The Principal Role in Data Driven Decision Making:

Using case study data to develop multi-mediator models of educational reform

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Abstract

The expectation that educators will use data in the service of school improvement and planning is a major feature of national and local reform agendas. Prior research has found that the principal plays a critical role in making policymakers' visions for data use a reality at the school and classroom levels. Most prior studies, however, have not fleshed out how the principal functions as a key agent in influencing other key players in data use. This article will illustrate the actions of the principal, teachers, students, and district personnel through simulation models of principal leadership that we developed based on a case study of a high school implementing this reform. We use these models both as a framework for understanding our findings and as a way to enhance understanding of the processes by which educational reform is co-constructed through the simultaneous mediation of the multiple agents involved in the system.

Introduction

Data driven decision making (DDDM) is the process by which administrators and teachers collect and analyze data to guide a range of educational decisions (Ikemoto & Marsh, 2007). Data use has become a prevalent feature of numerous countries' policies and reform agendas, including in the Netherlands (Schildkamp & Teddlie, 2008), England (Ehren & Visscher, 2008), and Canada (Earl & Katz, 2006). DDDM is also a major feature of the American Recovery and Reinvestment of Act of 2009 and the Race to the Top Competition sponsored by the US Department of Education (Hamilton, Halverson, Jackson, Mandinach, Supovitz, & Wayman, 2009).

The theory of action underlying these policies requires that educators know how to analyze, interpret, and use data so that they can make informed decisions in all areas of education, ranging from professional development to student learning. On the leadership front, the assumption is that when school and district leaders become knowledgeable about data use, they can more effectively review their existing capacities, identify weaknesses, and better chart plans for improvement (Earl & Katz, 2006). For teachers, the assumption is that examining test results will allow them to target instructional practices towards students' individual needs (Mandinach & Honey, 2008).

However, data need to be effectively used to improve instruction in schools, and individual schools often lack the capacity to implement what research suggests. In data driven decision making (DDDM), reform success is a joint accomplishment, or co-construction, of individuals and policies at multiple levels of the system (Datnow & Park, 2009). Local

education authorities, such as school districts, can play a key role in helping schools build the skills and capacity to use data for decision making (Supovitz & Taylor, 2003; Togneri & Anderson, 2003). However, the role of the principal as a site leader is the critical link in making district visions for data use a reality at the classroom level. This article will illuminate the role of the principal as an agent in the DDDM reform process by using qualitative data and developing multi-mediator simulation models.

Review of Literature on the Role of the Principal in DDDM

Recent studies have noted that the principal is a key player in DDDM (e.g., Ikemoto & Marsh, 2007; Mandinich & Honey, 2008; Wohlstetter, Datnow, & Park, 2008). Young's (2006) study of teacher data use found that principals were critically important in setting the goals for data use within school. Similarly, Wayman's (2005) study found that school leaders are key in building a culture of data use within schools. Kerr, Marsh, Ikemoto, Darilek, and Barney's (2006) study found that the principal played an important role in getting DDDM efforts off the ground and then in establishing distributed leadership for DDDM to take hold throughout the school.

Principals have been found to be pivotal in modeling effective data use and in enabling teachers to use technology (Mandinach & Honey, 2008). Principals are also critical in providing ongoing learning opportunities for teachers to discuss and analyze their students' data (Ward-Roberts, 2009). Principals play a key role in making sure that professional development and collaboration time is "protected" and focused on data use, rather than "administrivia"

(Butler, 2009). Supovitz and Klein (2003) sum up the importance of principal leadership noting that "the fingerprints of strong leadership are all over the data activities" (p. 36) found in data driven schools.

The above studies give insight into the key activities of principals in facilitating DDDM. At the same time, numerous studies have pointed to the ways in which principals can inhibit successful data use. One of the major obstacles to principals' effectiveness in leading DDDM efforts is their lack of data literacy (Wu, 2009). Educational leaders "often have no idea what the data mean or how to use it" (Earl & Katz, 2006, p. 17) and not surprisingly feel insecure about their schools in leading DDDM efforts (Wu, 2009). A data literate leader is defined as one who is able to (1) think about the purposes of data, (2) recognize sound and unsound data, (3) possess knowledge about statistical and measurement concepts, (4) make interpretation paramount, and (5) pay attention to reporting and to audiences (Earl & Katz, 2006). The problem, however, is that many principals have not had adequate training in understanding, analyzing, and interpreting data (Mandinach & Honey, 2008; Wu, 2009), and thus it is difficult for them to enable their teachers to do so.

The principal's lack of active engagement in the DDDM process has been cited as an additional barrier. The principals in Markarian's (2009) study purported to support DDDM, but the teachers described them as not having much follow-through in terms of active involvement in the DDDM process. One teacher described her principal’s approach to participating in the collaboration meetings as "putting on the board 'discuss assessments' blah, blah, blah..," but then

leaving it up to the participants to decide how much in depth they will go. The teachers wanted the principal to establish "more consistent meetings" and "guided rules" for DDDM.

Although all of these studies point to the important role of the principal, they have not examined in detail the ways in which the principal functions as a key agent in influencing the actions of others in the DDDM process. This article will illustrate the actions of the principal, teachers, students, and district personnel through simulation models of principal leadership that we developed based on a case study of a school that implemented this reform. Our models represent the multiple simultaneous mediation that characterizes educational reform as it is being implemented. The models incorporate the actions of the principal as site leaders, the principal's interactions with teachers and students within their own schools, all within the larger context of their interactions with their district administration.

We use these models both as a framework for understanding our findings and as a way to enhance understanding of the ways in which educational reform is co-constructed through the simultaneous mediation of the multiple agents involved in the system. We explain how schools, like other organizations, exhibit the property of dynamic stability, reacting to reform efforts with self-repair efforts characterized by the operation of multiple mediators, each operating on its immediate neighbors to maintain a specified relationship. Many reform efforts lead to some initial changes in the overall organization, which are "self-repaired" leading to a restoration of the overall structure of the organization with only minor lasting changes. However some reform efforts lead to a reorganization of the structure of the organization. The use of the framework

presented here helps us to determine the types of actions by principals that lead to self-repair and the types that lead to reorganization (i.e., more successful DDDM), through the characterization of the landmarks and mediators that characterize the organization. We explain the framework in more detail below.

Theoretical Framework on the Co-Construction of Educational Reform

In their seminal RAND Change Agent studies, Berman and McLaughlin (1978) aptly argued that implementation is not a technical-rational, linear activity, but rather should be seen as a process of mutual adaptation. They found that although policies can enable preferred outcomes, even fully planned, highly coordinated, and well supported policies ultimately depended on how individuals within the local context interpreted and enacted those policies (McLaughlin, 1987). Building on the importance of context suggested by the mutual adaptation perspective, the *co-construction perspective* (Datnow, Hubbard, & Mehan, 2002) on reform shows how multiple levels of the educational system may constrain or enable implementation. The *sensemaking perspective* (e.g., Coburn, 2001, 2006; Spillane, Reiser, & Reimer, 2002) also reveals the shaping features of context, but highlights social learning and cognitive capacity. Both assume some level of social construction at the local level. They place implementers at the forefront of reform, highlighting the process by which they interpret, adapt, or transform policy. Both perspectives show how actors (i.e., teachers) mediate reform, and how their beliefs and experiences influence the implementation of reform. Both the sensemaking and co-construction perspectives share a relational sense of context. Researchers assume that people's actions

cannot be understood apart from the setting in which the actions are situated; reciprocally, the setting cannot be understood without understanding the actions of the people within (Datnow & Park, 2009).

Co-construction has many of the same assumptions as sensemaking, but it also takes into consideration political and cultural differences, acknowledging the role of power (Datnow et al., 2002; Hubbard, Mehan, & Stein, 2006). As in the sensemaking perspective, the co-construction perspective recognizes that agents at all levels contribute to the policymaking process and that the process is characterized by continuous interaction among actors within and between levels of the system. However, differential access and use of power are affected by an actor's position in the system (Firestone, Fitz, & Broadfoot, 1999).

Multiple simultaneous mediation by various actors, agents and artifacts plays a central role in our models of the implementation of DDDM. As Mehan (1992) argues, "Social actors [do not] function as passive role players, shaped exclusively by structural forces beyond their control; they become active sense makers, choosing among alternatives in often contradictory circumstances" (p. 3). In some cases the various mediations operate collaboratively toward common goals; in other cases they work at cross-purposes leading to conflict; and in yet other cases they operate mostly independently of each other.

In this article, we use mediational models to illuminate the role of the principal in mediating the actions of others in the educational system as they attempt to implement DDDM.

The research questions guiding this study include:

1. How can a mediational model help us understand how the principal's actions with respect to DDDM fit within a broader context?
2. How do the actions of the principal interact with those of other key players (e.g., district leaders, teachers, and students) in DDDM in the model? Which interactions appear to lead to organizational self-repair and which lead to reorganization (i.e., reform)?

We will address these questions using case study data from a high school engaged in data use to inform simulation models we developed of the site leadership process.

Methods

The data that informed our simulation models were gathered as part of a previous case study of urban schools across the U.S. that exhibited positive outcomes which may be related to their implementation of data driven decision making (see Datnow, Park, & Wohlstetter, 2007; Datnow, Park, & Kennedy, 2008)[1]. Purposive sampling was used to identify and select the research sites (Yin, 2009) since we were interested in studying how school systems implemented DDDM practices. Sites were chosen on the basis of being strong implementers of DDDM and for their record of improving student achievement over time. In order to determine whether sites were strong implementers, we asked them a set of screening questions about the

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structures in place to support DDDM (e.g., a data management system, professional development regarding data use, benchmark assessments), and what evidence they could point to regarding a culture of data use. In order to be selected, schools also had to serve student populations that were diverse in terms of race/ethnicity and socio-economic status, and they had to show records of improving academic achievement on state assessment tests. Selected sites were chosen from a list of over seventy five sites that were recommended as fitting the criteria by educators and researchers whom we consulted with due to their expertise about data use. The research team narrowed down the list to 12 sites after reviewing system Web sites and conducting phone interviews with district and school leaders. While acknowledging the successes they had experienced in becoming more data driven, all leaders also were careful to note that their work was "in progress."

Although there were 12 sites in the larger study, for the purposes of this paper, we have chosen to highlight one site in detail. This site well illustrates the dynamics of how the actions of the principal intersect with other actors (teachers, students, district administrators) in the DDDM process. For the purposes of confidentiality, pseudonyms are used for school and district names.

Bear Valley High School is a large comprehensive high school in the United States. The district in which the school is located has continued to show improved student performance over time and has received accolades for their efforts at urban educational reform. During the period of our study, the district served approximately 50,000 students. Bear Valley's student

population was comprised of 1600 students, 52% of whom were Asian (primarily Vietnamese, with smaller groups of Chinese, Korean, and Japanese), 38% Hispanic, 8% White, and less than one percent of other ethnicities. Sixty-seven percent of the students received free- or reduced-price lunch, and 42% were English Language Learners, many of them recent immigrants. Bear Valley has been a leader in data use in the district, which itself has had a culture of data use – and structures to support it -- dating back almost a decade.

Our research team conducted case study data collection in the district and school during the period of 2007-2008. We interviewed three administrators from the district office, the principal and another administrator at the school site, and twenty teachers across grade levels and academic disciplines in a combination of interviews and focus groups. In addition, the team observed in ten classrooms and attended four meetings focused on data use in order to collect data to triangulate findings. Finally, the team analyzed a plethora of documents at the school and district levels that were pertinent to our study.

All of the interviews and focus groups were recorded and transcribed verbatim. Field notes of classroom and meeting observations were also typed. Using the case study data, we developed simulation models of the site leadership process, implemented in NetLogo (Wilensky, 1999). We use this simulation framework so that we can represent the processes of the multiple simultaneous mediations that operate in our case study of DDDM. The models that we present here are instances of agent-based modeling, in which many different agents simultaneously interact with other agents. Even though the character of the interactions is relatively simple, such agent-based models can represent complex activity since the complexity

emerges from the multiple simultaneous interactions. Such agent-based models are widely used in the physical and biological sciences, but only recently have been used to model educational situations (Abrahamson & Wilensky, 2005; Abrahamson, Wilensky, & Levin, 2007; Blikstein, Abrahamson, & Wilensky, 2008).

Findings

The findings of our paper are presented in several main sections according to our research questions. First, we explain the broader context in which principal actions are embedded. Second, we show how principal actions are related to the actions of district leaders, teachers and students. Third, we use our simulation models to show how the principal's actions are influenced by actions at other levels, revealing the importance of a set of key principal actions, implemented in tandem, in order to implement DDDM.

The Role of the Principal in Broader Context

In order to understand the role of the principal in the DDDM process, it is important to first situate the principal's role in a broader context. In Figure 1 below, we show that while principals play an active role in site leadership, there are also other actors who play important roles in the co-construction of the reform.

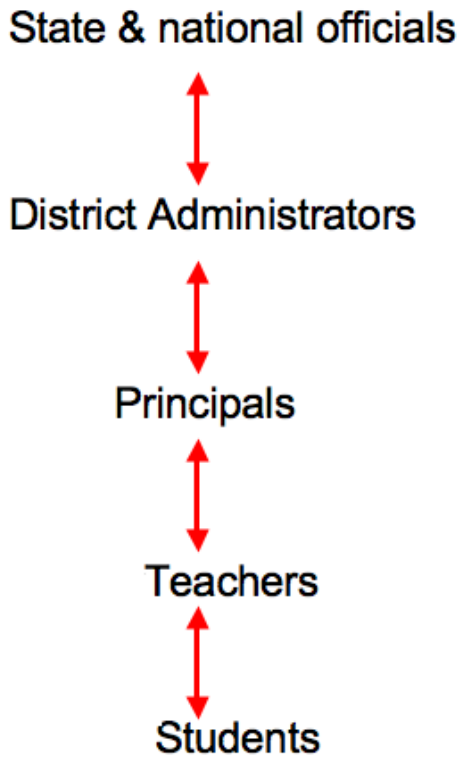

Figure 1: The context for our leadership model for DDDM.

The vertical dimension is that of power, and the actors involved serve as landmarks defining that dimension. Site leadership is a mediation that involves actors from multiple levels of this power dimension. That is, principals ideally work in an interactive relationship with teachers to influence student learning. Principals mediate district policies that frame teaching and learning activities in the classroom, and they also set school level policies working in concert with teachers and other leaders at the school, such as assistant principals or lead teachers.

Before we operationalize this model with respect to Bear Valley High School, we will first briefly describe the context for data use at the school.

Context for Data Use

The district and the school both had very stable leadership during the period of our study. The superintendent and her two cabinet members had all been in the district most of their careers, moving up from the ranks of teachers. The superintendent was applauded by school site staff for providing strong, but steady leadership for the district and for being very supportive of school site autonomy and decision making. She promoted an incremental approach to change. Her mantra, according to the principal of Bear Valley, was "take it slow." She was very careful to find ways to develop teacher ownership for reform efforts, rather than imposing mandates from above that might produce resistance. The principal echoed this style in her own leadership. She was described by her staff as a leader who gently brings others along, rather than pushing them into things. As one teacher described, "She is really good about saying, 'here's where we're going,' but kind of letting the teachers have a little more ownership… She's really into doing the baby steps and letting people first volunteer. Then it kind of infuses throughout the whole campus and then even those naysayers start to say, 'well, I'll check it out…'"

Bear Valley was always thought to be a comfortable place for teachers to work and for students to attend school. Teachers were described as "caring." Interestingly, it was the arrival of a new principal in 2000 and the push towards standards-based instruction that initially catalyzed change and higher expectations for students. The principal noted, "I've seem the staff evolve in that now we see we can also be very caring AND challenge our students." One

teacher explained, “It was projected that we were going to be designated a Program Improvement (PI) school because of test scores dipping one year…We got a heads up that we better do something.” With leadership from the principal, the school staff decided to be proactive, as did the district, which soon thereafter partnered with external consultants to help them improve on standards based education. The school never did fall into PI status and student performance has increased ever since. The principal was credited by several teachers as having led the school into data use and out of possible designation as a PI school.

The superintendent noted that Bear Valley's interest in data use pre-dated the district’s own work in the area: “Some of what they have been doing there has been incorporated as part of the system… but the school’s very much invested in what they’re doing as well. So it’s a little bit of a different kind of ‘bottom up.’ And now the top is helping the bottom, rather than kind of top-down.” She contrasted the data use efforts there to other districts where it often completely top-down.

Principal Key Actions in the Data Use Process

An analysis of the case study data revealed that there were four broad key actions by the principal that facilitated DDDM at Bear Valley. However, this case makes clear that actors at multiple levels played important roles, and that their actions worked in tandem (or sometimes in conflict) with each other. In the sections that follow, we highlight the principal actions in four key areas, while also displaying their interconnections to other levels (e.g., district, teacher, and

student).

1. Formulating goals that are specific to the needs of the school and community;
2. Providing structures to support DDDM;
3. Building human and social capital;
4. Creating a climate of trust and collaboration and a culture of data use.

These four actions were distilled by using our qualitative data to develop a list the various principal actions we observed and the frequency of them. We used tally marks to record the principal actions that seemed to come up over and over again (the four above) versus those that emerged less frequently. The pattern of critical actions was mostly consistent across all 12 case study sites, but we focus on the Bear Valley example here.

Goal setting. Although district administrators were careful to acknowledge the important role of site level actions at Bear Valley, the district itself had a strong initiative for data use, driven by the district's explicit, measurable system-wide goals for student progress. First, students were expected to progress through the bands on the state test annually. Within five years of being in the district, all students were expected to be at least scoring at the proficient level and no student was to drop out of the proficient/advanced proficiency level. Second, all English language learners were expected to progress through the state English language proficiency levels annually.

The school worked diligently to achieve the district's student achievement goals. One of

the key actions for the principal then was formulating goals tied to improving learning and instruction that were specific to the needs of her particular students and community. As noted earlier, when the principal arrived at the school, her first major initiative was to orient teachers around the goal of high expectations for all students. A teacher explained that they had also developed their own goals at the school site, which went above the district goals in some respects. She said, "This is what a Bear Valley graduate should look like, how they should stand out from the rest." This was to be reached by diligently teaching towards the state standards, which was the district's expectation. In addition, the principal and the school staff was also working on the goal of having more students be college-ready when they leave high school. As the principal shared, "Everything stems from that… instructionally, how we set up our master schedule, whatever we think we need to do to make sure all our kids get there…" Thus, even before the district set a goal of having all students complete the course requirements for entry into the state university system, Bear Valley had been working towards this goal as a school.

Structural supports for data use. After goals for student learning had been established at Bear Valley, the principal led the staff in creating curriculum guides for each subject that embodied the state standards and reflected the goal of college readiness for all. As one teacher stated, "She took the lead to do curriculum alignment before it was the huge thing." The teachers worked within departmental collaborative groups to create these guides. The principal then set the expectation for teachers to create their own benchmark assessments in all core subjects. She was very careful to ensure that the teachers developed their own sense of

leadership in this effort, and they did. Several teachers remarked on the high degree of trust the principal had for the teachers and how much she respected their judgment.

After the reform efforts were underway at Bear Valley, the district learned from what had been accomplished among the staff there and established district wide structural supports for data use. First, the district created curriculum guides. Teachers from Bear Valley were brought into the process at all stages, and in fact the guides developed at Bear Valley were used to help inform the district guides. Teachers also were given previews and piloted the guides and instructional materials. The principal credited the superintendent for validating the work of teachers in this effort, "She was phenomenal. She said, 'we don't want to undo what you've done.'" While teachers were involved in the development and felt credited, they also struggled to reconcile the district guides with their own once they reached the level of full implementation in the district. The teachers were accustomed to their own guides and felt that the district's pacing guide did not allow them enough flexible time for reteaching. The principal served as mediator between district policies and local needs, helping the teachers make informed decisions about curricular pacing. A teacher remarked that they were respected as professionals by both the principal and district leaders and were permitted to make adjustments that were in their their students' best interest.

In addition to rolling out curriculum guides, the district required all teachers in core subjects to administer quarterly, district produced benchmark assessments. The district also invested in a web-based data warehouse system that enabled users to access student achievement from the tests within a few days. Reports from state assessment, benchmarks, and

other teacher created tests were also uploaded into the system. Assessments were seen as a way to assess students' progress towards meeting the state standards. The results from the assessments were then ideally used, as one teacher said, "to be able to say 'these standards are being met'" and, if they aren't, "to be able to go back and make sure students achieve mastery of them."

The principal's role in ensuring that data from the assessments were analyzed and used for action planning was critical. As one teacher said, "data became a focus ever since our current principal came. It's what she likes, and it's obviously what she's good at because we've done well with all this data collection and analysis." She provided time for meetings to discuss data, flexibility for re-teaching, and curriculum and material resources in order to facilitate data driven instruction. Structured time for data discussions among teachers was probably the most important scaffolding for continuous improvement. When reform efforts began at Bear Valley, the principal encouraged teachers to meet at lunch or after school. However, later the district provided for planned teacher collaboration time, which was seen as a major positive improvement. The principal established a schedule whereby meetings would take place from Wednesdays from 7:30-9:00 a.m. Students would arrive at school at 9:30, allowing the teachers 30 minutes from the end of the meeting to the beginning of instruction. Building in this transition time was seen as important by the principal who didn't want teachers to feel rushed and thus tempted to use data discussion time for class preparation.

In order to improve the quality of the meetings, the district created data analysis protocols for teachers, and in some cases for students as well. Data discussion templates were

used to guide teachers through a discussion of strengths, areas of weaknesses, grade level trends, and subgroup trends. The discussion was then followed by a brainstorming session among teachers on instructional and grouping strategies and action plans. A Bear Valley teacher explicitly stated that the expected outcome of the data discussion was "modification of instruction." An teacher reiterated, "I'm really trying hard to go back to the standards that the majority of the class hasn't hit on… Let's see if I can teach it in a different way. Or maybe that's where I can talk to other teachers and ask how they did that." One teacher said she consulted her students after identifying weakness areas, asking them what she could do to perhaps teach the material more effectively. However, as noted above, a limitation was the time available for re-teaching of content. As one teacher noted, "So when we come up with an action plan….we have to be very strategic in making sure that we can get it in within the time."

Nevertheless, a staff member at Bear Valley shared that data discussions are key because "data is only good as you understand it and you analyze it, and then it's only good as you do something about it." The superintendent also believed it was important to follow through and take actions based on data: "What good is data if it doesn't change something? It is like knowing your blood pressure is high, but if you don't do anything about it, you're going to die anyway. Well, I might as well stop taking the reading!" She added: "Bear Valley is ahead of the curve… in terms of a willingness to start going there."

Building Human and Social Capital. As the above discussion implies, the third important action was building human and social capital in the form of building the knowledge and skills of teachers. To be sure, the district was very engaged in providing professional

development to teachers. As one teacher explained, “They are very proactive. ” District-run professional development concentrated on instructional issues. One of the goals of the professional development offered by the district through its Strategy Academy has been to use common instructional strategies and approaches across departments. Teacher representatives from across departments came together with assistant principals, principals, and counselors several times a year. They discussed strategies for writing across the content areas, looking at students reading below grade level, assessing the needs of English language learners, academic vocabulary, and student placement, among other issues. Teachers also received training in how to use the data management system. Numerous teachers we spoke with wished for more training in this area. Even though significant resources had been committed to professional development on improving instruction, district office administrators spoke about the long road ahead. “We have loads of work to do ...on strategies, differentiation… all those things,” said the superintendent.

In addition to the districts' professional development efforts, site leadership efforts were critical in supporting teachers' data use efforts. In her efforts, the principal attempted to build two types of capacity regarding data use -- the capacity to analyze and interpret the data and the capacity to change their instruction accordingly. The principal said she looked for “leverage points” in her work with the faculty, finding entry ways into getting them on board to try new practices. One of the ways she does this is by using a distributed leadership approach. A teacher explained, “She’s really good at using teacher leaders, the department chairs, the leadership team… You know really in a lot of cases, if the principal says it, it’s going to be

viewed negatively... so using other voices can be very effective. ”

The principal assembled a data team of two teachers for the purpose of supporting data driven decision making at the school site. The teachers who formed the data team had attended special trainings in how to use the district's information management system and in how to help guide their colleagues in making decisions on the basis of data. They were teachers who were particularly committed to using data and thus volunteered for this extra responsibility.

The principal attempted to create a climate wherein teachers learned a great deal from each other. For example, one teacher remarked that while looking at "the numbers" did not inspire her, as she knew how her students were doing, but the opportunities to compare results with her colleagues to share instructional strategies that arose out of the data discussions were very useful. Overall, teachers described working together on a frequent basis. One science teacher said that she and the teacher next door collaborate continuously: "Our door is open between every period, all the time. We're constantly going back and forth."

The teachers at Bear Valley were seen by each other as unusually willing to try new things and experiment with data use, especially if the supports were available to do so. As one teacher explained, though some teachers are certainly more comfortable with data use than others, "The one thing about our teachers is if you sit down with them and you show them and you walk them through it and they feel like they have somebody they can rely on, they will try anything new." Thus, although teachers were interested in using data and found it useful, they were also aware of its limitations: "It's not everything…. But it's just another way for us to try

and improve and help our kids."

Building teacher capacity was still an ongoing challenge for some. One teacher said that the young teachers are a bit more apt to use data because they are more familiar with technology: "If you're having a hard time just logging on, that can be overwhelming!" Another teacher, who actually appeared to be quite comfortable with the whole process of DDDM lamented, "To be quite honest, you have to be a statistician to go through some of the data unless you've actually had training in it." She added that the grade level chairs were supposed to be "expert" and "explain what it means to all of us," but it didn't always work well. She said that math teachers knew how to read the results, but she sometimes found them hard to decipher.

Creating a Climate of Trust and Collaboration. Leadership also played a critical role in providing the expectations for data driven instruction among teachers, as well as creating a climate of trust and collaboration so that teachers could work in professional learning communities to improve their practice. The principal made clear that data driven decision making was a focus at the school. As one teacher explained, "It was really something that [the principal] wanted to push. …It's just assumed that you will use the data to help drive what you need to do and where you need to go." The principal was credited by a teacher as, "presenting [data use] in a positive light ….I mean she's offered opportunities that if you struggle, here's your safety net. If you've failed, try again. You know she's done it in a very non-judgmental way and let people get to their levels."

The relationships between the district administrators and the principal, as well as the

principal and the teachers, were characterized by mutual trust and respect. The district accorded the principal autonomy to make decisions on the basis of data. For example, the principal explained that "every year it [the intervention classes] looked different, and it still looks different." She added, "Every year we analyze the data on our interventions… and have been willing to tweak it. As noted earlier, the principal also allowed the teachers to have decision making responsibilities. For example, one teacher explained that the principal allowed teachers to opt out of a district-wide professional development on textbook use because apparently the teachers were more knowledgeable than the instructor. "My point is that we have a lot of say," said the teacher.

Teachers by and large reported being comfortable sharing their student performance data with each other. In fact, the fact that teachers were willing to look at data and discuss it was considered a strength. Moreover, a climate of trust was present. As one teacher noted, "The teachers don't take it personally; I failed. I didn't do… It's like okay, this is what the data says; how can we do something to make the kids perform better? There's not that negative." Most teachers viewed the use of data as relevant and necessary. They believed that using data caused them to reflect more on their instructional strategies in relation to their students' progress, and many of the teachers we interviewed said that they were differentiating instruction more now that they knew which students needed help in particular areas.

Interaction between Principal Actions and the Actions of Teachers, Students, and

District Personnel

The above discussion gives some insight into the how the district and site leaders actions interacted with those of the teachers. There was alignment between leaders' actions and the actions of teachers important to the implementation of DDDM. Bringing students on board was critical as well. While almost all teachers found assessment data useful for improving instruction, they acknowledged it did not tell them everything they needed to know to help students be successful. Teachers frequently cited affective elements that could not be captured in any type of assessment. One science teacher said, "The data tells me a pattern" but they won't explain what makes a student "tick." She added, "I want to know you personally. I want to know what makes you tick." Similarly, a teacher expressed that state test data were just one measure of performance, and she required more information about her students in order to help her best meet their learning needs:

> I have a hard time. I go back and forth looking at this data because I don't necessarily know if it is a true reflection. …I may look at it but I don't take it as a whole. I look at the state tests... but where was that kid coming from? What's that kid's home life like? .... So as much as the data tells me it doesn't tell me everything. I don't necessarily think it's a true reflection of who they are.

In addition to the teacher use and interrogation of data, a big push instructionally was to get students to take ownership of their own learning. This was being achieved in part through the

use of data in the classroom. A teacher noted that not only did state test results provide an incomplete portrait of students' achievement, the lack of accountability on the part of the student made the results problematic: "There are kids that actually take it seriously and do well. But for a lot of these kids there's no buy-in for them to take it seriously and they know that." She added, "There's no accountability for the child."

In addition to "putting up pie charts," she noted, for the whole class to see, the teachers were beginning to ask students to look at the data themselves, note their strengths and weaknesses, and write a reflection on "what strategies they can use themselves to meet the standard…That's a great way to use this data." She added: "It opens up that dialogue" with the teacher, as a student can then say "I need this from you too…" In one of her classes, students were writing action plans that go in their portfolios. The teacher was hoping to revisit the plans with students at the end of each quarter to discuss whether they followed through and what results were achieved. She thought this was particularly important for failing students who needed to take some avenues in which to chart their own improvement. The principal was very supportive of these efforts, facilitating the sharing of examples of how to bring students into the data use process among the staff.

As this analysis makes clear, district actions, principal actions, teacher actions, and, student actions influenced each other to co-construct the success of DDDM at the school level. Each played a role in determining how DDDM played out at the school level. We will explain in more detail how differing actions can impact each other. Before doing so, it is helpful to first

summarize the key actions at each level, as revealed by the case study data.

District actions

- Formulate district-wide student learning goals
- Provide structural supports for data use (e.g.,district-wide assessment, data management systems, protocols to use in data meetings).
- Build human and social capital among teachers
- Promote a culture of data use and trust

Principal actions

- Formulate schoolwide student learning goals
- Provide supportive structures for DDDM
- Build human and social capital among teachers
- Promote a culture of data use and trust

Teacher actions

- Formulate classroom student learning goals
- Analyze student achievement data and collaborate with colleagues to engage in joint action planning
- Change instruction on basis of data
- Develop ownership of data use

Student actions

- Engage with teachers in examining own data

- Develop ownership of own achievement results
- (Or the converse), ignore achievement results

In the section that follows, we use multi-agent simulation models to show how the multiple actions of each actor in the DDDM process can interact with other actions. In our model, some actions support others, others conflict, and some have no impact on others. The resulting state from these multiple interactions hypothesizes which actions are more active and thus have a larger impact than others. These models are informed by our qualitative case study. However, their main purpose is to serve as a heuristic -- or set of hypothetical models -- for understanding the relationships between various actors (and their actions) in the reform process.

A Multi-Mediator Model of Principal Leadership in DDDM

In the multi-mediator modeling framework that we have developed, each action concept is represented by a named circle and has an activity level, shown by the size of the circle. The more active a concept is, the more active will be another concept connected from the first by a supporting connection, represented by an arrow connecting the two:

On the other hand, the more active a concept is, the less active another concept will be that is connected from the first by a conflicting connection, represented by a line with a bar at the end: 

All the concepts are simultaneously active, and simultaneously have impacts on the concepts that they are connected to. A concept that has a zero activity level has no impact; a

concept that is highly active has a substantial impact on the other concepts it is connected to, either raising or lowering their activity levels depending on the kind of connection.

Within NetLogo, a model is constructed by creating some number of active agents, each of which does whatever it has been programmed to do at the same time as the other active agents. Each agent can communicate with other active agents, having an impact on those other agents.

In our multi-mediator models, the concept nodes and the connecting links are both active agents in NetLogo. Each of the concept nodes (represented visually as a named circle) has an associated activity level (a number between 0 and 100). That activity level is shown visually by the size of the circle and the intensity of the color of the circle – the higher the activity level, the larger the circle and the more intense the color.

Each of the connecting links is also an agent. For each positive link (shown visually as a green arrow), the activity level of the concept at the pointed end of the arrow is raised by an amount proportional to the activity level of the concept at the non-pointed end. For each negative link (shown visually as a red line with a line at the end), the activity level of the concept at the line end of the link is lowered in proportion to the activity level of the concept at the other end.

The parallel activity of the simultaneous impact of all the links is maintained by a "double bookkeeping" system. The impact of each link is calculated by incrementing or decrementing a copy of the current activity level of each concept, and then when all the agents have had their

impact, then the activity level of each concept is replaced by these copies. In this way, there are no order effects, and outside of this time quantum "step", the processing is the same as true parallel processing. So, for each "cycle", the impact on activity level of each link is computed, the activity level of each concept is changed, and then the visual display of each concept (with size and color recomputed) is updated.

Each concept also may have an "external" source of activity. This represents the "context" that the model sits in, where the external activity is the net result of all other factors impacting that concept that are not part of the current model. For some concepts, the external activity is constant; for others, the model provides sliders so that the model viewer can change those external activity levels and observe the impact that has on the model.

This fundamental parallel processing of the concepts and links is the same for each of the multi-mediator models presented in this article. The only difference between the models is the set of specific concepts and links among them, and the external activity for each concept specified by slider settings or as a constant.

Can we use this modeling framework to gain insight into specific educational reform efforts? Figure 2 shows a model of the principal actions and teacher actions at Bear Valley High School. Figure 2 shows in the upper half the interactions among the actions of the principal, and in the lower half the interactions among the actions of the teachers related to DDDM. Figure 2 also shows how the principal actions interact with teacher actions. It is within these cross-level interactions that we see some aspects of the co-construction of reform.

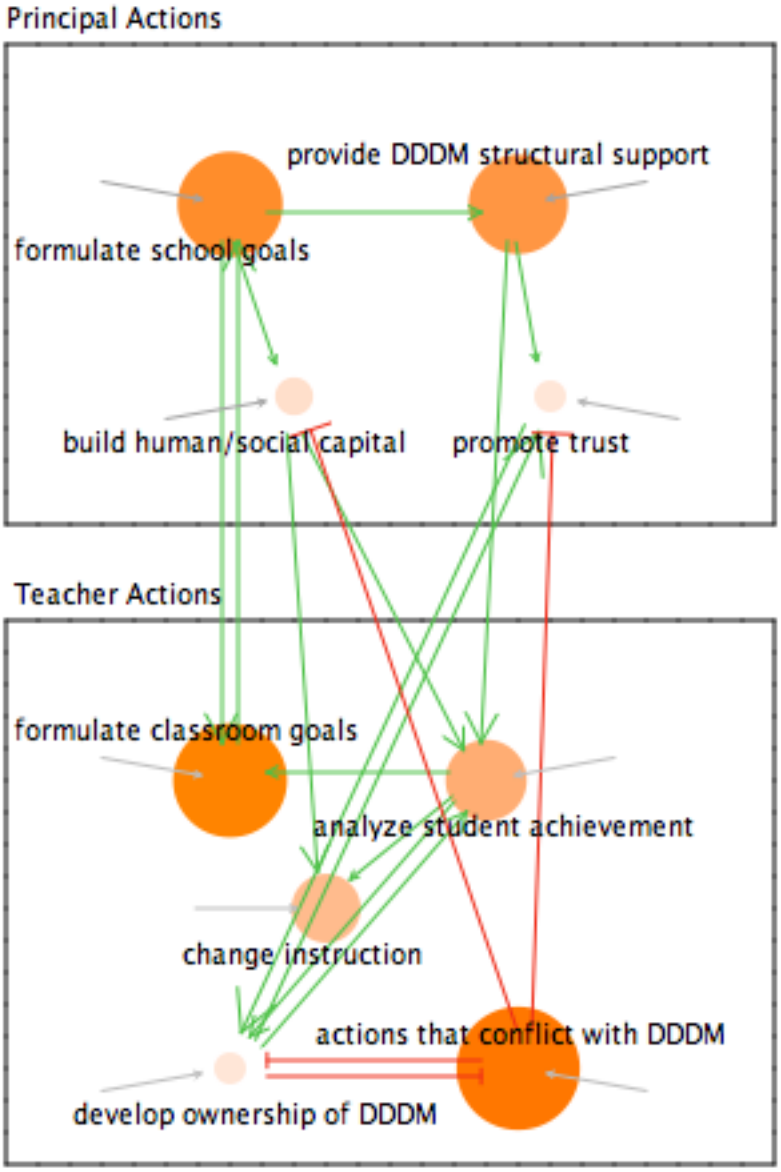

Figure 2: Interaction of principal actions with teacher actions related to DDDM educational reform
(http://edsserver.ucsd.edu/~jlevin/netlogo4.1/principal-actions-teacher-actions.html).

The size of the circles represent the activity level of each action. The higher the activity level of a given action, the more impact it has on the actions it is connected to. That is, the principal establishes structures to support DDDM, which influences teacher implementation of

DDDM. This supports actions to build capacity among teachers. The principal also formulates goals for DDDM, and the principal promotes a climate of trust.

However, hypothetically, there would be a mutual negative interaction between taking ownership and the teacher actions that conflict with ownership.

Figure 2 is hyperlinked to an online applet version of the model, which is at http://edsserver.ucsd.edu/~jlevin/netlogo4.1/principal-actions-teacher-actions.html . (If you access this applet, it may take a while for the NetLogo library to be transferred, so please be patient.)

This applet representation of the model allows you to change the external activity inputs to the four principal actions, and to observe the hypothezied impact of those changes on the interactions that the model predicts. Some of these change cause a relatively linear change in the system, while others have non-linear impacts.

The linear changes lead to "self-repair", in that if the changes are reversed, the system returns to its previous state. The non-linear changes lead to "reorganization", in that if the changes are reversed, the system does **not** return its previous state.

While the model shown in Figure 2 is relatively complex, we have been able to hypothesize which sub-elements lead to non-linear change. The crucial elements are mutual negative relations between two elements, along with two sets of mutual positive relations. This minimal non-linear system is shown in figure 3.

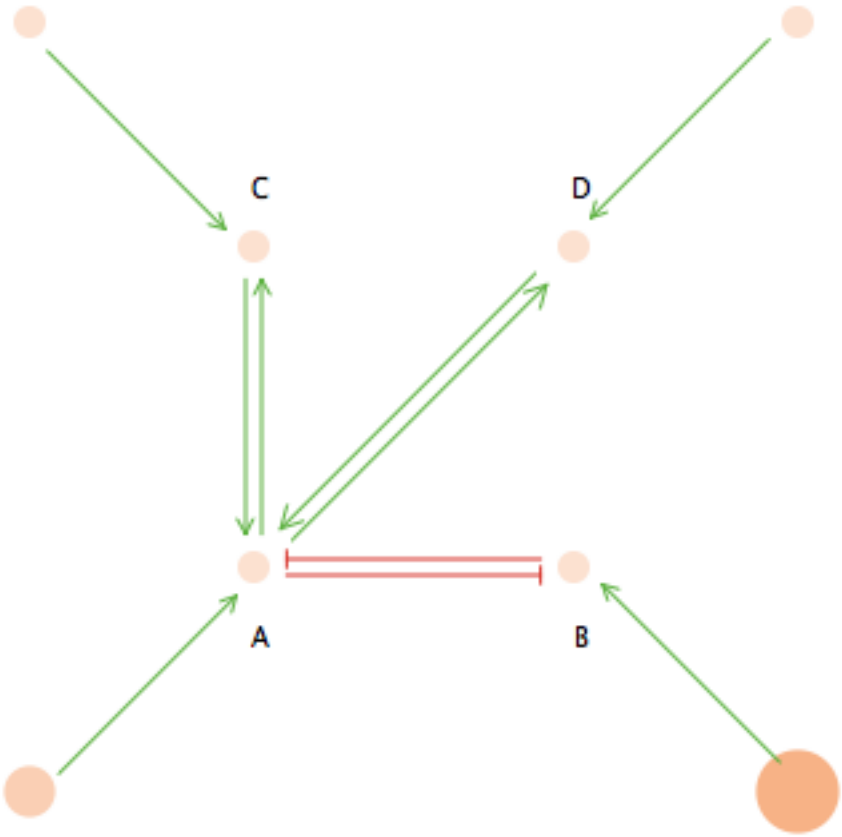

Figure 3: A minimal non-linear system

(http://edsserver.ucsd.edu/~jlevin/netlogo4.1/femu-2.html).

This non-linear system is subpart of the model shown in Figure 2, involving the teacher actions of "develop ownership of DDDM" in mutual negative relations with "actions that conflict with DDDM", and with the "develop ownership" action in mutual positive relations with the teacher action of "analyze student achievement" and the principal action of "promote trust." Note that the teacher actions conflicting with DDDM are hypothetical, as the Bear Valley case did not reveal significant incidents of teacher resistance to data use, which may be present in other schools. However, it serves as a useful illustration to show how different types of actions may

play out.

Figure 4 shows a more complete model of the interactions among principals, teachers, students and district personnel concerning site leadership for DDDM issues.

Figure 4: A multi-mediator model of DDDM educational reform, including principal, teacher, student, and district actions (http://edsserver.ucsd.edu/~jlevin/netlogo4.1/principal-teacher-student-district.html).

This model shows more clearly what we mean by co-construction. There is a multi-directional flow of activity, with principal actions influencing teacher and district actions, and teacher actions influencing principal and student actions, etc. Changes in this system can start with changes in principal actions, but can also start with changes in teacher actions, student actions, or district actions.

The impact of the broader context on the aspects of DDDM reform being modeled here is implicit in the factors that determine the activity levels of each of these concepts, independent of the influence of the connections shown here. That is, there are a number of factors outside of what we are modeling here that have an impact on the activity level of the teacher goal of "implement DDDM". We indicate these "external" contextual factors by the arrows coming in from the sides.

Note that the nature of the co-construction with four levels is much richer than with just two levels. Instead of relatively simple two-level interaction, we have multiple kinds of interaction in the model shown in Figure 4 by which change can propagate through this model. Each of these landmark levels (district, principal, teacher, student) can be seen as a mediator of the interaction among the other levels. It is through this multiple simultaneous mediation that we can start to capture the complexity of the educational reform process without being overwhelmed it.

Self-repair vs. reorganization. Most educational reform efforts run their course, leaving little change once the extra efforts to implement the reform have been removed (see for example, Tyack & Cuban, 1995). In these kinds of multi-mediator systems, we call this

"self-repair". Stable dynamic systems are stable because all of the different forces have reached a dynamic equilibrium, and the equilibrium is often such that efforts to move the system to a new state lead to changes that do not last when the efforts cease. One teacher in the study referred generally to educational reform efforts as "going in one year and out the other." Even beyond individual resistance to reform efforts, a complex organization like a school would not last very long if it responded to every outside change effort.

Yet sometimes these complex systems do change. How do we represent this very common self-repair outcome while still representing the less common reorganization outcome to educational reform? Imagine a ball at the bottom of a rounded hole, like the one shown in figure 5. An effort to push the ball up a side of the hole would make the ball move, but if that effort ceases, the ball will return to the bottom of the hole (the equilibrium state).

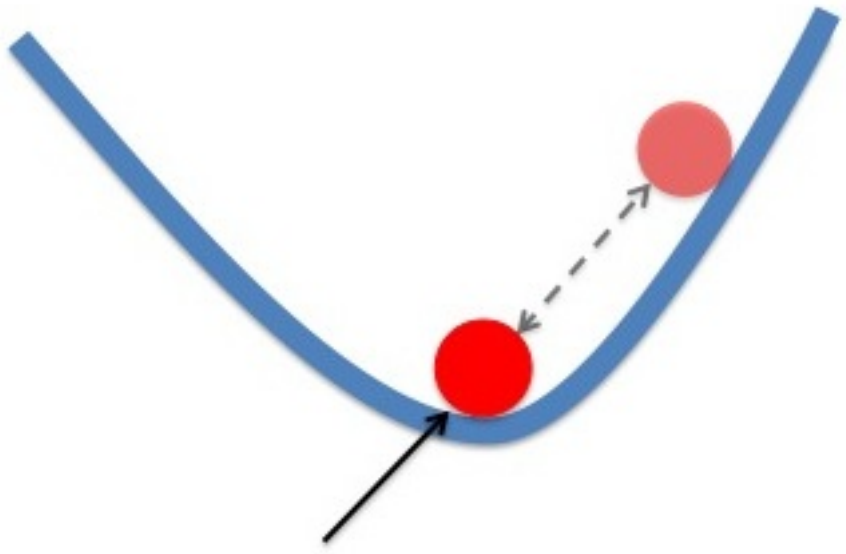

Figure 5: A ball in a hole, where the change effort moves the ball only partway up the wall, so it returns to the bottom when the effort ceases.

Now imagine that we zoom out, to see that this hole is next to another hole. An effort to push the ball up the side will have a "reorganizing" effect if it pushes the ball up far enough that it then falls in the other hole. This is shown in Figure 6.

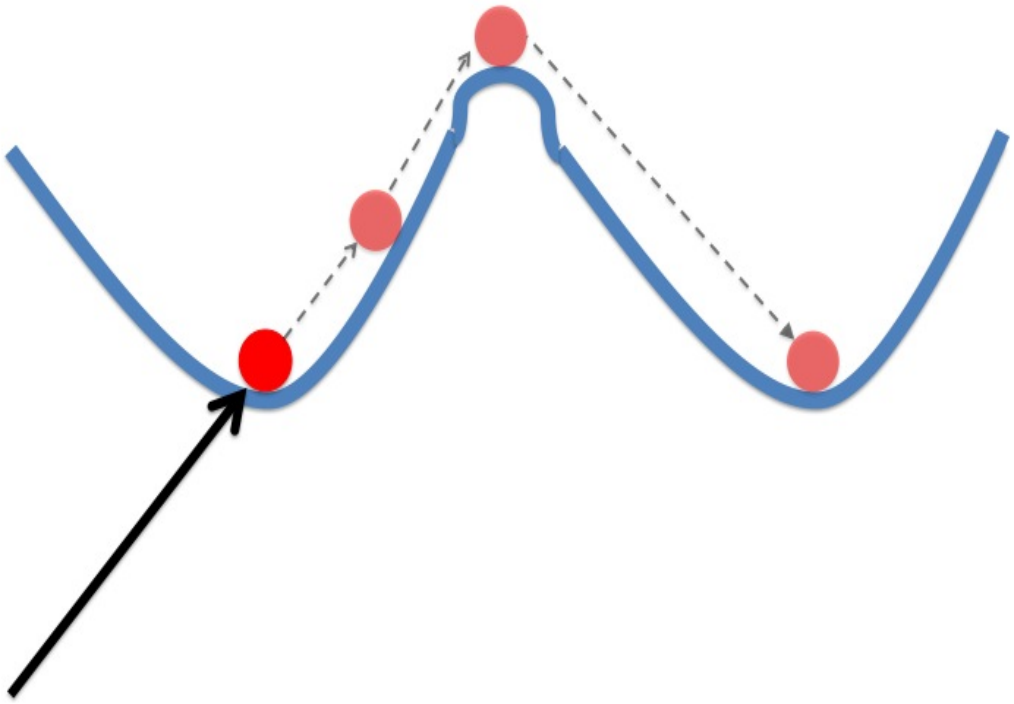

Figure 6: A ball in a hole, where a larger change effort moves the ball all the way up the wall, then into another hole, where it stays when the effort ceases.

Complex multi-mediator systems like the ones we are modeling here have equilibrium states, such that efforts to change those states will have only temporary effects if those efforts then cease. However, they also have multiple equilibrium states, so that certain efforts in certain directions will have an effect that persists even if the change efforts are relaxed.

In simple cases, an increase in a principal's action to support a change such as DDDM might lead to an increase in the actions by teachers and students to implement the change, but often that change is temporary, lasting only as long as the increased principal action continues. This "in one year and out the other" change is what we call self-repair, a very common property of stable systems such as schools. Resistance to change initially leads to no change at all, but a large enough effort for change applied at the right time and place will lead to reorganization, a kind of organizational learning that persists even when the change effort ceases. At the same time, this model suggests that immediate responses to actions to implement a change are an indication of a change that may **not** have lasting impact but that will only last as long as the change effort is sustained. In contrast, change efforts that meet initially with resistance may (or may not) eventually lead to reorganization and a lasting change.

The models presented here are similar to the Creemers and Kyriakides (2008) dynamic model of educational effectiveness in that both our models and their model are multi-level models, both specify relations at the same level as well as relations between levels, and both aim to capture non-linear phenomena. They differ in two important ways. First, the focus of the Creemers and Kyriakides model is on the interactions between the teacher and student levels,

while the data our model is based on is stronger at specifying the interactions between the principal and the teacher levels. We have included the student and district levels in Figure 4 to illustrate the complex co-construction loops that might exist when at least multiple levels of the power structure of education are included, but our data set to support the specifics of the model at the student level is less strong than our data for the other levels. The second difference is that our model has an underlying simulation implementation that allows us to represent changes over time better than a model expressed just on paper in print. The model presented here in figure 1 is similar to the Creemers & Kyriakides model in that it exists only as specified on paper. The models presented here in figure 2 through 4 exist on paper but they also are represented as computer-based simulation models that may better represent the changes over time that are essential to any model of educational change.

The challenge for using these kinds of multi-mediator simulation models is that the conventional way of making models available is through print, such as this article. To address this challenge, we have linked our underlying simulation models through hyperlinks to Internet-accessible applets that the reader can interact with, and have included the URLs in the figure captions. We have selected ways to display the state of the model that will work with "snapshots" that we display as figures in print. We will continue to work to develop better ways to display the operation of our multi-mediator models.

Conclusion and Implications

Our goal in this paper is to illuminate the principal's role in influencing actions of others in the DDDM process. We used case study data to identify the key principal actions in DDDM,

highlighting these actions within a broader reform context to show the principal's role in co-constructing the reform. The key principal actions we identified included (1) formulating goals that are specific to the needs of the school and community, (2) providing time for teachers to discuss data, flexibility for re-teaching, and curriculum and material resources to support DDDM; (3) building human and social capital in the form of building the knowledge and skills of teachers; and (4) creating a climate of trust and collaboration and a culture of data use. These actions are consistent with prior research but extend prior research in new way by providing a detailed picture of principal actions and their connections to the actions of district administrators, teachers, and students.

The actions outlined above would be very useful for principals to undertake in their efforts to implement DDDM in their school sites. The case we presented also points to the critical district leadership role in the data use process. The district was a key player in the co-construction of successful reform in Bear Valley. It is difficult to imagine the principal being able to fully implement data use without the district having supportive data use structures and cultures, though many of the efforts at Bear Valley were undertaken ahead of the district's own initiative to spread data use across the district.

The simulation models we developed incorporate the actions of principals as site leaders, their interactions with teachers and students within their own schools, all within the larger context of their interactions with their district context. Educational reform has a long history of failure in American education (Tyack & Cuban, 1995), and the findings from this article can help us better understand the leverage points that make reform efforts sustain or

falter. We can draw some conclusions by looking at the number of connections between actors, and arguably the number of connections can point to the tightness or looseness we observed. For example, it appears that tight connections between the principal and the teachers helps to enable reform; the actions between the principal and the teachers were well connected with each other. In the case we examined, we also saw a great deal of consistency of actions between the principal and the district administrators, which also facilitated change. By contrast, we observed more looseness in the relationships between the actions between principal and students, which seemed appropriate as teachers' actions impact students' actions more closely, with the teacher serving as a mediator. Teachers were more loosely connected to district actions, with the principal serving as a mediator. From these patterns, we can easily draw some implications for principal practice in the data use process. That is, principals may wish to seek tight connections with the district and the teacher and to serve as a mediator between the district and the teachers. Teachers should ensure that data use does not stop with them, but rather seeks to influence student action as well.

Using models to show the fluid nature of the change process across a set of key individuals in the reform process could be used more broadly to show how some arrangements lead to more successful reform while others are more likely to lead to the organization returning to business as usual. Such models may be useful for other researchers seeking to draw themes out of qualitative case studies of educational change. One challenge is systematically evaluating the accuracy of the qualitative simulation models in capturing the qualitative data. In this respect, we think it is important for researchers to integrate qualitative case study data with qualitative

simulation models. Our goal in this work is to demonstrate a novel approach to using qualitative data to generate qualitative simulation models. Our hope is that our modeling of qualitative data also provide some lessons to guide educational practice.

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