussion

Teaching practices are affected by many cognitive and contextual factors. School teaching depends on, among other things, the cognitive structure of the subject matter (Stodolsky, 1993; Stodolsky & Grossman, 1995), teachers’ knowledge and beliefs (Richardson, Anders, Tidwell, & Lloyd, 1991), the age and prior knowledge of students (Brophy, 2002), and the policy contexts in which teaching takes place (Grossman & Stodolsky, 1994; McLaughlin & Talbert, 1993). The fact that all teachers (followed by the majority of principals and supervisors) in this sample focused pedagogical changes on the format of instruction and on getting-it approaches may be explained from few perspectives.

First, the fact that urban districts are often struggling to increase test scores in math may force teachers, given the pressure for content coverage, to adopt an efficiency-driven approach to get students to learn as much as possible related to what the state test will require. The use of more traditional approaches to teaching math (even if more constructivist tools are employed) seem to be an effective and less time-consuming means to deliver the content. Second, teaching practices might be affected by teachers' beliefs about whether and how students may be able to achieve in math. If educators believe students are visual, or unable to think abstractly, their belief may act as barriers to more thinking-driven approaches, and teaching may become too trivialized, further worsening the gap between what urban and suburban children learn. It is possible that even the educators might have difficulty with abstract thinking, thus avoiding it in their lessons. Third, the way educators are evaluated greatly influences how they may conduct instruction (and on what they may believe in terms of instructional method). If they are evaluated in terms of how well their students perform in the state test (rather than in terms of the types of instructional goals they use in the classroom), there will be less incentive for educators to review their beliefs about teaching (particularly if more traditional approaches continue to work). Recall that when asked to propose solutions for the math achievement gap, not a single teacher proposed teacher training as one of the solutions to the problem. Apparently, they are all satisfied with the way they teach. Finally, it is possible that teachers simply reproduce in the classroom their intrinsic beliefs about how to solve problems and engender involvement. Recall that all teachers focused their solutions on system maintenance and were transactional (either imposing or persuasive) in their approaches to involving others in the problem-solving process. The approaches teachers might carry in the classroom might be a reflection of that mindset.

Examining Participants' Responses in Absolute Terms

The analyses performed to examine participants' causal thinking and problem solving were inductive; that is, the categories and themes used for data analysis emerged from the data itself. Scores, as a consequence, were relative: A high score was not given to the best possible answer (i.e., the more systemic one) in absolute terms, but to the best response compared to others in the sample. With this in mind, it is important to note that even the more systemic answers found in the study fell far short of the in-depth systemic analyses discussed in the urban education literature (e.g., Anyon, 1997, 2005; Fine, 1991; Hursh, 2004; Hursh & Martina, 2003; Kozol, 2005; Lipman, 2003). Two major differences can be noted between the types of causal explanations provided by the participants in the sample and the ones discussed in the systemic reform literature: The view of the educational system and the role of the individuals in the system.

View of the educational system. Systemic accounts of education view the education system as open, that is, as influenced by variables that go beyond the educational context itself. For example, some authors (Anyon 2005; Hursh, 2004, and Lipman, 2003) have discussed the role of neoliberal macroeconomy in shaping the reality of urban areas (wages, jobs, housing, transportation, etc.) and the quality of urban education, while widening social inequalities. According to this view, schooling in urban areas represents no economic prospects to the students who pursue it and the reasons for that are linked reciprocally. On one side, urban students leave low-quality urban school unprepared for the competitive neoliberal market, with little chance to gain access to high-paying jobs. On the other side, the perpetuation of neoliberal "policies such as minimum wage statutes that yield poverty wages, affordable housing and transportation policies that segregate low-income workers…all maintain poverty in city neighborhoods and therefore the schools" (Anyon, 2005, pp.2-3). As a consequence, within this view of education as an open system, the problems we see in education (such as a the math achievement gap as well as all other gaps) are not caused by the educational system itself, but by the macroeconomy that creates and perpetuates unemployment and poverty through a perverse competitive system to which only a minority have true access. As Anyon put it so well, "[p]roviding economic opportunity and realistic hope in urban neighborhoods will be necessary to create the conditions that allow for and support successful urban schools, but these nurturing conditions will have to be supplemented by reforms that prevent racial tracking, low-level curriculum, and poor teaching (for example)" (p.3).

Contrary to the view of education as an open system, the participants (37.5%) in the study who provided causes related to the larger policy and professional context (only 12% of all causes), viewed the educational system as a closed system. That is, they explained that educational problems are caused by the education system itself. Even when urban family dynamics were mentioned, they were mostly used to justify urban students' and parents' dispositions toward schooling and differences between suburban and urban students. Implicitly, this view of the educational system carries the assumption that education can help education, *if* parents and students do their work. Along the lines of Fine's (1991) argument, while schools remain solely committed to academics, they can always consider student problems as a private matter of family and community. This certainly exempts educators and schools from a myriad of responsibilities.

Role of individuals in the system. Another difference between participants' responses and what the systemic reform literature discusses concerns their views about the role of individuals within the system. Among teachers, principals, and supervisors, the role of individuals in affecting the system is exacerbated. Of all 150 causes mentioned, the most cited cause (30.7%) was related to individuals' dispositions and traits. In addition, participants never considered themselves as part of the problem. Principals and supervisors talked about the importance of teacher training, but teachers did not. One supervisor talked about the importance of leadership, but overall participants focused on causes and solutions that did not include themselves.

Both the focus on individual-related causes and personal detachment from the problem contrast sharply with the systemic view adopted in the education reform literature. In such a view, individual-related explanations are often interpreted as face-saving justifications for justifying students' low achievement (Fine, 1991; Valenzuela, 1999). If the onus for low achievement is mostly explained by students' characteristics and home dynamics, there is little for schools to care about or to be accountable for in case students fail or drop out. Similarly, by detaching themselves from being part of the problem, educators and educational leaders waste a valid opportunity to examine how their own attitudes influence the culture of urban schooling (Anyon, 1997; Fullan 2001; Lieberman, 1995). As Anyon (1997) wrote, "classroom change is also in great measure dependent on changes in the culture of the school…changing attitudes of people in all parts of the system – from teachers and students in classrooms, to district administrators, to legislators in state capitals…" (p.12). Therefore, if self-criticism is absent, change is less likely to occur. Recall that in this study the majority of participants were resistant to revising their mental models of the system when faced with contradiction. This lack of flexibility to question and revise their mental models of the problem might further hinder individuals from engaging in productive self-criticism.

CHAPTER SIX

Conclusion

I would never die for my beliefs because I might be wrong.

– Bertrand Russell.

Causal beliefs are not the only components that determine systematicity in thinking; however, inferences about systemic causal thinking say something very directly about systems thinking. Individuals with a non-systemic causal understanding of the system are unlikely to be systemic thinkers. Yet we cannot assume that individuals classified as systems-oriented (i.e., with a systemic causal understanding of the system) will necessarily be systemic thinkers. The fact that most educational leaders and teachers in this sample displayed a poor causal understanding of the system suggests that these individuals might be very unlikely to engage in systems thinking. Several findings supported this claim. First, causal explanations were mostly focused on local levels of the system. When they expanded to higher levels of the system, causal explanations often lacked a logical connection among the levels of the system. Second, there was a poor understanding of the system hierarchy. This was particularly evidenced by the majority of pictorial representations that lacked a view of the system hierarchy and how the levels of the system may affect one another. Third, there was a poor understanding of system effects, such as delays and feedback loops. Most participants viewed time to achieve results as predictable and continuous, disregarding unanticipated feedback and delays (due to system's resistance to change) that might be created by the very actions they proposed.

Providing participants with the opportunity to talk further about the causes of the problem might improve the breadth and depth of causation. For instance, in the first question of the study, most participants focused on individual-related and local causes. To give participants a chance to go into more depth, a second-order causal question asked participants to talk about the causes of the causes. When asked this second-order question, participants' causal analyses extended from individual-related causes to causes within intermediate and higher levels of the system. By the time participants were asked to explain why the problem of the math achievement gap was difficult to solve, more causes within higher levels of the system were mentioned. It is true that some individuals (teachers, in particular) never mentioned the highest-level causes or did so very seldom. However, the more encouraged participants were to think about causality in their causal analyses, the more likely they were to be less centralized in their causal local-level causes.

The majority of participants who emphasized teaching in their solutions followed a getting-it approach to change instruction. This approach inadequately promotes higher-order thinking and a more sophisticated epistemology in the students—two crucial learning goals that have been increasingly emphasized in testing. In addition, the focus on concrete learning as a way to get instruction down to the "tactile" so students can "visualize" mathematics may contribute to trivializing instruction; this tactile focus may hinder the development of abstract thinking to the point that the gap between what urban and suburban students learn widens even further. It is possible that a getting-it approach may contribute to generating short-term results in the achievement tests: The teachers exhaustively practice with students the problems that might be asked on the test, how problems are worded, and so on (using whatever tools and methods are available, such as manipulatives, hands-on activities, repetition, multiple ways of solving the same problem). Eventually, after intensive training, students may perform better on the test. Everybody celebrates the results, which in turn reinforces the idea that the problem was indeed “solved” through “better” instruction. However, as mathematical reasoning was not adequately developed and the true causes of the problem were not actually addressed, as soon as the test changes, students fail the test again.

In systems dynamics, what has been described above is a system archetype called “shifting the burden” (Senge, 1990). That is, individuals prefer to focus on a *symptomatic solution* over the more thorough and difficult *critical solution,* because a symptomatic solution seems to alleviate the problem in the short-term. However, only the critical solution addresses the real causes of the problem, solving it in the long-term. In the context of this study, this symptomatic solution was to put pressure on teaching, as most participants emphasized. This might alleviate the problem in the short-term: As teachers focus on helping students “get math,” test scores might increase. Short-term results then might decrease individuals’ drive to find the critical solution for the problem because it appeared that the problem had been handled. Sadly, the focus on symptomatic solutions, which might be effective in the short-term, might in itself decrease the chances of individuals’ ever pursuing a critical solution (Forrester, 1971, 1998; Senge, 1990). As a consequence, the problem–the math achievement gap–persists, indefinitely fuelled by the very short-term (but inefficient) solutions pressured to be applied with the intention to solve the problem.

With the exception of the individuals clearly distinguished as either non-systemic or systemic-oriented, the other individuals (i.e., localized-linear and complex) were not systemically consistent in their answers (as depicted in figure 9). It is important to note that I refer to "inconsistency" as the mismatch between what participants suggested as solutions and what they suggested as ways to involve others in problem solving. For instance, some complex thinkers (classified just one level below systemic thinkers) focused on system maintenance, while suggesting empowering ways to involve others. Some localized-linear thinkers proposed changes to system, while focusing on non-empowering ways to involve others. In reality, it should be expected, for example, that localized-linear thinkers might never actually achieve system change because they suggest ways to involve others that are inadequate to promoting true system change. This finding about individuals' lack of systemic consistency suggests two possible explanations. One is that examining individuals' causal beliefs from a systemic perspective might be a necessary but insufficient method of determining which approaches to problem solving individuals might engage. This is expected since causal beliefs are not the sole determinant of systematicity in thinking. Therefore, further studies are necessary to investigate other cognitive components (besides causal beliefs) that should be included in the model to more precisely predict systematicity in thinking and in problem solving. The other explanation is that individuals may not all be consistent in their answers, and the findings from this study only reveal the problem-solving inconsistencies that certain types of non-systemic thinking (such as localized-linear and complex) may present. In this case, further studies should investigate through a wider range of problem-solving tasks which other types of inconsistencies less systemic-oriented individuals may present during problem solving.

In this sample, individuals displayed some level of inflexibility that may help explain some of the barriers to productive system change. For example, the majority of participants were not willing to revise their mental models of the problem when faced with the contradiction of no improvement after implementing solutions. Contradictions help individuals' question and revise their mental models in ways that might improve their systemic understanding. Not being open to self-criticism is a barrier to improving the understanding of the system. If causal thinking is systems-oriented, but self-criticism to question one's own mental model is absent, individuals may not truly engage in systems thinking because they fail to see contradictions as a source of information about the system. Another signal of inflexibility came particularly from teachers. None of them mentioned teacher training as a possible solution for the problem, even though they all suggested instructional changes that were inadequate for the new high-order thinking requirements of testing. If teachers do not see training as necessary, the real efficiency of professional development initiatives should be questioned. After all, can individuals learn something that they consider they already know?

This study has some limitations. First, the idea of levels of the system, system hierarchy, and connection among these levels had to be inferred from participants' answers. For an exploratory study such this one, this is an expected limitation because questions were open-ended given the goal of pinpointing major categories, themes, and orientations in answers. This limitation was addressed to an extent by giving participants the opportunity to represent their thinking in a drawing to help elucidate previous inferences. However, it can always be the case that individuals may not be able to express in a drawing what they really think. Therefore, further studies should investigate through specific questions whether participants' understanding of levels, hierarchy, and connection among levels match or approach what was discussed in this study.

Another limitation is that the definition of the levels of the system and the system hierarchy adopted in the study is in no way definitive. In fact, these definitions of levels and system hierarchy were induced from the overall responses that participants provided during the interview. Nevertheless, if it were to be defined in absolute terms, the education system would be much more complex than defined in this study, and, as a consequence, participants would have performed much poorer in terms of normative systemic causal understanding and problem solving. In this study, my intention was not to establish a systems-dynamics model of the education system. My intention was to show how participants reason about causality and solve a complex problem, even when the education system is described in very simple terms. Current discussions sponsored by the National Science Foundation and the Department of State on how to apply systems dynamics to education urge scholars to develop a complete description of the education system not only in terms of lines of authority or political geography, but also in terms of the dynamics of interaction in the system (Kaput et al., 1999). According to Kaput et al. (1999), these dynamics of interaction could be investigated through questions such as the following:

> Which institutions and social practices, which sources and users of information and material and human resources are tightly enough coupled and interdependent in their behavior that they must be included within the system? Likewise, what are the ranges of time scales characteristic of the critical processes that enable the system to maintain itself? What are its significant levels of organization…in terms of characteristic structures and characteristic emergent processes and patterns at each level? What kinds of material resource and information flows connect adjacent and non-adjacent levels? How is information transformed, filtered, re-organized, and added to from level to level? How is information-overload avoided by emergent systems for pattern-recognition that extract from large data-flows only what matters for the dynamics of the next higher level? (p.6)

The small sample and short interview time posed some limitations on the variety of themes that could be explored in the study. If more time had been available, it would have been possible to add more probing and follow-up questions that would allow for a richer variety of themes to emerge. This would have contributed to enriching the coding schemes that were developed for the analyses as well. The limited time also reduced the amount of field notes collected. The notes collected were insufficient to demonstrate any major pattern that could work to validate some of the findings. For instance, field notes could have worked to triangulate whether individuals' verbal responses matched how they actually behave in their functions. The small sample limited the number of causal understanding patterns that could emerge from the data. The four causal thinking patterns that this study described were, by no means, exhaustive. As they were established inductively, drawing from the data, it is possible to speculate that if the sample were larger, more patterns would be likely to emerge.

Finally, an important limitation to be noted concerns the type of problem that was used in the study. It was a single, broad and ill-defined problem. It is possible that many of the responses that participants provided (including the levels that were established for analysis) might have been an artifact of the problem. Should the problem be about another topic (i.e., a topic that a particular group could be more familiar with) or more well-defined (although still complex) participants might have performed differently and the study's conclusions might have changed. For instance, if the problem was about instruction (a topic teachers deal with extensively), teachers might have pointed other factors and levels and they might have been able to display a more systemic understanding of the problem. In this study, teachers might not have thought about the questions in terms of the realities of their own work. Future studies should investigate whether the ability for individuals to achieve a systemic causal understanding and problem solving might be content-specific. Future studies should consider the use of alternative types of problems and contexts to examine effects on individuals' ability to think and solve problems more systemically.

CHAPTER SEVEN

Implications of the Study to Education

This study corroborates several findings that have been documented in the science education literature regarding individuals' causal understanding of complex systems (c.f., Kali et al., 2003; Penner, 2000). While most studies in the science literature have been conducted with students dealing with unfamiliar problems, this study employed real practitioners dealing with a problem they are familiar with. Regardless, most participants in this study displayed similar misunderstandings and flaws displayed by students when reasoning about the causality of a complex system. This suggests that the difficulties associated with systemic causal understanding might be pervasive across different age groups and fields of experience.

This study adds to the growing literature on the effects of systemic understanding on problem solving, showing that individuals more prone to systems thinking (i.e., those whose causal understanding is systems-oriented) propose solutions and ways to involve others in the problem-solving process that are associated with system change. Even though one cannot assume that individuals with a systems-oriented causal understanding may necessarily be systemic thinkers, the findings from this study showed that systems-oriented causal understanding is strongly associated with more systemic problem solving.

Individuals less prone to systems thinking (i.e., those whose causal understanding was less systemic or non-systemic) proposed solutions and ways to involve others that were incommensurate, showing that poor causal understanding of the system affected problem solving in ways that might not have been visible if only one decision outcome was analyzed. For instance, if only solutions were observed, both localized-linear thinkers (i.e., individuals with an inadequate level of causal understanding) and systems-oriented thinkers would be systemic in their decisions, focusing on system change. This would have provided the mistaken impression that localized-linear causal thinking was not detrimental to solutions associated to system change. Similarly, if only ways to involve others were observed, both complex and systems-oriented thinkers would be systemic, focusing on empowering people. This would also have supported the mistaken view that less systemic causal understanding is not detrimental to proposing empowering ways to involve others. Only when both solutions and ways to involve others were examined could the inconsistencies of less systemic causal understanding become visible. This suggests that future cognitive studies in the area should investigate a wide range of decision outcomes. As more decision outcomes are examined, patterns of causal understanding might become clearer and more well-defined.

The role of schools of education will be crucial to helping form individuals more knowledgeable about systems dynamics and, more importantly, individuals open to revising their beliefs and mental models. Beliefs "are stocks that characterize [our] mental states"; as they become deep-seated, they generate inertia in our attitudes and behavior (Sterman, 2000, p.195). Therefore, education needs to be geared towards changing individuals' beliefs and mental models on how complex systems are structured (their major causes, causal loops, feedback structures, etc.) as the first step towards developing a way of reasoning and solving problems on education.

Implications for Teacher Education

Preservice teachers might need specific training on systems thinking or, more specifically, on how to frame educational and instructional problems systemically. Most books on educational psychology (e.g., Ormrod, 2003; Santrock, 2004; Woolfolk, 2007) display knowledge as a compendium of theories of learning with their respective tools and problem-solving frameworks (see diagram 1 below). For example, a chapter on *behaviorist views of learning* offers concepts and tools to analyze and modify behaviors. A subsequent chapter on *cognitive views of learning* adds a new perspective on learning (fulfilling gaps of the previous theory) and introduces new concepts and tools on how individuals acquire and process knowledge and solve problems. At the end of the book, preservice teachers have been exposed to a rich body of knowledge and tools, but not necessarily to a way of reasoning about education. It is not uncommon for students consider *social views of learning* (as it often corresponds to a later chapter on the book) as more advanced or "correct" than the previous views. Knowledge on problem solving often appears just as a sub-item of a chapter on *Complex Cognitive Processes*, not as a general framework to reason about all the educational theories, tools, and instructional problems. Similarly, some ideas related systems thinking are often limited to the chapter on human development.

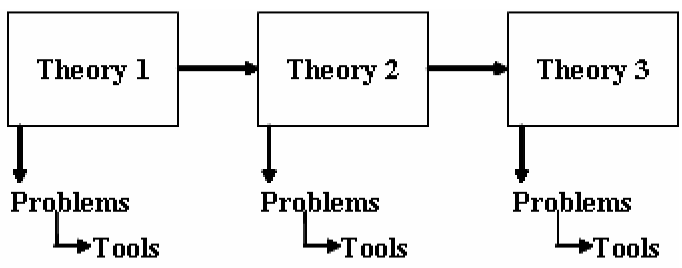

Figure 10: Traditional Way to Learn Educational Psychology

Preservice education geared towards developing systemic thinking should start by placing problems and a framework for systems-thinking in the center of the process of learning (see diagram 2 below). In such a view, acquiring knowledge on theories of learning becomes a supporting system to understand problems, causal loops, and system archetypes. For this type of instruction to work, it becomes critical to recognize and overcome the major barriers to systemic causal understanding, since it is usually counterintuitive. This study has helped document the major gaps (including inadequate causal beliefs) that may prevent individuals to achieve systems thinking, so specific instruction to overcome these gaps can be designed. This approach of framing problems in education within a systemic framework can benefit enormously from the well-established research field of problem-based learning (c.f. Albanese & Mitchell, 1993; Cognition and Technology Group at Vanderbilt [CTGV], 1997; Hmelo-Silver, 2004), which also adopts a learning model in which knowledge and reasoning strategies supports problem solving.

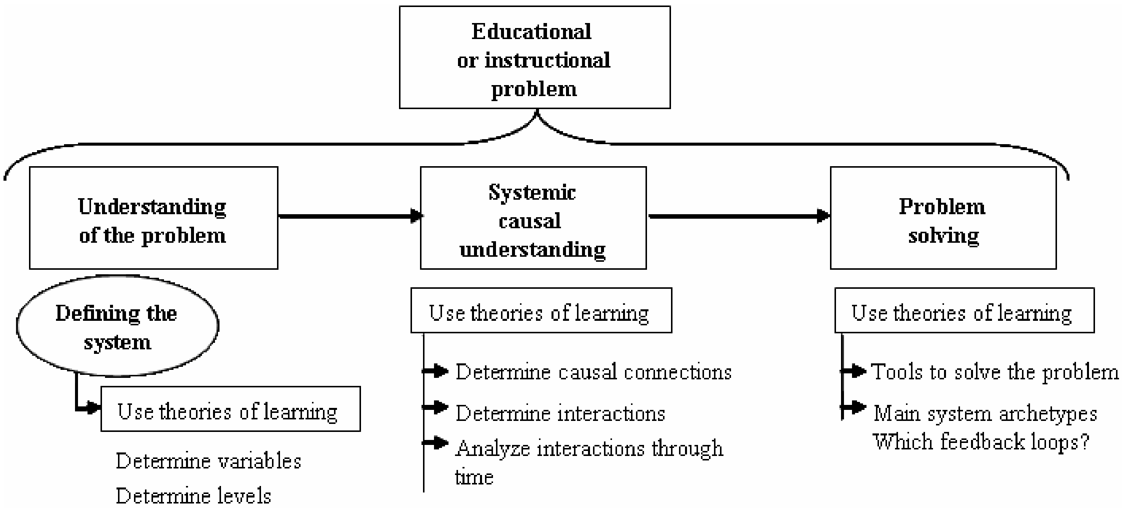

Figure 11: Educational Psychology in a Systems-Thinking Framework

The development learning models on how to develop systems thinking among preservice teachers is a very complex and under-researched task. Among the five most important research areas on complex systems and education, Michael Jacobson and

Working Group 2 on a NSF Panel on National Initiative on Complex Systems in K-16 (Kaput et al., 1999) raises two questions related to teacher learning: (a) what should change in terms of teacher preparation and inservice teacher training? and (b) how should teachers and university faculty in teacher education units in colleges and schools of education learn about complex systems ideas? Future work should aim at fulfilling these research gaps.

Some pioneer learning groups have begun the task of providing research ideas, space for discussion panels, and tools to support the application of systems thinking to education. One example is the Creative Learning Exchange (CLE, www.clexchange.org). The CLE is a nonprofit foundation that acts as a clearinghouse to provide information on system dynamics in precollege education and to help teachers share their experiences. It has a partnership with the Massachusetts Institute of Technology (MIT), represented by Prof. Jay Forrester. The CLE offers materials, assistance and direction for curricular and organizational innovation, K-12 discussion group over the internet and also hosts a biennial conference dedicated to create "Systems citizens."

Implications for Leadership Education

There is also a concern with how to prepare educational leaders to think more systemically. As this study has shown, the majority of participants lacked the causal understanding necessary for systems thinking, suggesting some reflections on the role of national institutes for leadership and schools of education in preparing future educational leaders and policy makers.

Developing a way of reasoning about the world using systems thinking and systems dynamics (the difference between the two is that the latter applies computer simulation and mathematical models to confirm and test causal loop structures) may lead individuals to value the importance of the design of systems. Forrester (1998) questioned the efficacy of management schools, suggesting that most "train operators of corporations…[with] no attention to designing corporations" (p.8). As the curricula of schools of educational policy and administration are often inspired by those of schools of management, the same concern on how to not to form simply "system operators" applies to education as well

I believe that are two main barriers within leadership education that may prevent the development of systems thinking. First, consistent with recommendations of the NSF Panel on National Initiative on Complex Systems in K-16, there is a lack of: (a) explicit mental frameworks for systems thinking and (b) explicit and specific teaching on the concepts and terminologies related to systems thinking. Policy students on schools of education do have access to literature on the major educational problems, often analyzed from a systems-thinking perspective (e.g., Anyon, 1997, 2005; Fine, 1991; Hursh, 2004; Hursh & Martina, 2003; Kozol, 2005; Lipman, 2003). However, the systems-thinking framework behind the ideas being discussed is seldom made explicit to students. Classroom discussions often focus on analyzing the authors' arguments and ideas, not their thinking model. For example, Anyon (2005) discusses several ways in which neoliberal policies of the country have reinforced education inequalities. In one of her main arguments, she clearly discusses a reinforcing mechanism of feedback (i.e., the fact the neoliberal policies define minimum wage statutes that segregate low-income workers and reinforce poverty in urban neighborhoods), but she has not made explicit the systems-thinking archetype (i.e., feedback loop) she is using for her analysis. Many professors leading discussions about Anyon's book may similarly neglect to make the systems-thinking archetype explicit.

The second barrier for developing systems thinking in educational leadership is the excessive emphasis on the figure of the leader, very much inspired by the same tradition in the business administration area (as evidenced by all the best-selling books on what a superb leader should be and look: *Heroic Leadership*, *The Welch Way: 24 Lessons from the World's Greatest CEO*, *The seven habits of highly effective people*, etc). For instance, the current curriculum of the National Institute for School Leadership (NISL) seems to place principals as the individual responsible for leading school change, as evidenced by many of the course units (such as *The principal as team builder, ethical leader,* and even *driver of change*) and by the book that is officially recommended for the course: *The Principal Challenge* (title analogous to the best-selling business book *The leadership challenge*), which is a proposal to help principals lead change in standards-based schools. The problem with relying excessively on the role of leaders to promote change is the risk of reinforcing two biases known to prevent systems thinking: (a) The fundamental attribution error (i.e., the tendency to attribute causality to individuals' traits and dispositions, overlooking contextual variables – Ross, 1977) and (b) centralized thinking (i.e., the tendency to attribute the causality of a complex phenomenon to "lead or seed" (Resnick, 1996). It is important to investigate the extent to which these biases may end up being promoted with a curriculum such as the NISL's. To develop systems thinking, leaders need to learn not only how their actions may impact the system, but more importantly, how the dynamics of a system may afford and constrain most of their intended behaviors. I believe this later aspect has been under-taught in leader preparation.

Along the lines of making concepts and frameworks explicit for students, there are several topics in policy and education administration that seem suitable for this type of approach. The Evans School of Public Affairs at the University of Washington offers several topics in which the use of a systems-thinking framework may apply, including: (a) Social policy analysis and management, (b) managing policy in a global context, (c) administrative and policy skills, and (d) economic transformation and the regional workforce. Most descriptions of these courses seem to focus on developing knowledge and skills to solve problems in the area. It remains doubtful whether these courses are also concerned with developing a way of reasoning that look at social institutions as systems. According to Forrester (1998), the relative lack of progress in understanding social systems (as compared to the understanding of technical systems) is associated with individuals' failure to recognize social institutions as systems and, therefore, learn how to design them more effectively.

There is an important difference between learning to think about problems and learning how to solve problems. The literature in business administration and, as a consequence, in education administration (since the latter is often inspired by the first) is overfilled with tools to solve problems. Tools come and go because they are simply the consequence of how individuals think about the world. Consulting and training companies often sell the illusion that learning tools will lead someone to think "better." In fact, it often leads individuals to mistakenly generalize solutions or "force" solutions onto situations they do not fully understand. Therefore, it is crucial to reframe courses on policy analysis and management to reflect a concern with developing a systemic way to think about the world. However, it is also important to avoid the risk of transforming systems thinking simply into a set of tools and frameworks, rather than a way to understand causality, patterns and feedback loops of actions.

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Table 1

Interview Protocol

Introduction: Thank you very much for your participation in the study. This interview is being conducted to find out what educational leaders think of the problem of the math achievement gap in elementary urban schools. All your answers will be kept strictly confidential, as explained to you in the consent form. I will be glad to share more details of the study at the end of the interview if you wish. The interview will be recorded.

Goal	Question	Rationale
First-order causation	1) Based on your experience, what do you think are the major causes for the math achievement gap in urban elementary school?	Capture beliefs about causal agency, breadth of causation, and implicit levels of the system involved in the analysis.
Second-order causation	2) What do you think leads to _______? (repeat the question for each of the causes raised in the first question)	Capture beliefs about breadth of causation, implicit levels of the system involved in the analysis, and relationships with the previous question (1^{st}-order causation)

Table 1 (continued)

Interview Protocol

Goal	Question	Rationale
Problem solving	3) What would you do to solve the problem of math achievement gap in elementary urban schools? Let's imagine that you have the power and the resources to solve the problem. a. If not spontaneously explained, then ask: How do you think these actions will help solve the problem?	Examine whether different causal understandings of the problem might lead to different solutions to the same problem.
View of time for actions to produce improvement	4) Let's suppose that all your suggestions are followed to solve the problem, how long do you think it would take for us to see improvement in the math achievement of the students? a. If not spontaneously explained, then ask: Why do you think it will take this amount of time to start seeing results?	Capture whether different levels of causal understanding impact in individuals' view about the time that takes for improvement to occur after implementation.

Table 1 (continued)

Interview Protocol

Goal	Question	Rationale
Follow-up question regarding causation	5) Many people dedicated and knowledgeable as you are have thought about this problem and it still has not been solved. Indeed, many actions have been taken to try to solve it. How would you explain the fact that the math achievement gap has persisted in most urban school despite all the efforts to solve it?	Investigate whether new ideas about causation would emerge if participants were asked to think harder about the problem.
Explaining no improvements after proposed solutions	6) Let’s suppose now a hypothetical situation in which your suggestions to solve the problem are followed and you still do not see any improvement in math achievement. How would you explain it? What could have been wrong?	Capture how participants would make sense of a situation that contradicted their expectations. Explore possible relationships between causal understanding and how individuals deal with contradiction.

Table 1 (continued)

Interview Protocol

Goal	Question	Rationale
How to involve others in the decision process	7) How do you get others to implement your ideas and how would you deal with possible resistance?	Examine whether different causal understandings of the problem might lead to different ways to involve others in the problem-solving process.
Pedagogical changes in math instruction	8) What do you think are the pedagogical changes that need to happen, a t the level of the classroom, to help students achieve better in math? a. If not spontaneously explained, then ask: Such pedagogical change is good for what? How does it affect student achievement? (repeat for each of the pedagogical changes mentioned)	Investigate whether view of pedagogical changes (whether form-focused or function-focused) could be possibly related to participants causal understanding.

Table 1 (continued)

Interview Protocol

Goal	Question	Rationale
Pictorial representation of causal understanding	9) My last question is somewhat different. I am going to ask you to draw a picture for me of the variables involved in the problem of the math achievement gap and how these variables are related to explain the problem. Take as much time as you need and you can explain your drawing to me at the end (participants are given a blank sheet and a pencil). a. Would you like to explain your drawing to me? b. (only if arrows were drawn) Could you explain the direction of these arrows?	Visualize causal beliefs that up to this points were inferred through participants' verbal responses.

Table 2

Demographic Information

Participant	*Years of administrative experience*	*Years of teaching experience*	*B.A.*	*M.A.*	*Ed.D/Ph.D*
Principal A	*2*	*28*	*Education (Special Ed.)*	*Special Ed. and Ed. Administration*	
Principal B	*8*	*30*	*Elementary Ed.*	*Ed. Administration*	
Principal C	*9*	*24*	*Education, Spanish*	*ESL*	
Principal D	*15*	*10*	*Science Ed.*	*Yes (but not specified)*	
Principal E	*less than a yr.*	*15*	*Political Science*	*ESL*	*Multicultural multilingual studies*
Principal F	*11*	*5*	*Not specified*	*Special Ed. and Ed. Leadership*	*Ed. Leadership and Policy studies*
Principal G	*less than a yr.*	*19*	*Not specified*	*ESL*	

Table 2 (continued)

Demographic Information

Participant	*Years of administrative experience*	*Years of teaching experience*	*B.A.*	*M.A.*	*Ed.D/Ph.D*
Supervisor A	*less than a yr.*	*29*	*Not specified*	*Theological studies*	*Math Ed. & Theology*
Supervisor B	*5*	*30*	*Education (Elem. Ed.)*	*Education (technology)*	
Supervisor C	*6*	*10*	*Business Administration*	*Business Administration*	*Ed. Leadership*
Supervisor D	*17*	*8*	*Elementary Ed.*	*Education, K-12*	
Supervisor E	*3*	*36*	*Business Administration*	*Ed. Technology. & Adm.*	
Supervisor F	*10*	*20*	*Mathematics education*	*Student personnel service*	
Supervisor G	*15*	*22*	*English Education*	*Liberal Studies*	
Supervisor H	*13*	*25*	*Mathematics*	*Mathematics*	

Table 2 (continued)

Demographic Information

Participant	*Years of administrative experience*	*Years of teaching experience*	*B.A.*	*M.A.*	*Ed.D/Ph.D*
Teacher A	*None*	*4*	*Marketing*		
Teacher B	*None*	*8*	*Elementary Ed.*		
Teacher C	*None*	*14*	*Especial Ed.*		
Teacher D	*None*	*15*	*Literature*		
Teacher E	*None*	*22*	*Elementary Ed*		
Teacher F	*None*	*11*	*ESL*		

Teacher G	*None*	*23*	*Elementary Ed.*	
Teacher H	*None*	*28*	*ESL, elementary ed.*	*Fine arts*
Teacher I	*None*	*10*	*Language Ed.*	*Ed. Leadership*

Table 3

Classification of Causes within the Levels of the Educational System

Level of the system	Definition	Example of answers given
Individual	*Issues related to personal dispositions or traits, individual cognition, motivation, views, beliefs.*	*Student motivation and self-esteem, student attention, student background knowledge, student listening and reading skills, student logical thinking, teachers' beliefs and expectations, teacher knowledge, teacher competence, students' and parents' language barriers, individuals' resistance to change, parents' characteristics (e.g., lack education, don't value education, don't provide support, don't instill love of learning).*
School context	*Issues related to instruction, classroom dynamics, content of instruction and testing.*	*Content and characteristics of the curriculum (how it affects instruction), instruction techniques (pacing, real-life instruction, hands-on, consistency, mastery), types of materials (manipulatives, calculators), content and characteristics of the testing (too hard, different from the past, etc.), student performance (test scores), class size, school leadership, teacher support (coaching, modeling), grade level meetings, school building, school staff*

Table 3 (continued)

Classification of Causes within the Levels of the Educational System

Level of the system	Definition	Types of answers given
School context (continued)	*Issues related to instruction, classroom dynamics.*	*School staff (e.g., to help students who may need extra help), extra-curricular activities, amount of time spent in school (compared to outside it)*
Urban life	*Issues related to the reality of urban areas*	*High mobility, violence, parents have many jobs (lack time), urban areas are less attractive to teachers, teachers in urban areas are less prepared, parents lacking money, etc.*
District context	*Issues related to decisions and resources at the district level*	*District resources, district budget, district decisions about changes in curriculum, personnel, time for testing, selection of textbooks, new testing and instructional requirements, opportunities for training, district support (math coaches, math leaders), teacher training (PDs, workshops…), facilities, after-school programs, tenureship policy.*

Table 3 (continued)

Classification of Causes within the Levels of the Educational System

Level of the system	Definition	Types of answers given
Larger policy and professional contexts	*Issues related to major economic, social, and policy factors affecting education*	*External resources (like federal and state decisions of the amount of money that goes to districts according to classification), higher ed. institutions, teacher ed. programs (preparation, certification, licensing), federal programs and policies (NCLB), labor market (teacher availability), resources allocated to urban districts, American culture (how it values other ways to solve math), economic structure of the country, American tracking system, American social ills (e.g., segregation), TV influence*

Table 4

Sample of Participants' First- and Second-Order Main Causal Explanations

Participant	First-order Explanation	Second-order Explanation
Principal A	"I think with the new emphasis on being able to explain, it's no longer computation…it's no longer good just to memorize the answer and know the process."	"For years there was an emphasis on just regurgitating of the facts. Now you have to be able to explain that answer and I think across the board, that has widened the achievement gap….I think colleges have to revamp how teachers are prepared. And the expectation level....I don't think the expectation level is there for them to achieve."
Principal B	"There's a lack of continuity from what we call vertical articulation by textbooks and curriculum."	"Kids are being tested on that say in March, but they're getting it [probability] according to the curriculum guide until say May or after the testing."
Principal C	"The students I feel need much more reinforcement than they're getting…and there's not always the support from home to reinforce.	"I've told the parents that even though they [students] might be doing homework there [boys and girls club after school], it is still their obligation to check the work…that's still a parental responsibility."
Principal D	"There were several types of sample problems in the frameworks that teachers weren't using…Teachers prefer to concentrate on language arts."	"..you [teacher] have to be able to understand it so that you can teach it to the children. And if you do not receive enough content-area training in the subject matter, it's going to be very difficult for the teacher to be able to simulate the math and to be able to teach it."

Table 4 (continued)

Sample of Participants' Main First- and Second-Order Causal Explanations

Participant	First-order Explanation	Second-order Explanation
Principal E	"Teachers lack the knowledge necessary to teach math...they aren't sure how to fill the gaps that students have in terms of initial math knowledge"; "Parents don't instill any math knowledge with the kids at an early age…"	"The teacher education program is the main culprit. I am a certified elementary teacher and I never had one class in how to teach math."
Principal F	"…is the lack of experiential knowledge with the kids coming in [sic]."	"If your world is very small, OK, say you grow up in state housing, governmental housing, etc….so again the opportunities [for experiential knowledge] don't present themselves as much in urban districts than they do in affluent districts or middle class districts.
Principal G	"major causes have to do with maybe trying to bridge the traditional skill building approach that a lot of educators have had in their past training…you know 15 years ago…as opposed to the hands on and what we're finding is that in the testing that the children are receiving..."	"it may be a matter of just because it's something that people are used to or were used to doing. It could have to do also with the training that they're receiving on the graduate level….I've often questioned what is it that, what type of education are teachers receiving?"

Table 4 (continued)

Sample of Participants' Main First- and Second-Order Causal Explanations

Participant	First-order Explanation	Second-order Explanation
Supervisor A	"you have to get their attention. The attention of the student….then you need to begin to develop their own self esteem….[because] They have been told so many times they're not worth anything."	"the last thing on most of those youngsters' minds is mathematics….in many urban situations, you're talking about youngsters who are born and bred in a life of serious danger."
Supervisor B	"…if I think that [have low expectations towards students], then I will instruct differently…My expectations may drive it….so the teacher may come back and say, oh well I'm thinking maybe this kid doesn't have that support at home and so then your expectations get lower, then you instruct differently."	"I think a lot of our teachers, are so caring, a lot of the special ed teachers go into that field because they're caring, caring people [reciprocal causation]. But because of that, it's almost like a learned helplessness and then there's no cognitive dissonance, the kids aren't presented with a problem that are head-scratches. And then there's no opportunity to learn…"

Table 4 (continued)

Sample of Participants' Main First- and Second-Order Causal Explanations

Participant	First-order Explanation	Second-order Explanation
Supervisor C	"Preparedness, support, the natural correlation between I guess the economy, the amount of money a person has, or districts have, and the people in that district…The people in the district. And that is probably the major cause."	"By the time we figure out how to bring the scores up, the testing changes…what you did is you taught to the test. And you taught them how to answer the test questions correctly. And to some extent, that's true. But to the extent that you can bring up scores in an urban district as we did is still a credit to the teachers....once the teachers are trained, it's up to them….the score [in the test] is the bottom line. And that's what we're being judged by. That's what we're being trained to judge ourselves by unfortunately….kids spend maybe, maybe...and we're lucky if that...180 hours a year...on math to some extent...it's really not going to change the life of a child as a whole….Teachers may have an impact in the kids' life...but by and large, I think many times we overestimate the effect that we're going to have....home life I think is so much more important than the tiny bit of time [in school]....when I want to hire a teacher, I think the misperceptions and fear sometimes the racism from people keep them from coming here [in an urban district]."

Supervisor D	"the problem is not using a hands-on approach with students."	"when students started with the concrete, they were able to understand the concepts where as just giving them the formulas and the written as pects was not working."
Supervisor E	"major cause is parental involvement….They [parents] don't place an emphasis on education."	"more emphasis needs to be placed on pacing so that the teachers cover all the materials…they need to be more [sic] observations for, of the teachers to see what they're doing."

Table 4 (continued)

Sample of Participants' Main First- and Second-Order Causal Explanations

Participant	First-order Explanation	Second-order Explanation
Supervisor F	"I don't think they're [students] exposed to the types of toys that they need to extend their experiences so that they come to school with prior knowledge."	"a lot of parents themselves lack education…education isn't a priority for them."
Supervisor G	"students come to school not prepared for math courses."	"when districts are able to expose their children to pre-K and K programs, then the children are exposed to literature, exposed to math, exposed to science, exposed to social conditions that would make it easier for them later in life acquire and maintain certain skills."
Supervisor H	"Probably a lot of factor [to explain the math achievement gap]. We probably just, the lack of education, the economic status of the family contribute. We have overcrowding in our classrooms. That contributes. Probably not enough additional support after school, and pre-school. That hurts. We often cannot find certified math teachers, especially for the upper grades…We have a lot of children who are either special ed but more [sic]. We have many, many who are English language learners. English is not their primary language."	"I think there is a perception that somehow teaching in a suburban district is better. I think it's a misperception." "we have a number of our school buildings are over 100 years old. We land poor, so there's not a lot of resources to put new school buildings."

Table 4 (continued)

Sample of Participants' Main First- and Second-Order Causal Explanations

Participant	First-order Explanation	Second-order Explanation
Teacher A	"…the math program…it didn't have enough computational math. It was missing a lot of elements."	"Not everybody is good in math, and they may need extra support….They [students] need some extra teachers. Not assistants. Not, you know, certified teachers." "…they [parents] think when they [kids] go to school, that the teacher opens the top of their head up, like a beer mug, and pours the knowledge in their head and closes it up and then they know it….a lot of parents think they just go to school and learn. They don't have to do anything…"
Teacher B	"the constant change in curriculum. This is my second year at this school and it's also their second year of the new mathematics program."	"Poor test scores. Basically, everything in this education worldwide is data-driven. They're looking at a specific grade, and whether that grade is meeting that standard of the state. And when it's constant repeatedly not meeting the standard of the state, the administrators and the superintendent...will go out and look for a new program."
Teacher C	"They [students] have very little life exposure. They don't go places, they don't do things like suburban kids do. So their life experience is limited."	"It's hard to apply concepts when they [students] don't have background knowledge….without high expectations, students will not achieve."
Teacher D	"I think the language. The language deficiency."	"the parents themselves don't have much of an education so they don't regard education as an important part of life….The kids, students see that and so they com to school not as motivated as maybe some students in the suburban districts."

Table 4 (continued)

Sample of Participants' Main First- and Second-Order Causal Explanations

Participant	First-order Explanation	Second-order Explanation
Teacher E	"The children aren't exposed to as many mathematical situations as children in non-urban areas…The parents, most of them do not have a good or even education at all."	"…I don't think we really know why there is this gap because I couldn't teach any better no matter where I was. I truly believe I am doing a really great job. And I wouldn't teach someone from a non-Abbott, non-urban area any differently than I'm teaching now. The only difference I think I would find is that they would, their knowledge that they come, their prior knowledge would be greater than these children."
Teacher F	"There are a lot of Spanish-speaking children, so it's very difficult for them even when they do start acquiring the language, just understanding certain concepts…"sometimes the questions [in the new curriculum] are a bit too hard for them. So maybe too challenging for them. They're not able to grasp it on their own..."	"There's a lack of teachers, lack of personnel that were hired. So there's not enough people to go around and give support."
Teacher G	"kids don't develop enough listening skills. Not maintaining the skills…addition and subtraction, multiplication tables…I don't think they master those skills."	"…once you learn how to add, subtract, multiply and divide, multiply, you can do anything else. So those things need to be mastered first." "I don't think there's enough drill and skill on it. I think right now we're working on get it, they'll get it later. Keep going, it'll spiral down to it. But still, those things have to be mastered."

Table 4 (continued)

Sample of Participants' Main First- and Second-Order Causal Explanations

Participant	First-order Explanation	Second-order Explanation
Teacher H	"I think the gap occurs because they're not exposed to baby math. And the best way of narrowing that gap between the children is to make math real for them."	"teachers don't take enough time to understand that that [make math concrete] is very important. And that children need to visualize and to feel the numbers."
Teacher I	"we've changed so many curriculums. That's one of the biggest disadvantages because there isn't enough time given to master the curriculum…"	"I think that's in all urban districts because they do have Title 1 money. They do have money to spend to buy these curriculums, yet they don't have the time invested to see them work.

Table 5

Total Number of Causes Classified According to Groups and Levels of the Educational System

	1st-order causation					2nd-order causation					Why it is difficult				
	Levels of the system					Levels of the system					Levels of the system				
	Indiv.	School	Urb.life	District	Larger context	Indiv.	School	Urb.life	District	Larger context	Indiv.	School	Urb.life	District	Larger context
Principals	4	5	0	0	0	5	4	2	5	3	4	1	2	1	4
Supervisors	6	3	3	2	2	5	4	2	3	3	7	2	1	5	6
Teachers	10	7	3	2	0	4	7	1	3	0	1	6	3	9	0
Total	**20**	**15**	**6**	**4**	**2**	**14**	**15**	**5**	**11**	**6**	**12**	**9**	**6**	**15**	**10**

Table 6

Pictorial Representation of Causes and Interrelationships: Rationale

	Variables	Relationships among variables	Levels	Hierarchy	Feedback loops?
Non-causal: score of 1 (n=4)	*Some, but poor*	*None*	*None*	*None*	*None*
Simple Causes: score of 2 (n=7)	*Yes*	*Listing or simple covariation*	*None*	*None*	*None*
Causal chain: score of 3 (n=4)	*Yes*	*Sequential (One-way)*	*None*	*None*	*None*
Reciprocal: score of 4 (n=2)	*Yes*	*Two-way and linear cause-effect*	*None*	*None*	*None*
Simple Level: score of 5 (n=4)	*Yes*	*No linearity, some interaction among levels*	*Yes*	*None*	*None*
Complex Level: score of 6 (n=2)	*Yes*	*Overlapping*	*Yes*	*Yes*	*None*
System effects: score of 7 (n=1)	*Yes*	*Nonlinear*	*Unclear*	*Yes*	*Yes*

Table 7

Coding Scheme for Types of Solutions

Category	Definition	Types of answers
(1) System maintenance	*Solutions that help the system work the way it is intended to. Proposes additions, improvement to the system, but no major changes: the idea is that the system is well thought out, but needs better implementation. There is a focus on implementation.*	*Extra help for students (stated vaguely), family nights, after school programs, more supervision (to make sure that decisions are implemented correctly), grade level meetings (to facilitate communication), alignment, workshop for teachers (as a way to help them teaching,* but the person does not mention change in the curriculum*), more staff, new buildings, instructional support for teachers, instructional improvements (*without mentioning teacher training*: e.g., more field trips).*

Table 7 (continued)

Coding Scheme for Types of Solutions

Category	Definition	Types of answers
(2) Local changes	*Changes are proposed, but they are focused on specific parts of the system. Alone, they cannot change the system.*	Instructional changes: *Changes in the curriculum (e.g., more arts in the school, more skill building, more discovery, etc)* together with teacher training; *Teacher training, workshops* together with change in the curriculum*);* *Differentiated instruction, smaller class sizes; change language in the classroom;* *Preschool education (idea that students will get to school with more adequate prior knowledge).*

Table 7 (continued)

Coding Scheme for Types of Solutions

Category	Definition	Types of answers
(2) Local changes (continued)	*Changes that are focused on specific parts of the system, but these changes alone will not lead major changes the system itself.*	Policy changes: *Change in the tenureship policy; Apply same curriculum for the whole district (which minimizes learning gaps in areas where students mobility is high); Change leadership, change leadership vision; Change the way administrators spend money.*
(3) Broad changes	*Change in instruction* and *policy structure. Changes that may have the potential to alter the design of the system.*	*Two or more changes geared towards both instruction* and *policy.*

Table 8

Coding Scheme for Involving Others and Dealing with Resistance

Perspective	Description
1. Imposing	*Involvement is kind of imposed by supervision, monitoring, fear of punishment, training and modeling (it has an implicit idea of molding behavior), have control over teachers/staff.*
2. Persuasive	*Involvement by persuasion and explanation. Showing people data and providing information and argumentation (reasons). Focus on convincing people to implement things the way administrators want.*
3. Peripheral participation	*Seek involvement by providing discussions, dialogue, participations in meetings (but no participation in decisions, vision development, etc). Provide resources. Acknowledge isolated initiatives (focus on results).*
4. Empowering	*Involvement by building values, leaders as role model (modeling values). Empower individuals through learning communities, participation in the planning process. Develop local leadership*

Table 9

Coding Scheme for View of Time: Participants' View of How Long It Takes to Achieve Improvement

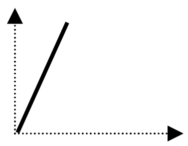
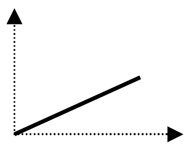
View of time	Description
1. Accelerated (3 yrs. or less) 	*Assumption that variables assumed in the beginning of the process will grow rapidly, without resistance, if they are worked out intensively (ignores feedback loops, systems resistance, and the effect of unexpected, uncontrolled variables that may arise along the way). Change is seen as a predictable process with no system resistance.*
2. Slow, continuous growth (> 3 yrs.) 	*Assumption that variables assumed in the beginning of the process will grow slowly due to individuals' internal resistance. Resistance is seen as a function of individuals' dispositions (i.e., individuals might be resistant to change), not a property of systems. Change is still seen as a predictable process.*

Table 9 (continued)

Coding Scheme for View of Time: Participants' View of How Long It Takes to Achieve Improvement

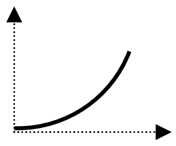
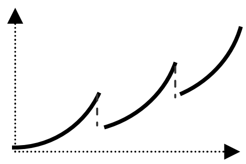
View of time	Description
3. Incremental growth 	*Assumption that change is slow and improvements are incremental because variables do not change proportionally as the time goes by (perhaps to variables' characteristics). It considers the role of unanticipated variables that might play out in the system, slowing the process of change. There is a clear demonstration that change is not a steady, predictable process, but lacks to idea of system resistance.*
4. System growth 	*Concern about the issue of sustainability of change. Assumption that change is a process of incremental changes* and resistance. *Because of feedback loops, previous improvements may not be sustainable, and change becomes a very slow process. Change is a constant game in which variables difficult to anticipate play out and interfere with the process. Change is seen as an unpredictable process.*

Table 10

Coding Scheme for Explaining No Improvements

View	Description
1. Rejecting	*Rejected the hypothesis of no improvements or could not think of an explanation.*
2. Focus on individuals	*Gave individual-related explanations for no improvement (particularly focusing on teachers and students)*
3. Focus on implementation	*Gave explanations based on the implementation process. No questioning of the model. Assumption that the model is good; implementation was problematic. No focus on individuals.*
4. Focus on reviewing the model	*Accepted the challenge and attempted to question initial assumptions and model.*

Table 11

Distribution of LC Scores Across the Three Groups

	LC scores			
	Score of 1	Score of 2	Score of 3	Score of 4
Supervisors	1	3	2	2
Principals	0	4	2	1
Teachers	0	7	2	0

Table 12

Solutions across the Three Groups: Number of References in Each Category

	Curriculum	Instruction	Teacher support	Teacher training	More staff and teachers	District policy and infrastructure
Supervisors	4	5	1	7	2	5
Principals	3	9	4	3	2	0
Teachers	3	10	1	0	4	9

Table 13

Total Number of Solutions by Category

Types of solutions		% of references
School-related		
	Instruction (e.g., new instruction techniques)	32.9%
	Teacher support (e.g., coaching, lesson study)	9.6%
District-related		
	Curriculum change/improvement	13.7%
	Teacher training	13.7%
	More teachers and staff	10.9%
	Infra-structure (e.g., day cares, after school programs)	19.2%

Table 14

Distribution of Types of Solution Across the Three Groups

	Types of Solution		
	Score of 1 Sys. Maintenance	Score of 2 Local Change	Score of 3 Broad Change
Supervisors	2	1	5
Principals	6	1	0
Teachers	6	3	0

Table 15

Distribution of Scores for Time to See Improvements

	Accelerated	Slow-continuous	Incremental	Systemic
Supervisors	2	3	1	2
Principals	2	2	2	1
Teachers	6	2	0	0

Table 16

Distribution of Scores for Ways to Explain no Improvement

	Rejecting	Focus on Individual	Focus on Implementation	Reviewing Model
Supervisors	2	3	1	2
Principals	1	3	2	1
Teachers	3	4	1	1

Table 17

Distribution of Scores for Ways to Involve Others Across the Three Groups

	Imposing (*score 1*)	*Persuasive* (*score 2*)	*Peripheral* (*score 3*)	*Empowering* (*score 4*)
Principals	*1*	*2*	*2*	*2*
Supervisors	*3*	*1*	*1*	*3*
Teachers	*5*	*3*	*0*	*0*
Total	*9*	*6*	*3*	*5*

Table 18

Distribution of Thinking Patterns Across the Three Groups

	Thinking Patterns			
	Non-systemic	Localized-linear	Complex	Systems-oriented
Supervisors	2	2	1	3
Principals	2	2	3	0
Teachers	4	4	1	0

Table 19

Distribution of Scores for Solutions and Ways to Involve Others Across the 4 Thinking Patterns

	Thinking Patterns			
	Non-systemic (n=8)	Localized-linear (n=8)	Complex (n=5)	Systems-oriented (n=3)
Solution type				
Maintenance	8	3	3	-
Local	-	3	2	-
Broad	-	2	-	3
Involving others				
Imposing	3	5	1	-
Persuasive	3	2	1	-
Peripheral	-	1	1	1
Empowering	1	-	2	2

Figure Captions

Figure 1. Rationale supporting the two main goals of the study

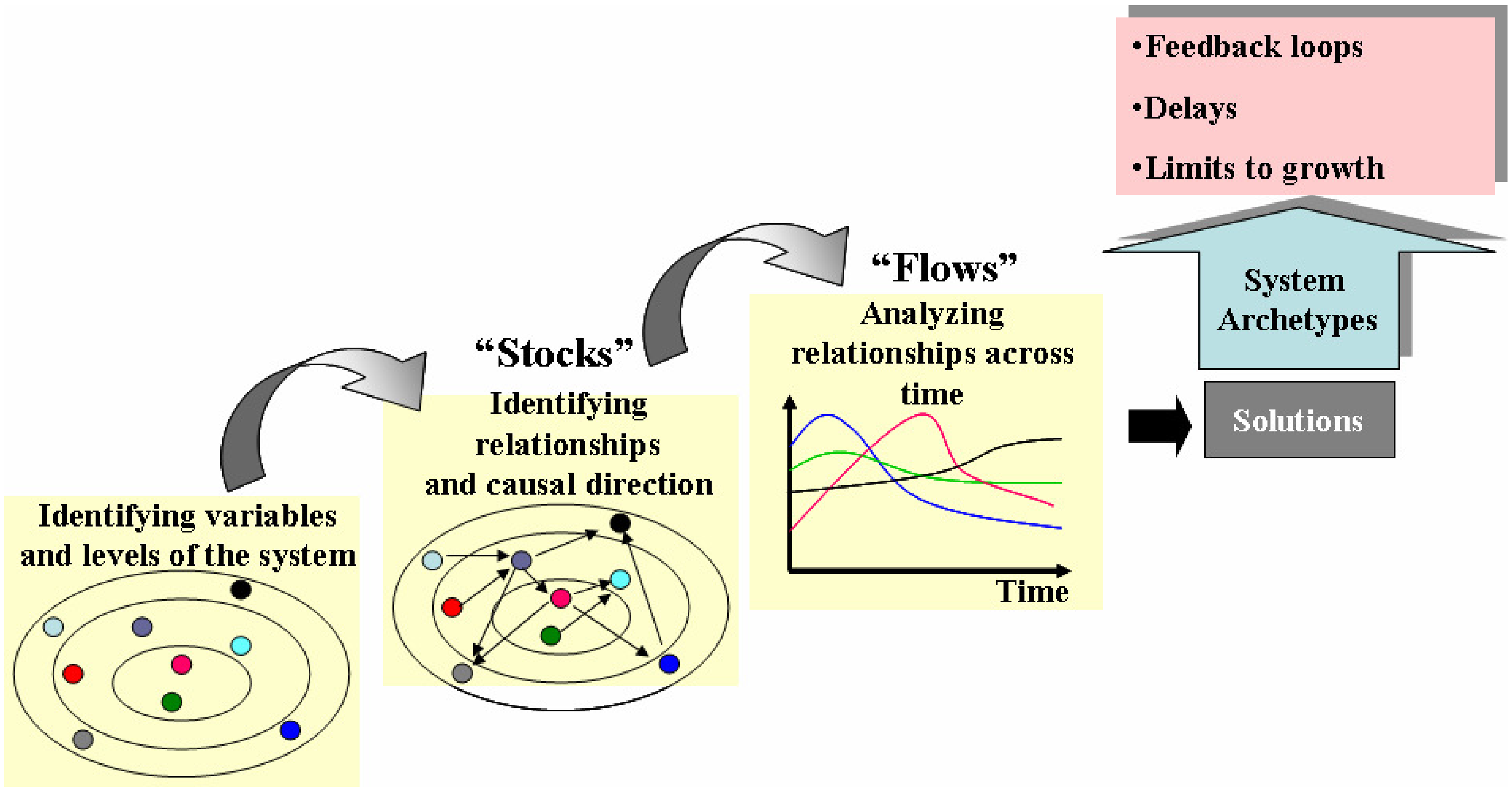


Figure 2. Example of a non-causal representation

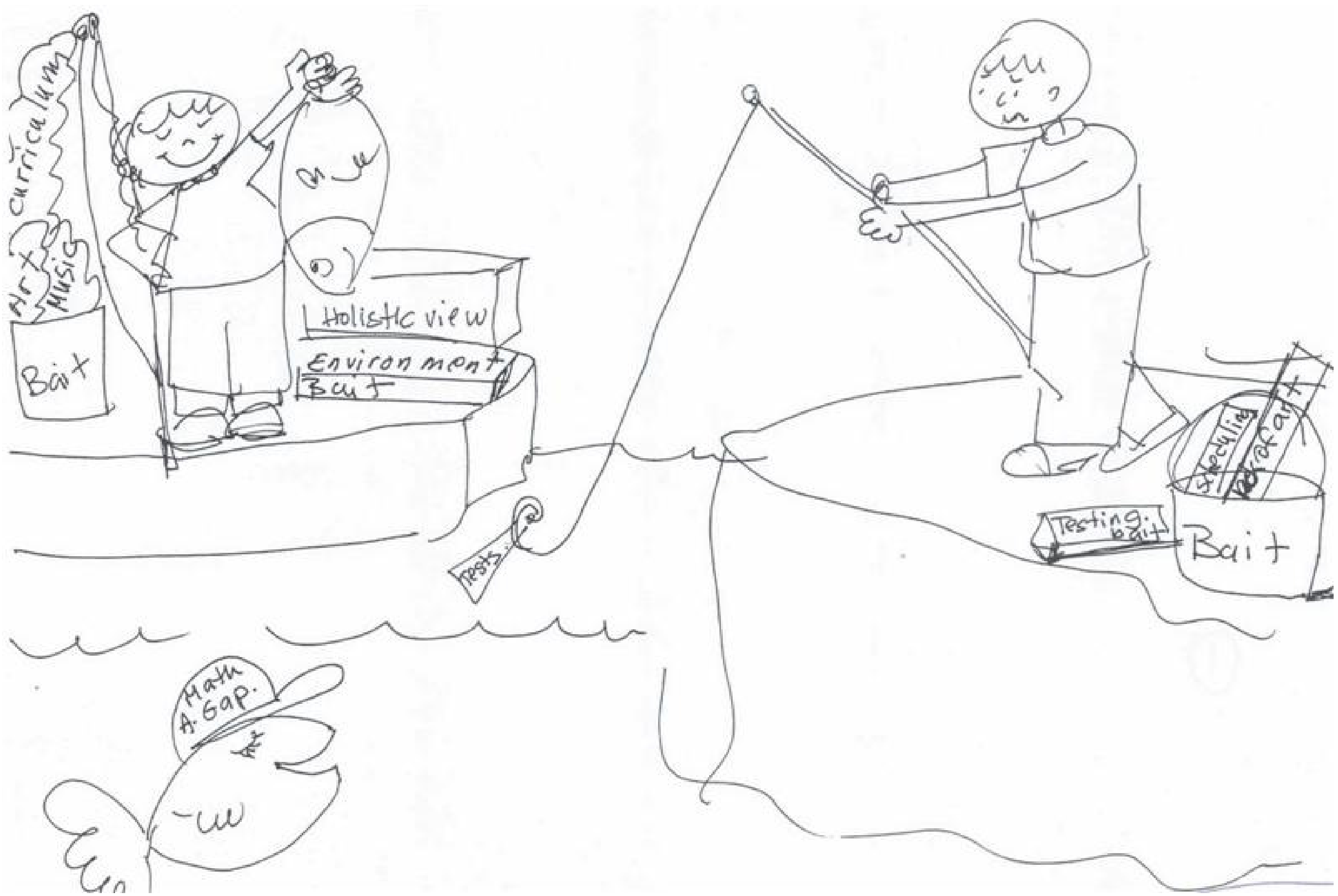


Figure 3. Example of a simple causation representation

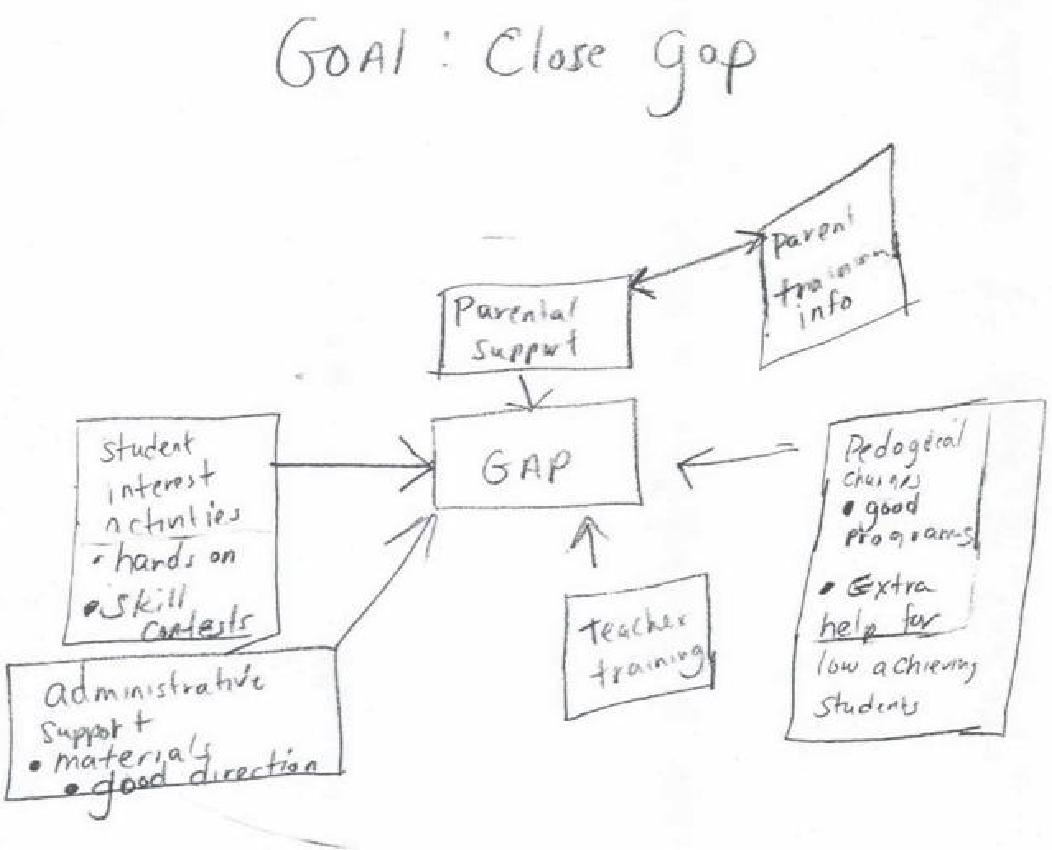


Figure 4. Example of a causal chain representation (The participant defined as a "zipper")

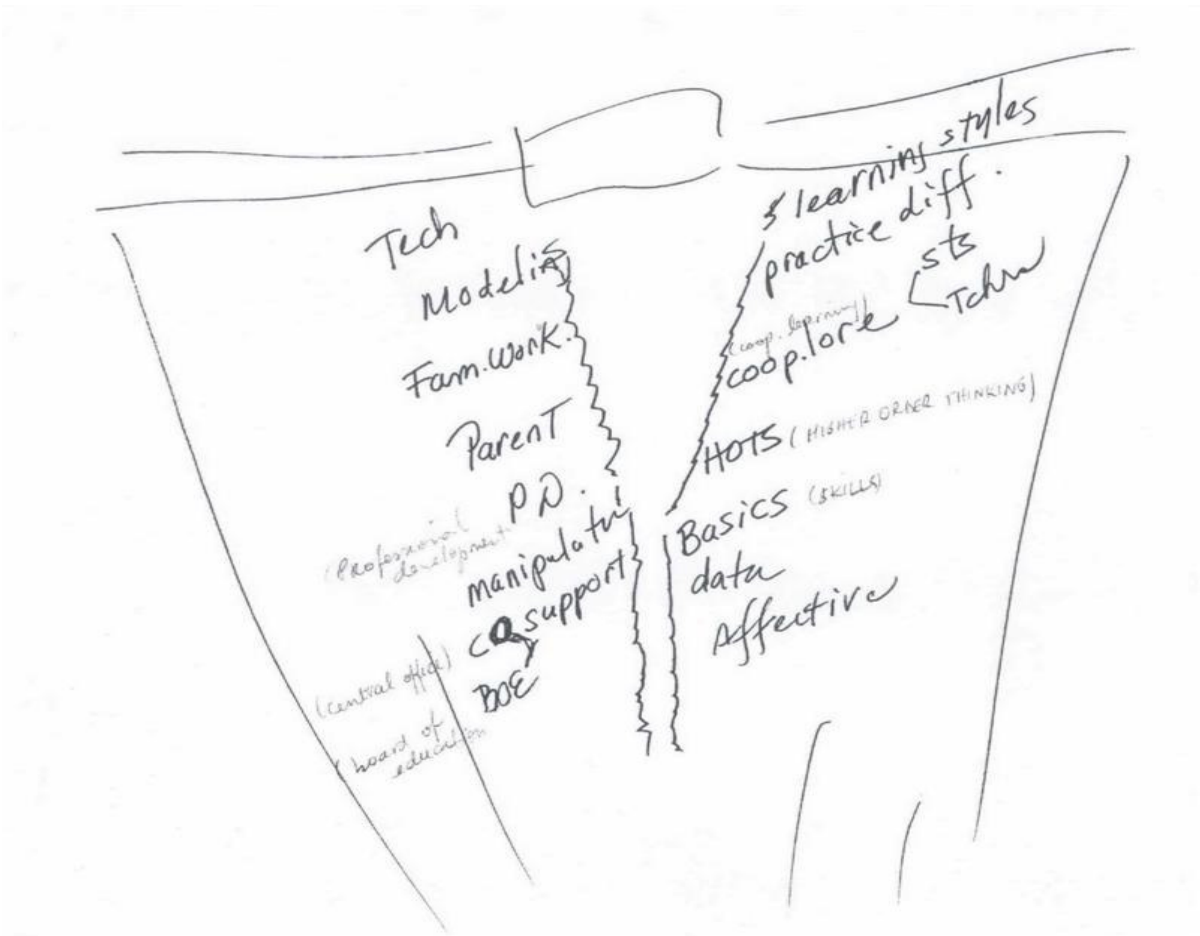


Figure 5. Example of a reciprocal causation representation

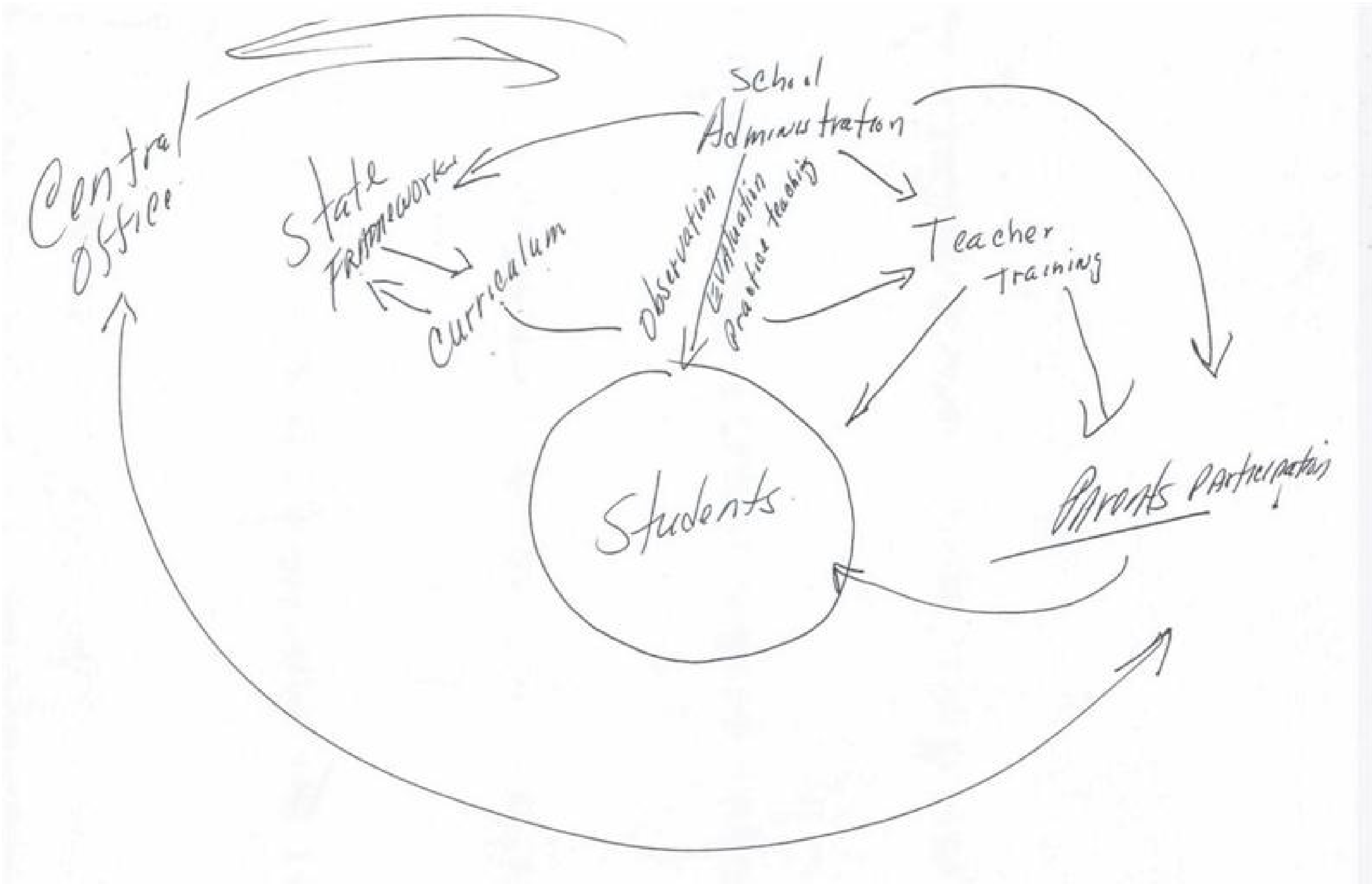


Figure 6. Example of a simple level representation (with additional details provided verbally)

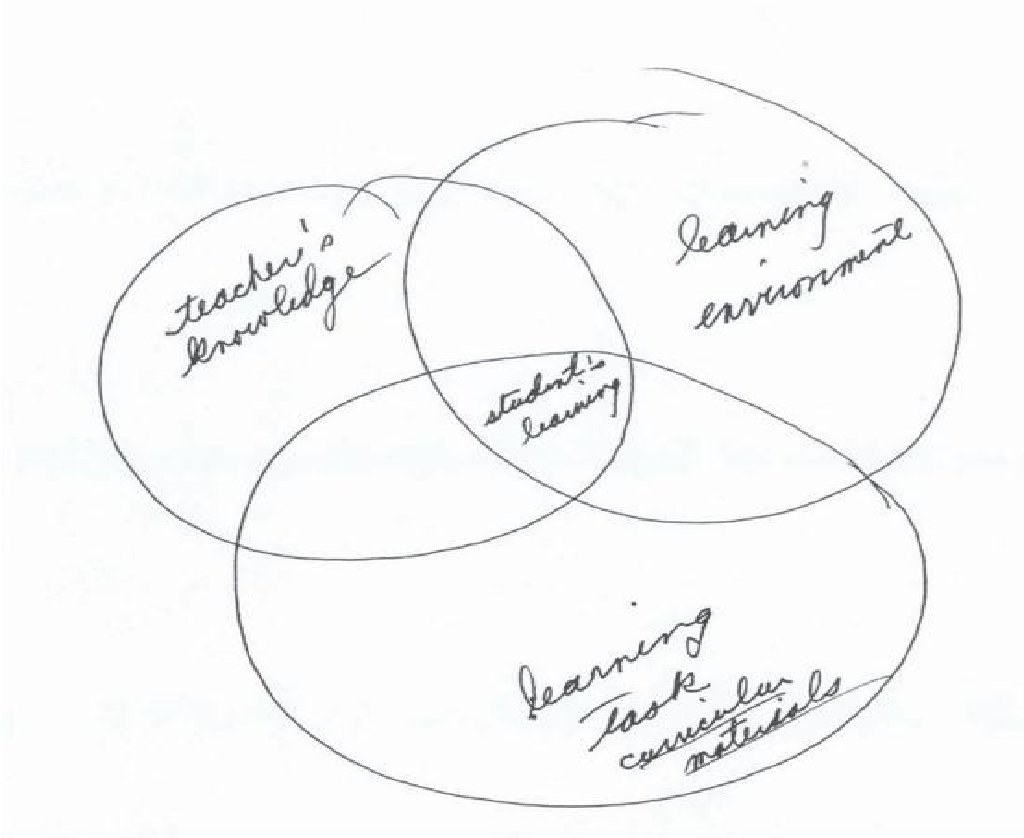


Figure 7. Example of a complex level representation

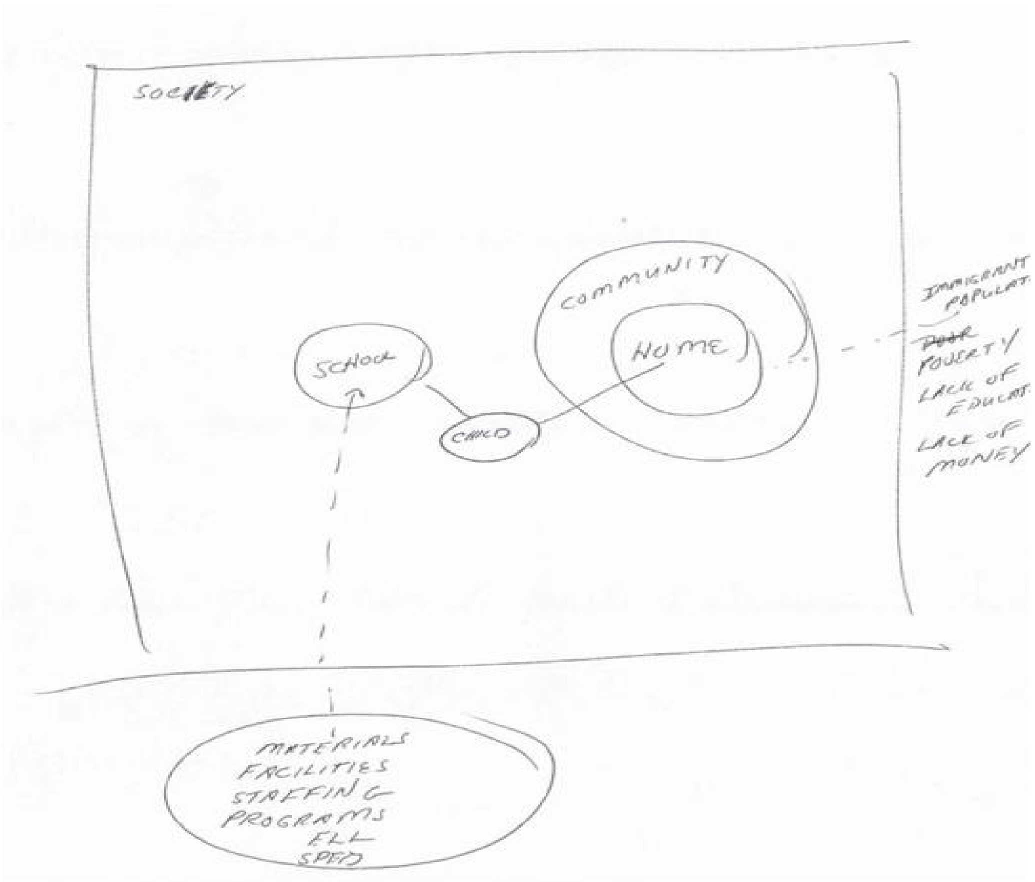


Figure 8. Example of a system-effects representation

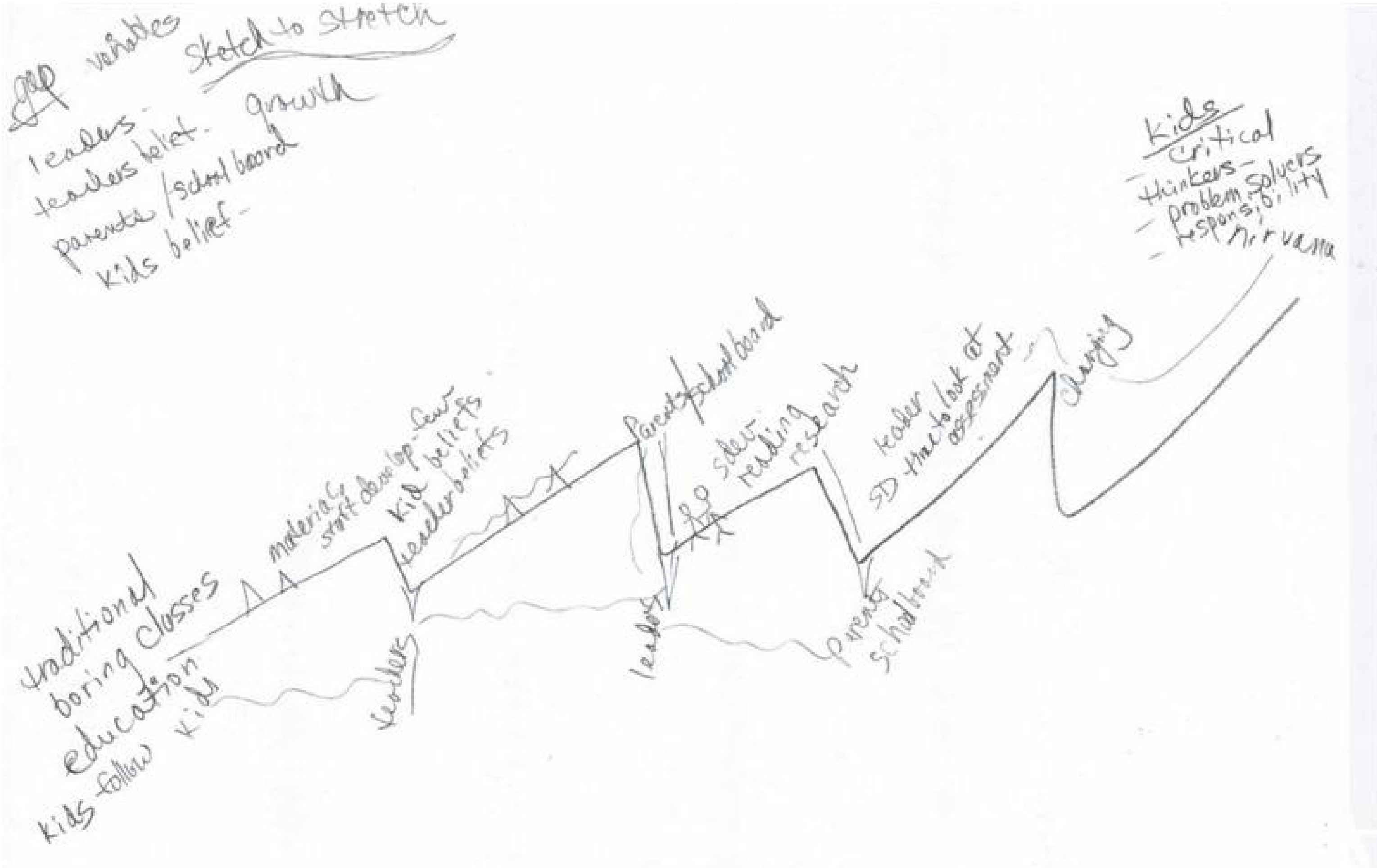


Figure 9. Problem-solving patterns across the four causal thinking patterns.

	CHANGE IN THE SYSTEM	NO CHANGE IN THE SYSTEM
EMPOWERING WAYS TO INVOLVE OTHERS	SYSTEMS-ORIENTED CAUSAL THINKING	COMPLEX CAUSAL THINKING
NON-EMPOWERING WAYS TO INVOLVE OTHERS	LOCALIZED-LINEAR CAUSAL THINKING	NON-SYSTEMIC CAUSAL THINKING

Curriculum Vitae

Maria Carolina Da Costa

Education

2007 (Oct)	Ph.D., Education; Rutgers, The State University of New Jersey
2001	M.A., Business Administration; EAESP-FGV, São Paulo, Brazil
2000 (Jan-May)	Exchange Program, Business Administration; University of Texas At Austin, Texas
1996	B.A., Business Administration; EAESP-FGV, São Paulo, Brazil

Professional Experience

2007	*Department Head*, Teaching & Learning Dynamics, Ibmec São Paulo, Brazil
Sep05-May06	*Graduate Assistant* to Dr. Clark A. Chinn
Sep04-May05	*Graduate Assistant* to Dr. William Firestone
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May03-Sep01	*Teaching Assistant*, Department of Educational Psychology, GSE

Publications

Chernobilsky, E., DaCosta, M.C., & Hmelo-Silver, C. (2004). Learning to talk the educational psychology talk through a problem-based course. *Instructional Science, 32,* 319-356.

Chernobilsky, E., DaCosta, M.C., & Richard, L.F. (June, 2003). Case-based instruction: Answered and unanswered questions. Presented at *The American Occupational Therapy Association's 83rd Annual Conference and Expo, Washington, DC.*

DaCosta, M.C. (October, 2005). Learning to see the whole: The impact of systemic thinking in explanation and decision making. Presented at the *Graduate School of Education's Brown Bag Series*, *Rutgers University, NJ.*

DaCosta, M.C. (May, 2003). Towards an assessment methodology for pre-service teacher thinking in an online problem-based learning environment. Presented at the *Graduate School of Education's Annual SAC Poster Session, Rutgers University, NJ.*

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DaCosta, M.C, & Chinn, C. (June, 2004). Who is to blame? The impact of views of causal agency on reasoning and decision making. Presented at *the International Conference of the Learning Sciences (ICLS), Santa Monica, CA.*

DaCosta, M.C**.,** & Chinn, C. (May, 2004). The impact of causal agency on reasoning. Presented at the *Graduate School of Education's Annual SAC Poster Session*, *Rutgers University, NJ.*

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