The Impact of Data-Driven Decision Making tools on Educational Practice: A Systems Analysis of Six School Districts

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Introduction

One of the hallmarks of the *No Child Left Behind Act* (NCLB, 2001) is the requirement that states develop annual assessments to measure school and student progress and that educators use data to help improve the learning of *all* students. As a result, the administrators and teachers are being confronted with complex and diverse sources of data from which they must make informed instructional decisions. Increasingly school districts are turning toward technology-based solutions that they believe will help them to use data more effectively and there are a growing number of technology-based products that enable districts to provide data to many levels of the system – the teachers, administrators, parents, and policy makers - as a means to improve instruction, student learning, and communication.

Examining how technology-based tools can facilitate decision making, and how administrators and teachers use such tools and data to enhance instruction is therefore essential if we are to understand how assessment data can be used effectively to inform educational decision making. This project brings together complimentary evaluation techniques, using systems thinking as the primary theoretical and methodological perspective, to examine the implementation and use of data-driven applications in school settings. The project has two goals: (a) to build a knowledge base about how schools use data and technology tools to make informed decisions about instruction and assessment; and (b) to develop an evaluation framework to examine the complexities of dynamic phenomena that will inform the field and serve as a knowledge building enterprise (Mandinach, 2005; Mandinach & Cline, 1994).

Theoretical Framework

Research on Systemic Reform Research and Data Systems

One consequence of the standards and accountability movement is that district and school administrators are being asked to think very differently about educational decision making, and are beginning to use data to inform everything from resource allocation to instructional practice. As researchers at the UCLA Center for Research on Evaluation, Standards, and Student Testing (CRESST) note, "Data-based decision making and use of data for continuous improvement are the operating concepts of the day. School leaders are expected to chart the effectiveness of their strategies and use complex and often conflicting state, district, and local assessments to monitor and assure progress. These new expectations, that schools monitor their efforts to enable all students to achieve, assume that school leaders and teachers are ready and able to use data to understand where students are academically and why, and to establish improvement plans that are targeted, responsive, and flexible" (Mitchell, Lee, & Herman, 2000, p. 22).

The literature on systemic efforts to improve schools has been principally focused on the role of data for accountability in developing, guiding, and sustaining organizational change that leads to improvements in student learning (Fullan & Stiegelbauer, 1991; Massell, 1998; Schmoker 1996). However, the research literature on data to support instructional decision making is still limited. Some of the first research in this area was done in the 1980's (Popham, Cruse, Rankin, Sandifer, & Williams, 1985; Shepard 1991); however, as a whole the field did not gain traction, especially at the classroom level, due to the technical limitations in assembling and disseminating data across complex systems.

Recently, the education community has again become interested in data-driven instructional decision making, largely because growing numbers of school systems and states have the capacity to process and disseminate data in an efficient and timely manner (Ackley 2001, Thorn 2002). This trend has been further accelerated by the requirements of NCLB to use data to improve school performance (Hamilton, Stecher, & Klein, 2002).

Of the nascent but growing body of literature on the use of data systems, tools, and warehouses to support decision making processes in schools, research indicates that a host of

complicated factors need to be addressed if these tools are to be used to support instructional improvement. There are a number of initiatives being implemented across the country for which research is only in the most formative stages. These projects include the Quality School Portfolio (QSP) developed at CRESST (Mitchell & Lee, 1998), IBM's Reinventing Education initiative in Broward County Florida (Spielvogel, Brunner, Pasnik, Keane, Friedman, Jeffers, John, & Hermos, 2001), the Texas Education Agency and the South Carolina Department of Education (Spielvogel & Pasnik 1999). There is ongoing work being conducted on data-driven tools in New York, (Educational Development Center, in press; Honey, 2001; Honey, Brunner, Light, Kim, McDermott, Heinze, Breiter, & Mandinach, 2002), Minneapolis (Heistad & Spicuzza, 2003), Boston (Sharkey & Murnane, 2003), and Milwaukee (Mason, 2002; Thorn 2002; Webb 2002).

Stringfield, Wayman, and Yakimowski-Srebnick (2005; Wayman, Stringfield, & Yakimowski, 2004) and Sarmiento (n.d.) provide some of the first comprehensive reviews of the tools available, identifying some of the technical and usability issues districts face when selecting a data application to support instructional planning. Technical challenges include data storage, data entry, analysis, and presentation. Other challenges include the quality and interpretation of data, and the relationship between data and instructional practices (Cromey, 2000). Work done on the QSP in Milwaukee indicates that educators are hesitant to base decisions that affect students on data they do not necessarily believe are reliable and accurate (Choppin, 2002). The standardized test data provided in many of these data systems were often not originally intended for diagnostic purposes (Popham, 1999; Schmoker, 2000). Educators' knowledge and training in the use of data is also a confounding factor. While teachers and administrators need not be experts in psychometrics, they must have some level of assessment literacy (Webb 2002). However, most educators are not trained in testing and measurement and assessment literacy is therefore a major concern (Popham, 1999).

While debate about the merits of using state mandated testing data for diagnostic purposes continues, responding to accountability requirements remains a daily challenge that schools and districts must address now (Pellegrino, Chudowsky, & Glaser, 2001; Stiggins, 2002). Although high-stakes accountability mandates are not new, the NCLB legislation places public schools under intensified external scrutiny that has real consequences (Fullan, 2000). Not only are failing schools identified, but parents are given the option of removing their children from such schools or using school resources to hire tutors and other forms of educational support. District and school administrators are struggling to respond to these heightened expectations, which by design call for different thinking about the potential of accountability data to inform improvements in teaching and learning. It is clear that NCLB is requiring schools to give new weight to accountability information and to develop intervention strategies that can target the children most in need. The growing interest in data-driven decision aking tools is no doubt a direct response to these mounting pressures (Hayes, 2004; Stringfield et al., 2005).

The Research

The purpose of this work is to examine technology-based, data-driven instructional decision making tools, their implementation, and impact on different levels of school systems (i.e., administrative and classroom). Examining different tools in diverse settings enables us to develop and validate an evaluation framework that will be sensitive to the dynamic and interacting factors that influence the structure and functioning of schools as complex systems (Mandinach, 2005; Mandinach & Cline, 1994). The framework includes: (a) the use of a systems perspective; (b) examining the system with multiple methodologies at multiple levels; and (c) recognizing its complex nature, and the need for the technology tools to become instantiated so that both formative and summative methods can be used. The research not only examines a methodological framework using systems thinking, but also presents a theoretical framework on how data-driven decision making occurs in school settings, and a structural framework that outlines the functionality of the tools that either facilitate or impede data-driven decision aking.

The Technology-Based Tools

The project is focusing on three tools – a test reporting system, data warehouses, and diagnostic assessments delivered via handhelds. The first application, the Grow Network uses a mix of print and web-based reporting systems. The print materials, called Grow Reports™, deliver well-designed, highly customized print reports to teachers, principals, and parents. The data displays in the printed reports mirror those used on the website, a strategy that has proved highly effective in reaching Internet-wary educators. Grow Reports™ for teachers give a concise, balanced overview of class-wide priorities, group students in accordance with their learning needs, and enable teachers to focus in on the strengths and weaknesses of individual students. The principal report provides an overview of the school, presenting class and teacher-level data; and the parent reports provide easy-to-interpret information that explains the goals of the test, how their student performed, and what they can do to help. Each report is grounded in local "standards of learning" (e.g., mathematical reasoning, number and numeration, operations, modeling/ multiple representations, measurement, uncertainty, patterns and functions) that encourage teachers to act on the information they receive and to promote standards-based learning in their classrooms. When teachers view their Grow Reports on the web, these standards of learning link to "teaching tools" that not only help to explain the standards, but also are solidly grounded in cognitive and learning sciences research about effective math and literacy learning.

Second, are two data warehouses, both locally grown initiatives that enable school administrators, teachers, and parents to gain access to a broad range of data. The systems store a diverse array of information on students enrolled in the districts public school systems including attendance information, the effectiveness of disciplinary measures, test and grade performance. This information is available to an increasingly larger set of stakeholders in a growing number of formats for use in various contexts. After refocusing attention to school administrators, designers of the tools began to work closely with many of these administrators in order to understand what the schools' needs were regarding data and design. The end results are that the data warehouse systems have accommodated new kinds of data, has created multiple mechanisms for making that data available in different formats, and is continuing to work with school-based users to further address their needs. With the availability of data to schools has come an understanding on the part of the district that administrators and teachers need support not only in accessing, but in interpreting information in order to make informed decisions regarding their students.

The third application consists of handheld technologies to conduct ongoing diagnostic assessments of students' mathematics learning and early literacy. In this system the teacher at the classroom level collects data on a handheld computer. Teachers upload their information from the handhelds to a Web-based reporting system, where they can obtain richer details about each student. They can follow each student's progress along a series of metrics, identify when extra support may be necessary, and compare each student's performance to the entire class. Customized web-based reports can be shared with mathematics and literacy coaches, instructional leaders, principals, curriculum supervisors, district administrators, and parents. The handhelds are: (a) built upon what we know from research about the key areas of mathematical knowledge and early literacy; (b) address real instructional challenges that teachers are facing and make the task of assessing student learning easy and practical to accomplish; and (c) tools to be applicable across multiple contexts and multiple curricula by addressing core learning challenges, not curriculum-specific skills and tasks.

The Research Sites and Data Collection

Two sets of sites were used for each application. The sites for Year 1 were the original sites and the Year 2 sites were used for validating the initial findings. The New York City Public Schools and Chicago Public Schools served as the sites for the Grow Reports. The Broward County Public Schools in Florida and Tucson Unified School District in Arizona served as the sites for the data warehouses. Albuquerque, NM and Mamaroneck, NY served as the sites for the handheld diagnostics. Three of these sites represented the first, third, and sixth largest school districts in the United States.

Research was conducted through interviews with administrators across all levels of the school districts and through interviews and focus groups with teachers and students. Surveys also were given to teachers and administrators. Analyses are continuing as staff is using data to construct systems-based models of the interrelationships among important variables that influence the implementation of the tools and data-driven decision making in each of the sites. Data also are being analyzed in terms of the construction and validation of the theoretical framework for data-driven decision making and the structural functionality framework for the tools.

Results

The Development of Three Initial Frameworks

The project is developing three frameworks: a methodological framework based on systems thinking; a conceptual framework for focused inquiry and exploration of data based on both theory and practice; and a structural functionality framework for the data-driven decision making technology-based applications. These frameworks are works in progress that are being refined over the course of the project.

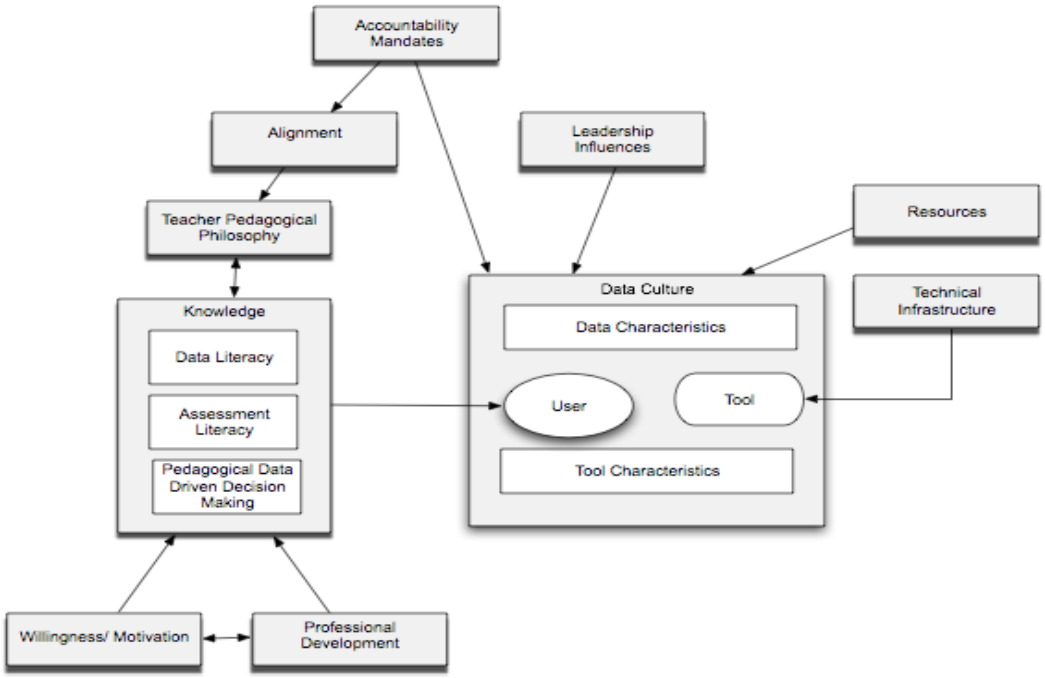
Systems-Based Methodological Framework

The methodological framework is founded on three principles. First, there is the need to recognize the dynamic nature of school systems in order to capture their complexity. Second, the methodology must account for the interconnections among the many variables that impact a school system. Third, the methodology also must account for the different levels of stakeholders within a school system. The goal, by the end of the project will be to have a systems model of each of the six sites, taking into account the dynamic nature of school, the interconnectedness among important factors, and the multiple levels at which schools must function. It is our hope that from these models, we will be able to draw parallels to other districts with similar characteristics and contexts, and providing a level of generalizability from the data.

We have developed a generic systems map (Figure 1) as well as a systems map for each of the six sites (see Figures 2 - 7). These maps depict the important variables that influence data-driven decision making in the given sites and how those variables interact to produce a data culture. The generic map depicts the importance of the data culture developed within a school district. This data culture is influenced by the characteristics of the tool as well as the data characteristics. Other important variables that influence the data culture include teachers' pedagogical philosophy and teacher knowledge, particularly data literacy, assessment literacy, and pedagogical data-driven decision making literacy. These variables influence the user within the data culture. Variables such as accountability mandates and the resulting pressure, leadership influences, professional development opportunities, motivation, resources, and technological infrastructure also affect the use of data-driven decision making in various ways. The technical infrastructure is thought to affect the tool, while resources, leadership, and accountability affect the data culture more broadly. Accountability is seen to create a series of causal links, beginning with the alignment of the measures to teacher pedagogical philosophy. This philosophy, in addition to motivation and professional development opportunities impact teacher knowledge.

The site maps depict the contextual surrounds and differences across the six school districts we examined. Some variables play a much more important role in a particular site than in others. The maps have attempted to reflect the differing levels of importance. The maps also outline the influences outside the district that influence data-driven decision making and the district's vision and data culture. For example, leadership at the level of the superintendent was found to be critical in a small district such as Mamoroneck or even Tucson, but played less of a role in Albuquerque and Chicago, while symbolic support from the highest level was in evidence in Broward County and New York City. The importance of building leadership was a consistent finding across all the sites. The degree to which there was strong building leadership and support for data-driven decision making varied across schools.

Figure 1. Generic Systems Map



For the purpose of this paper, we will not describe all six systems maps. Instead we will focus on one school district and work through its systems map and supporting to data to explicate how the systems mapping methodology aligns with the data we have collected.

Tucson's Systems Map

Tucson Unified School District (TUSD) is depicted in Figure 3. The data that we report below fed into the construction of this map. Figure 3 shows two major components within the district, the data culture and leadership with its vision as a surround. Also depicted are external components that influence the district. We began by examining the technology-based tools, the data warehouse, TUSDStats and the student information system, Mojave. Both TUSDStats (see Table 1) and Mojave have been constructed with particular tool characteristics. Further, the data that reside in these tools, in addition to the tool characteristics and the tools influence their use and ultimately the data culture within the district. Leadership within the district consists of the typical three levels. Both the superintendent and the central administration are highly supportive of the data culture and espouse the data vision to move beyond being data rich, but information poor. It is at the building level, however, that leadership plays perhaps the most important rule. As noted above, principals make things happen. If a principal is data savvy and model the use of data in everyday activities, teachers in that school tend to be much more likely to appreciate the need for data and espouse the same philosophy. Within Tucson's central administration reside three departments who have been tasked with the development, maintenance, and training around data-driven decision making and the technology-based tools. The Research and Assessment Department developed TUSDStats and its predecessor. Technology and Telecommunication Services developed and maintains the Mojave student information system. Instructional technology provides professional development and on-site assistance and training for both of these tools. These three departments have directly impacted how the tool characteristics have been developed and deployed. Another component within the district is district accountability, a result of district leadership and vision. The accountability measures create the majority of the local data that populates TUSDStats, and thus feeds into data characteristics. External influences such as state and federal policy mandates and accountability, the Arizona State Department of Education, charter schools, and the population influx have various effects.

Figure 2. Broward County Public Schools Systems Map

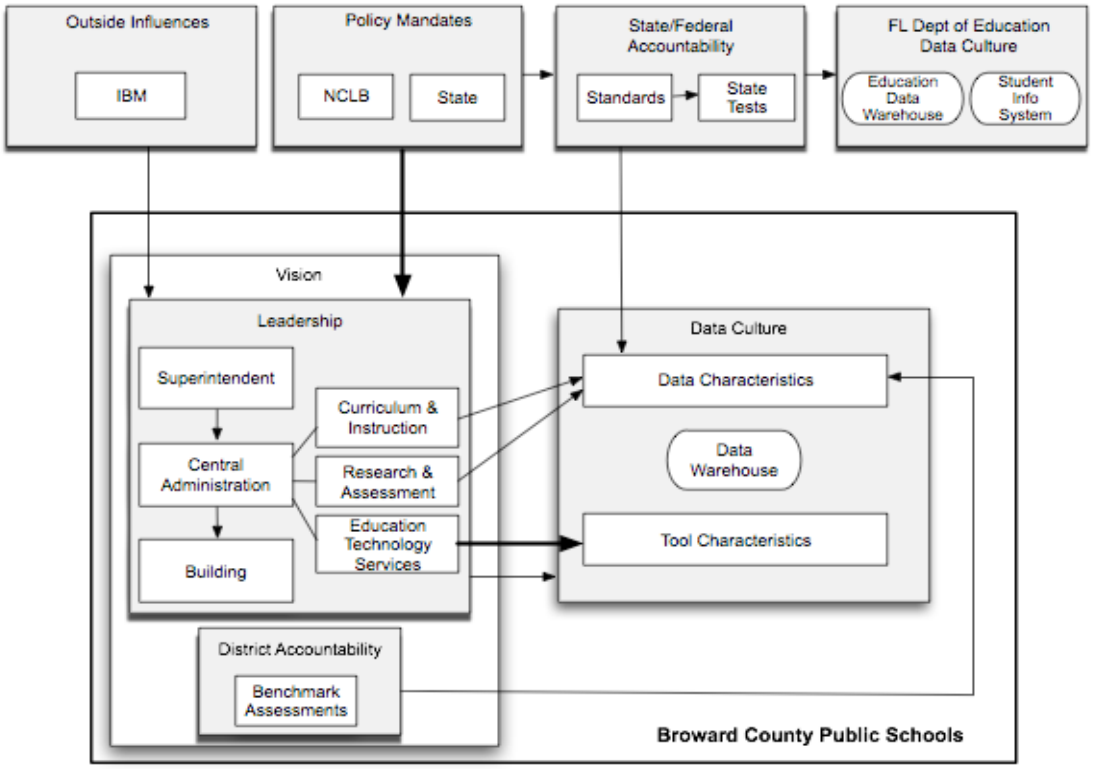


Figure 3. Tucson Unified School District Systems Map

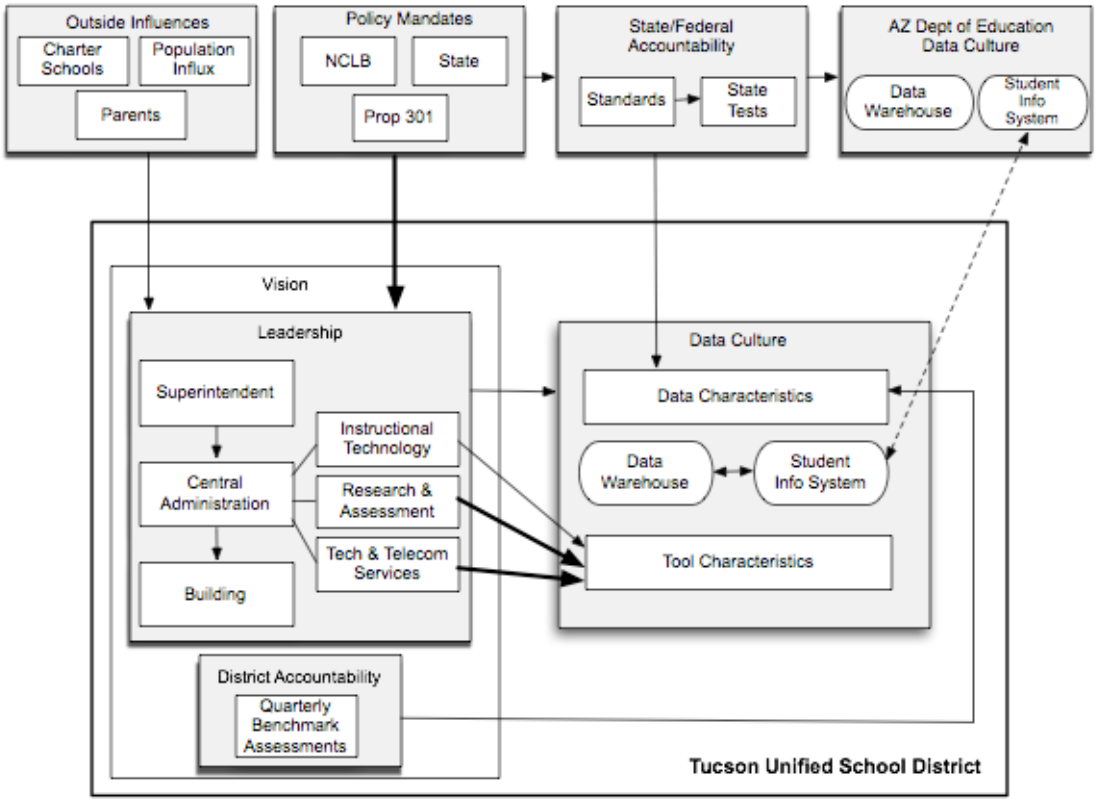


Figure 4. New York City Department of Education Systems Map

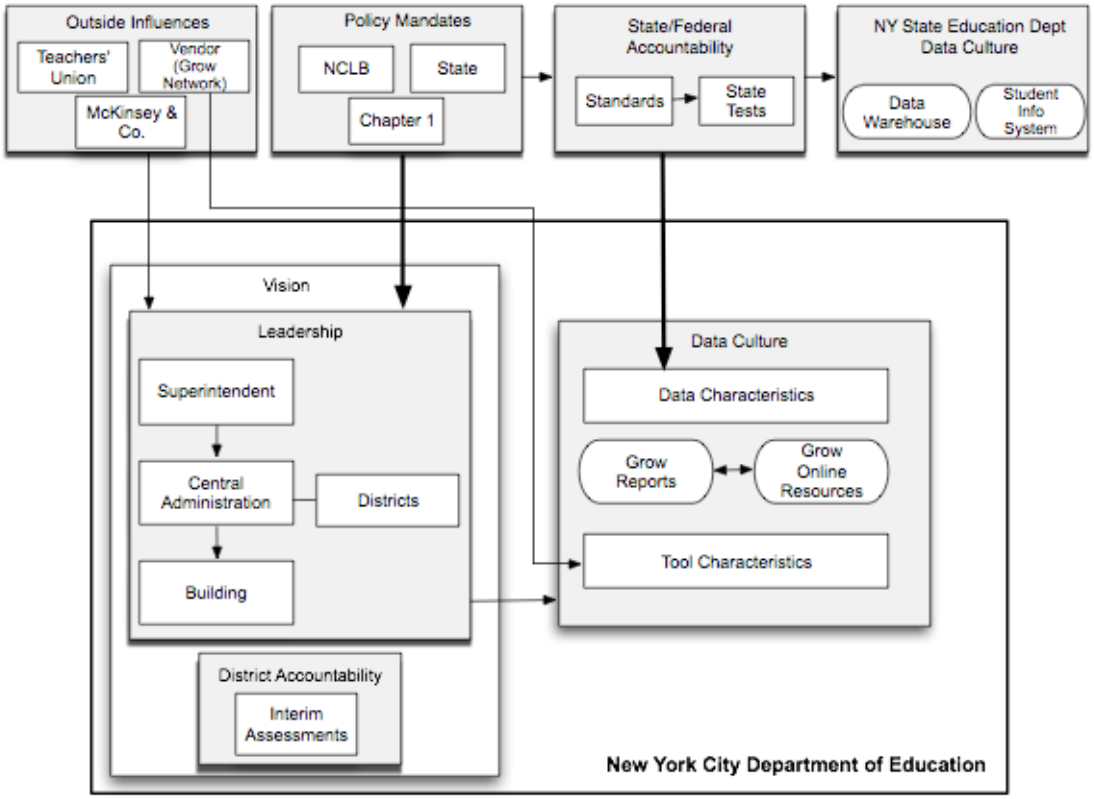


Figure 5. Chicago Public Schools Systems Map

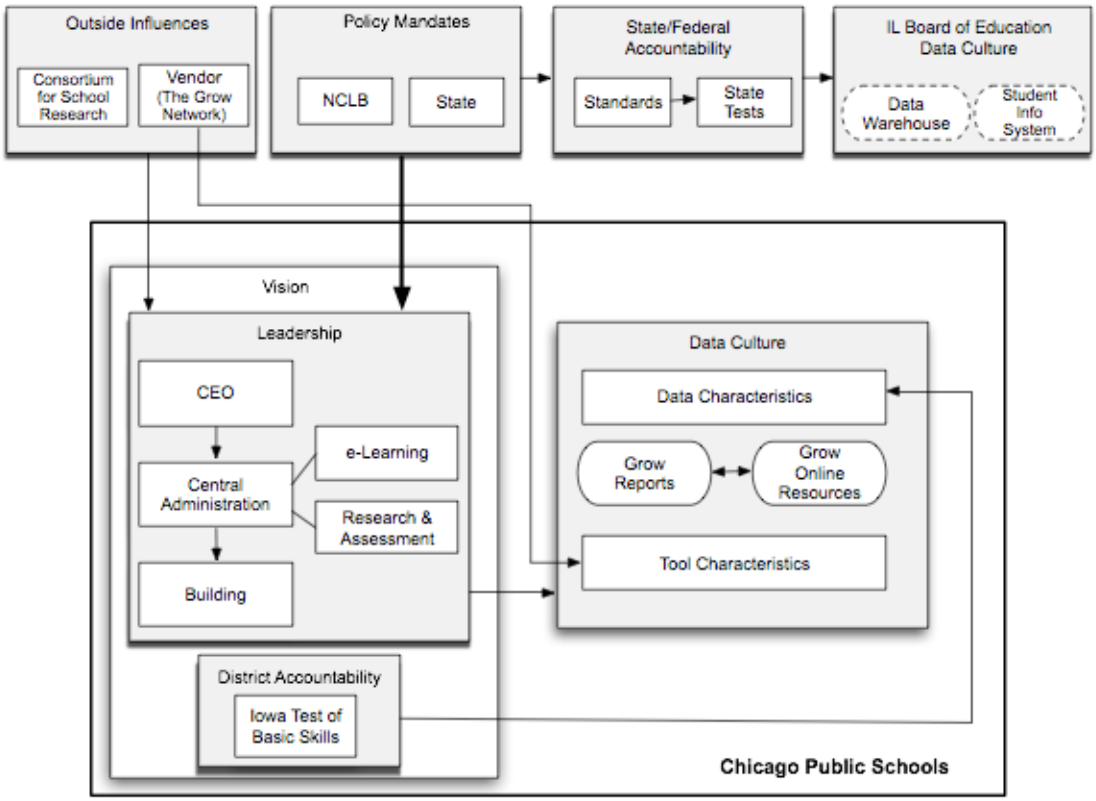


Figure 6. Albuquerque Public School Systems Map

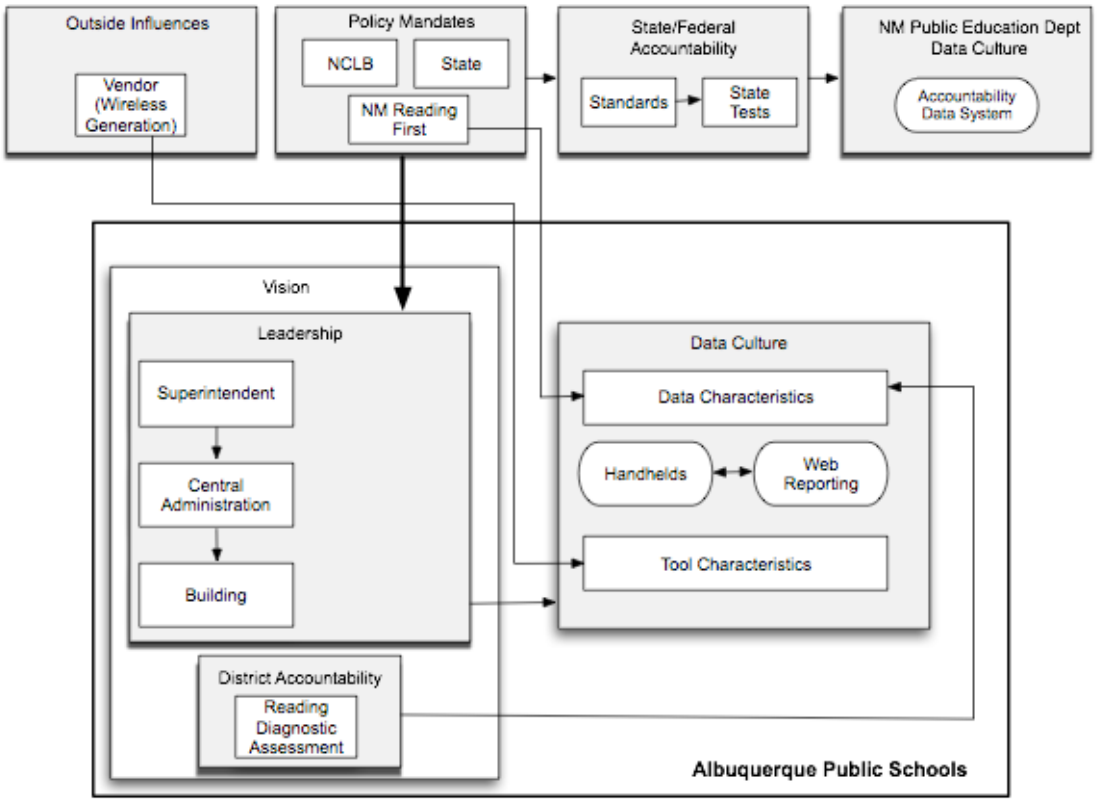
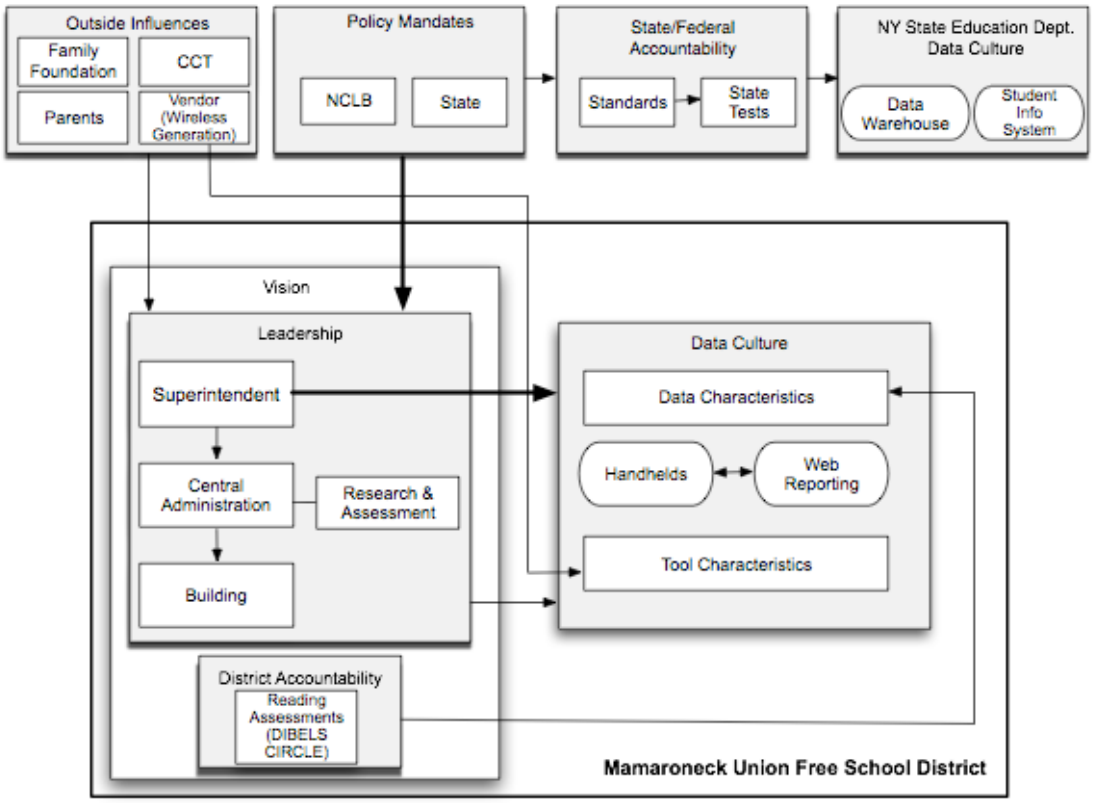


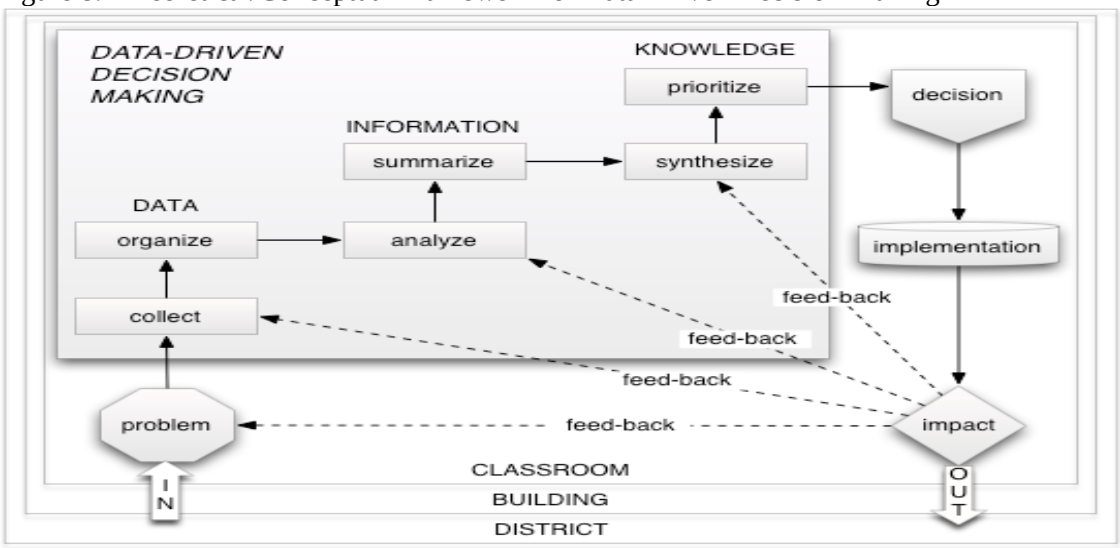
Figure 7. Mamaroneck Union Free School District Systems Map



Conceptual Framework

The conceptual framework approaches data-driven decision making as a continuum from data to information, to knowledge (see Mandinach, Honey, & Light, 2005, 2006 for more details). Figure 8 depicts the model that reflects our thinking about the conceptual model. An essential thing to keep in mind is the data culture being created in each setting that provides the context in which the model's variables reside. Key variables include collecting, organizing, analyzing, summarizing, synthesizing, and prioritizing. These variables are manifested differently, based on who the decision makers are and where in the school structure they are situated. The types of questions to be addressed are influenced not only by the location within the school hierarchy (i.e., class, school, district), but where along the data-information-knowledge continuum the focused inquiry falls. This conceptual framework further posits a continuum of cognitive complexity in data a decision making begins with data, transforms those data into information, and then ultimately into actionable knowledge. The data skills are collecting and organizing. The information skills are analyzing and summarizing, and the knowledge skills are synthesizing and prioritizing. Decision makers probably will not engage these skills in a linear, step-by-step manner. Instead, there will be iterations through the steps, depending on the context, the decision, the outcomes, and the interpretations of the outcomes.

Figure 8. Theoretical/Conceptual Framework for Data-Driven Decision Making



Structural Functionality Framework

The structural functionality framework identifies six characteristics of technology-based tools that influence how they are used and by whom. The first is *accessibility*. Accessibility deals with how accessible are the tools, and how do the tools support access to the data or information. The second is the length of the *feedback loop*. Feedback focuses on how much time passes between the time the data are generated and when results are reported to the end-user. The concern is that the data are still relevant by the time they are reported. The third is *comprehensibility*. It deals with: how understandable the functioning of the tool is; how clear the presentation of the data are; and how easy it is to make reasonable inferences from the information presented. *Flexibility* is the fourth component. This component focuses on whether there are multiple ways to use the tool and the extent to which the tool allows the user to manipulate the data. *Alignment* is the fifth functionality. It focuses on the extent to which the data align with what is happening in the classroom, the alignment with the standards, and to the curriculum. The final component is the *link to instruction*. It focuses on how the tool bridges information (either physically or conceptually) and practice. Table 1 depicts how these characteristics are manifested in the applications across sites. The type of tool and data characteristics necessarily impact how the six functions are realized.

Table 1. Functionality Table

	Alignment	Links to Instruction	Accessibility	Comprehensibility	Flexibility	Length of Feedback Loop
TUSD Internet-based Warehouse	Most data sources are aligned to standards (e.g., AIMS).	Warehouse contains instructional materials that are linked to a lesson planner.	All classrooms/ teachers have access. Also parental access.	Yes. The data are presented in easily understandable formats. Depending on data source, there are graphs, tables, and other forms of representations.	Can be queried directly by user and in a variety of formats.	Data dependent (e.g., AIMS tests are 6 months; the quarterly assessments are available a few weeks after the assessment).
BCPS Intranet – based warehouse	Most data sources are aligned to standards (e.g., FCAT).	Warehouse does not have instructional materials.	Nearly all classrooms/ teachers have access. Also parental and student access.	Yes. Most screens are easy to understand.	Can be queried via intermediate staff or user. Some queries require a data expert.	Data dependent (e.g., FCAT is 6 months; BAT is a shorter duration).
APS Formative data on handheld	Data are aligned to Reading First and the 5 Big Ideas of early literacy as outlined by the National Reading Panel.	Tool does not contain instructional materials, but the measures link to instructional suggestions.	All participating teachers have handhelds.	Yes. Easily understandable and interpretable. Data are presented in a variety of different formats.	Offers variety of pre-programmed views.	Immediate.
MPS[a] Formative data on handheld	Data are aligned to Reading First and the 5 Big Ideas of early literacy as outlined by the National Reading Panel.	Tool does not contain instructional material, but the measures link to instructional suggestions.	All relevant teachers have handhelds.	Yes. Easily understandable and interpretable. Data are presented in a variety of different formats.	Offers variety of pre-programmed views.	Immediate.
NYCBOE Summative test data via Internet	Reports state accountability test results.	Web-version contains instructional materials.	Accessible via the Internet, but not all classrooms are connected. Also have print versions of reports for teachers and parents.	Questionable. Some parts are easy to interpret, while others are confusing.	Offers variety of pre-programmed views.	6 months.
CPS Summative test data via Internet	Reports state accountability test results.	To the standards Web-based.	Accessible via the Internet, but not all classrooms are connected.	Some. Some parts are easy to interpret, while others are confusing.	Offers variety of pre-programmed views.	6 months.

[a] Assuming the use of the handhelds.

Observations from the Sites

We will summarize data that fall into two overarching topics. First, we will describe findings that relate to school issues. These include such factors as accountability and assessment, professional development and training, leadership, and data use. The second focus is on the affordances of the technology. We examine how the six characteristics that form the structural functionality framework impact the use of data.

School Issues. Accountability pressures by and large are one of the most important factors influencing the use of data and the tools. In the United States, there is increasing pressure at the local, state, and federal levels for schools to achieve performance mandates, as assessed by high-stakes tests. The more tests, the more pressures that are felt by the practitioners, and therefore the need to use data to make informed decisions about instructional practice that my lead to improving achievement, especially given the punitive consequences associated with failure. Because of this increase in testing, schools are faced with an explosion of data. The data need to be mined in different ways, and in particular, must be disaggregated. Simply put, there is so much data that educators are forced to use technological applications to deal with the wealth of data. As many educators say, they are data rich, but information poor. By this they mean that there is far too much information with which they must deal, but those data are not easily translatable into information and actionable knowledege. One goal of using the tools is to facilitate the mining of data from multiple perspectives that ultimately will provide the user with information from which they can make decisions.

A byproduct of the increase in testing is what happens in the classroom in terms of time allocation. As more testing occurs, teachers are forced to devote less time to instruction. Teachers report that they must teach to the tests, and in doing so many important topics get omitted. Teachers feel that they are not teaching as much as they are doing test preparation. Teachers also feel that their typical classroom practices are being changed by these pressures. Teachers know their students and tend to use multiple assessment strategies, quantitative and qualitative, summative and formative, to measure student progress. These strategies translate into a wealth of classroom data that needs to be collected and analyzed. Thus the applications play a critical role in helping educators to manage and examine the plethora of data.

Many teachers feel frustrated by the accountability pressures. Many see the use of data to make informed decisions a necessary survival strategy. Thus the applications by which data can be mined are key tools. Other teachers, however, are taking a more fatalistic approach. They feel that the pressures are just another passing fad and will fade in time, using a strategy to continue practice as usual. While yet another group of teachers are luddites who feel threatened by technology and balk at mining the data, entrusting that task to someone else in their school.

Some teachers' reluctance to use data the tools is grounded in a lack of training or a mistrust of data. Two kinds of training are salient here. First, there is a need for training on the use and understanding of data. Second, there is the need for appropriate and timely training on the tools. Teachers rarely receive preservice or inservice training. There are relatively few courses offered in teacher training institutions on data, and only recently have such inservice workshops begun to emerge. While teachers need to understand data, they also need to know how to use the technology that makes data mining possible. Again, only recently have professional development opportunities become available.

Leadership is the last major of the major school issues. Leadership makes a difference in terms of the message administrators communicate to their staff. In our experience, building leadership appears to be more important in facilitating or impeding the use of data and the tools. Although superintendents set the tone for a district's philosophy, principles have more direct contact with the faculty and therefore more influence on what they do. A principal who is data-driven or technically savvy can exert substantial influence on the faculty, communicating the importance and thereby stimulating use. In contrast, principals who are luddites communicate that

technology and data are not important. They may not be impediments but they certainly do not urge their teachers to make use of the data and technology.

Affordances of Technology

As mentioned above, we have identified six functions of the tools that contribute to their use. These characteristics play out differently across our three applications as well as other tools. It is clear that the more easily accessible, the more likely the tools will be used. The handhelds are easily accessible, even with minimal training. Teachers access data on the devices and almost as easily online with the downloaded data that allow for deeper data mining. In contrast, the interface of the data warehouses are much more difficult to negotiate and therefore far fewer teachers make effective use of the tool. Had the interfaces been more user-friendly, it is clear that many more practitioners would take advantage of the wealth of data that resides on the warehouses. The feedback loop is perhaps one of the biggest motivators for or impediments to use. The functionality involves both the form of assessment or data and the tool. The Grow Reports are seen as static data with less utility because of the five-month delay between testing to the delivery of the data. In contrast, the handhelds provide immediate data to teachers from which they can make informed instructional decisions. The warehouses are somewhere in between, depending on the type of data entered and mined, as well as who is accessing the data (the end user or the data inquiry specialist). The tighter the feedback loop, the more immediately useful that data appear to be. Comprehensibility deals with the understandability of the information. The more understandable, the more likely the tool will be used. Parts of the Grow Reports are highly comprehensible, while other parts are open to misinterpretation and ambiguity even by trained specialists. The handheld's data are fairly easy to understand.

Flexibility refers to the extent to which the tool can be used in multiple ways to examine data. The more flexibility, the more useful the tool will be. However, the more options a user has, the more opportunity for confusion. Looking at data in a variety of ways generally will help the user to understand more deeply the meaning of the information. This includes having a variety of visual displays such as tables, graphs, and charts, and presenting data at different levels of aggregation. Take for example the two data warehouses. One warehouse presents data at the individual student level. If an inquiry is made at the level of the class, a special data run must be made to aggregate the data at the class level. The other warehouse flexibly moves across different levels of aggregation and units of analysis – student, class, teacher, school, and district levels. Alignment refers to how well the data can be matched to standards, instructional goals, and classroom practices. The Grow Reports are customized to state standards and display student and class performance categorized into quartiles. Teachers can go to the Grow website to obtain instructional resources that may help to remediate particular performance deficits. In a similar manner, the sixth component, link to instruction, is manifested differently in the tools. The Grow Reports' indication of how the class performed in relation to the standards and the online resources are intended to help teachers plan instruction. Perhaps the most aligned to instruction are the handhelds. The diagnostic assessments administered via the handhelds are intended to be translated immediately into instructional remediation, thereby blurring the distinction between assessment and instruction. The handhelds can truly be a powerful instructional tool, not just an assessment device. The data warehouses have less direct links to instruction, requiring the teachers to develop links to classroom practice based on the data they have accessed.

An In-depth Analysis of Tucson's Data Warehouse Implementation

Profile and Demographics

TUSD is a mid-sized urban school district located in Tucson, Arizona. Currently, TUSD is the second largest school district in the state serving a student population of over 60,000. The district employs a total of 3,700 teachers, 3,600 support staff and 200 administrators. The ethnic makeup of students is comprised of 51% Hispanic, 35% Caucasian, 7% African American, 4% Native American, and 3% Asian American students. Although the student population is diverse, – individual schools tend to have more homogenous populations, ranging from 99% Hispanic within

some schools to 99% Caucasian in others. The district serves approximately 18,000 Title I students, the largest number in the state.

TUSD has a total of 110 schools. During the 2004-2005 school year, 14 schools did not make Adequate Yearly Progress (AYP) as defined by NCLB. Several of the district's schools are under-enrolled due to students leaving for charter schools. Within TUSD's boundaries there are 52 charter schools and all of the under-enrolled schools are geographically close to charters.

TUSD is governed by a five-member board elected by the public. In the past few years, the district has lacked stable leadership in terms of a superintendent. A former superintendent was brought back from retirement and named interim superintendent. The board later extended his contract until June 2006.

Federal and State Demands for Data

In addition to the accountability and reporting demands required by NCLB, TUSD must comply with the state of Arizona's mandates. State policies explicitly require districts and schools to use data for school improvement planning and processes. Arizona LEARNS (Leading Education through Accountability and Results Notification System) is the Arizona Department of Education's school accountability system. Unlike NCLB, Arizona LEARNS measures school performance over a three-year period (see Table 2). Measures include whether the school met AYP, results of the state mandated test - Arizona's Instrument to Measure Standards (AIMS), and graduation/dropout rates. Based on the results of these measurements, schools are identified and labeled as Excelling, Highly Performing, Performing, or Under Performing.

Table 2: Comparison of Arizona's Accountability Systems

NCLB	**Arizona LEARNS**
Required by federal law	Required by state law
One-year snapshot of student performance	Longitudinal examination of student performance
Components of evaluation: AIMS Scores Percent of students assessed Attendance/Graduation rates	Components of evaluation: AIMS Scores Measure of Academic Progress (MAP) Graduation/Dropout rates Adequate Yearly Progress (AYP)
Labels schools depending on whether AYP is met (yes/no)	Labels schools on a graded scale: Failing to meet academic standards Underperforming Performing Highly Performing Excelling

Source: Arizona Department of Education. www.ade.state.az.us.

Another state policy, Proposition 301, also implements specific educational accountability measures. Proposition 301, passed by voters in November 2000, authorizes a 0.6 percent sales tax increase to support education. As part of this proposition, each school district must submit

electronic data on a school-by-school basis, including student level data, to the Arizona Department of Education in order to receive state funding. Districts also are required to submit daily attendance electronically to the state.

Some of the funds collected from Proposition 301 are targeted to enhance teacher salaries based on performance. Each school district develops its own performance-based pay plan. In TUSD, school councils - elected representative groups of parents, teachers, school staff and community members - in collaboration with the principal, develop and approve a School Improvement Plan and three site goals for increasing student achievement. If a school attains at least two of the three goals, faculty earn a stipend. Site goals must be based upon analysis of data and must prioritize areas in which the school has the greatest need for improvement. Specifically, goals must measure student growth, clearly identify the group(s) of students to be measured, and include baseline data of where students began and how much progress they will make by the end of the school year. Additionally, schools must identify the data source and/or measurement that will be used for assessing improvement. An example of an acceptable goal is "All 3rd grade students will improve from 42% to 47% in reading achievement as measured by the AIMS."

Data Management Systems in the District

The district has a history of developing it's own data management systems. In 1990, the TUSD Governing Board charged the district to develop, administer, and maintain a student information system to standardize and unify student records. In response to the board's request, the Technology and Telecommunications Systems (TTS) department staff developed a student information system named Sonora and implemented the system in 1993. Sonora was accessible through a wide-area network within the district. During the 2000-2001 school year, TTS released Mojave, a web-based student information system making the system accessible through the Internet. Mojave only can be accessed by all district personnel and is mainly used by school staff including principals, teachers and support staff. The district requires teachers to enter grades and daily attendance grades using Mojave.

In the spring of 1998 the district began plans to construct a data warehouse. At this time, very few commercially available software options existed for collecting and analyzing K-12 educational data. The district had no choice but to build its own data warehouse specifically to suit its needs. District leaders assembled a team within the Accountability and Research (A and R) department to build the data warehouse. According to the developers, the project was kept alive by not trying to design every part of the system at once. Rather, staff conducted a needs assessment to figure out what type of data stakeholders needed and then built one module of the system at a time. The warehouse initially was implemented as an Intranet site accessible only to TUSD employees on district computers. It later evolved to a web-based data warehouse now known as TUSDStats.

TUSDStats

TUSDStats (http://tusdstats.tusd.k12.az.us) combines data from several sources, with most of the data coming from the district's student information system, 'Mojave'. TUSDStats contains four main categories of school and district data (assessment data, demographic data, school profiles and ratings, and information about special programs), student-level data, and several other related links (what's new, student-level information, resources, on-line testing, stats chat, handouts, and frequently asked questions).

The assessment data section contains data from AIMS, the Terra Nova, the writing prompts, the Core Curriculum Standards Assessment (CCSA), past tests (Stanford 9, SAT, and ACT), and student grades. The demographic data section includes data on attendance, mobility, suspensions, enrollment, stability, and dropouts. The section on school profile and ratings includes data on state and federal mandates, such as AYP, school quality surveys, percent of students tested, school profiles, and the StAAR Measure (Student Achievement Accountability for Results) which is a combined measure of AIMS, CCSA, and the Stanford 9. It also includes a graphing tool that enables users to represent the data in different ways. The special programs data site includes information on a variety of activities and programs, such as GATE, Title 1, exceptional

children, desegregation, math placement, the family resource and wellness center, language assessment services data, senior surveys, the Spanish exit test, and school improvement plans.

We now examine TUSDStats in terms of the six dimensions outlined above. Some of these dimensions are more applicable to data warehouses and relevance may vary depending on the type of user.

Access and Ease of Use

As a web-based resource TUSDStats is easily accessible to users through the Internet. While a large amount of data is accessible to the public without requiring a log in, individual student data are password protected and only accessible to authorized users. There are several data access levels to TUSDStats that require authentication. At the district level, central administrators have access to site-specific information at schools with which they are associated. School administrators have access to their school's teacher and student level data. Principals can view individual student and all class and grade aggregations for their school. Teachers have access to student-level information and class aggregations for their current and past classes. Teachers are also able to view AIMS assessment results for their students at the concept level (e.g., number sense). The warehouse also provides access to parents. Parents can create their own account to access TUSDStats and view their child's test scores, grades, attendance, and teacher's contact information. When a parent logs in, they also receive bulletin board messages from their child's school.

Length of Feedback Loop

The length of feedback loop varies for different types of data. Data such as attendance are updated daily. State assessment tests administered during the spring are available the following fall. Quarterly writing assessment results are entered into TUSDStats by teachers, making the data immediately accessible. Other data such as school profiles and school rankings are updated once per year.

Comprehensibility of the Data

TUSDStats organizes summary data into tables and graphs showing aggregate assessment scores. Data are color-coded depending on whether students met performance standards. The multiple forms of graphic representations are intended to make the data readily understandable to different users. TUSDStats also includes information about, resources for, and definitions of key measurement and instructional topics about which teachers should be knowledgeable. The Resources section of TUSDStats contains links to explanations of statistical terms, lesson planning assistance, information about the many tests and accountability measures students must take, and descriptions about the state standards. These resources are all written for maximum comprehensibility on the part of the practitioners.

Manipulation of the Data

TUSDStats contains pre-designed queries and web-based reports. Users can run queries and reports by selecting criteria from elements such as pull-down menus and check boxes. Users are able to select queries based on aggregate data and using criteria such as ethnicity, grade level, and school year. TUSDStats does not provide users with an advanced query tool. Thus if users would like a query that is not available on TUSDStats they would need to request it from the A and R department. If a number of people request the same query, A and R staff may decide to add a query to the options on TUSDStats, thereby customizing the warehouse to the needs of its users.

Utility and Quality of the Data

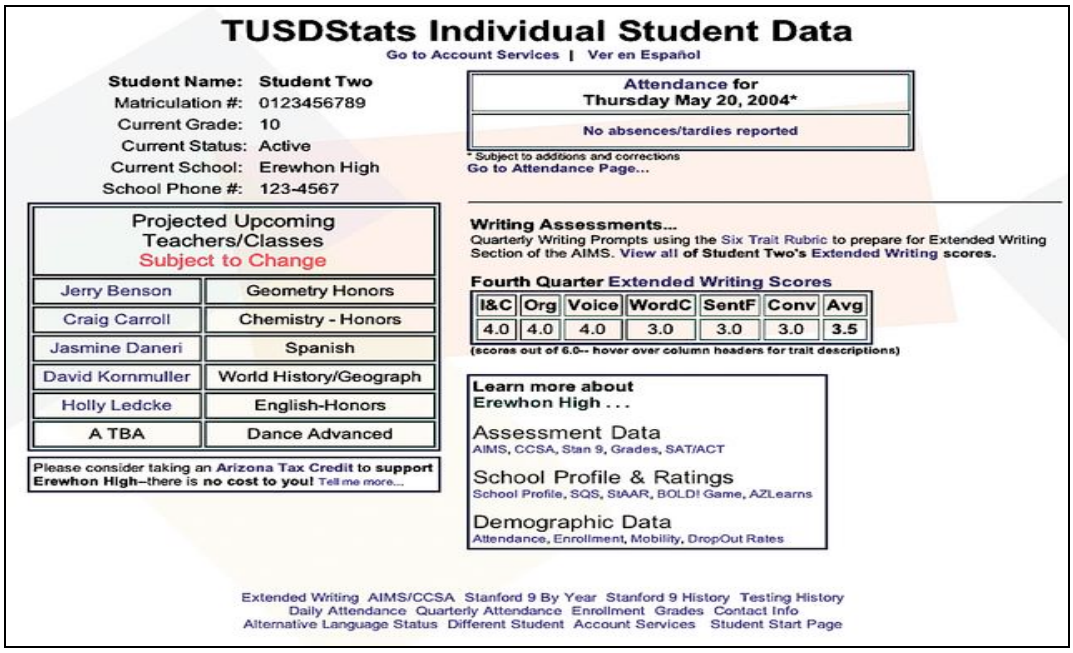
TUSDStats integrates school and student achievement data, offering administrators, teachers and parents access to a variety of educational data. The warehouse is organized into sections that include assessment, demographic and school profile data. Table 3 shows the data available within TUSDStats. Assessment data include test scores for district-developed assessments, state-mandated tests, and national assessment such as SAT/ACT scores. Course grades given by teachers are available for middle and high schools. Demographic information includes attendance data, student enrollment by ethnic background and gender, mobility rates for

schools, and dropout rates for middle and high schools. School profiles are available for all schools and include student achievement and student and school demographics. Additionally, school accountability ratings such as AYP can be looked up for each school.

Table 3. TUSDStats: Organization of Data

Assessment Data	School Profile and Rankings	Demographic Data	Special Programs
• State mandated norm-referenced and criterion based tests in reading, writing and math • District assessments • SAT/ACT scores • Writing prompt scores • Grades for middle and high schools • Scores for elementary schools	• District level measures to proficiency of goals • State and federal rankings • School profile • School quality survey results • Percentage of students tested	• Attendance • Enrollment • Mobility • Stability • Suspensions • Dropouts	• Gifted and Talented • Exceptional Education • Title I • Language Assessment • Desegregation • Senior Survey • Math Placement

Figure 9: Screen Shot of Individual Student Data



Links to Instruction

As depicted in Figure 9, the student data screen of TUSDStats contains a number of data sources, including direct links to the quarterly prompts and other assessment data. The quarterly prompts are administered by teachers for diagnostic purposes, and the results are intended to be readily amenable for use as an instructional tool in the classroom. Teachers are able to search the data warehouse, examine test scores, and then link to a section of the warehouse that provides suggested instructional steps based on student performance. There are several types of direct links

between assessment data and instructional supports included in TUSDStats's Resources pages. Among the resources is a lesson plan builder that enables teachers to use the assessment data to craft appropriate lessons, based on student needs.

Use of the Data Warehouse

Although TUSD has had data management systems in place for over 10 years, collecting data and using the data have had two different timelines throughout the district. With the implementation of NCLB, data use at all levels in the district increased substantially. In this section we discuss the use of data by district administrators, building administrators, and classroom teachers.

District Level Use

Many administrators with whom we spoke referred to the district as being "data-driven and people-powered." The district recognizes the need to have administrators and educators that are skilled in using data appropriately. With the proliferation of accountability mandates, administrators see the need to have access to and use of data for decisions. The district hopes that data accessed through TUSDStats will help educators focus on improving student achievement. Administrators use TUSDStats to view aggregate school data and identify low performing schools. They also use data to identify district-wide issues such as why students are leaving the district to attend charter schools.

Charting the Impact of Charter Schools

In 2003-2004, over 8,300 students who live within TUSD boundaries left the district to attend charter schools. The loss of these students reduced TUSD's revenue by $40 million per year. The district recently received a $40,000 grant from the National Education Association (NEA) to study why parents are pulling their children out of TUSD schools and to make recommendations to the TUSD Board. The data warehouse is being used to track when students leave and return to TUSD. Fairly complex cohort analyses have been used to identify these trends. The analyses indicated that parents tend to withdraw their child after elementary school and before they enter middle school, feeling that a charter school may provide more individualized attention than would be possible in TUSD's middle schools. However, many parents become disenchanted with the charters and re-enroll their child for high school due to limitations in the curriculum, lack of qualified teachers, and other factors. The interrogation of data on TUSDStats enabled district personnel to better understand the circumstances and trends around the charter school problem, and are now trying to determine what steps to take to remediate the problems and stem the outflow of children from the district.

Reducing the Number of Underperforming Schools

Prior to NCLB, the only schools that used the district's data systems for instructional decision-making were schools with low student achievement gains. The district was concerned about these schools and focused data efforts on them. When the first round of AYP results was released and Arizona LEARNS gave each school a label regarding school progress, teachers began the data investigation process. This occurred at the 26 schools that received a failing label. Over the course of three years, the district now has only one failing school.

Building Level Use of Data

District leadership believes that principals who use data for decision making will lead to more successful schools. For the past few years, the district has focused on providing professional development to principals on how to access TUSDStats and use the data. District-wide principal meetings are held at computer labs where principals have the opportunity to practice using the data warehouse. The district also hired a consultant to facilitate a workshop on how to use data specifically designed for building administrators.

Principals are strongly encouraged to use TUSDStats for instructional planning. Principal coaches work with principals to look at data and come up with strategies and interventions for improving test scores. The district requires principals to complete and submit their school accountability plan electronically using a template within TUSDStats. This plan prompts them to

focus on goals based on their test data, professional development to support those goals, and how they are going to meet their goals. In recent years, TUSD has incorporated a data exercise into the application process for new principals. To apply to become a principal, applicants take an online assessment, which includes viewing data for a fictitious school. In four hours, they have to look at the data, identify three problems, and then write a school improvement plan, a memo to parents, or talking points for meeting with their staff.

During our interviews, building-level administrators reported that they were using data for conversations and presentations made to their community and to identify student needs. Principals also are encouraging teachers to use data for instructional planning.

Using Data for Conversations and Presentations

Some of the principals we interviewed include data in presentations to faculty and parents. They present assessment results and discuss strategies for raising test scores. One principal we interviewed noted that everything she presents to her faculty is always backed by data or research. Another principal commented on how data add legitimacy to conversations and explanations of problems. Another principal explained that before the data warehouse when she met with teachers about their performance, she would just say, "you're doing a good job." Now, she can show them the data that confirm that they are doing a good job and talk about specific areas and activities.

Identifying Student Needs

Principals look at aggregate student data to make determinations about where to place individual students. Most principals mentioned looking at AIMS assessment scores to identify trends. They view demographic and achievement data to see how different groups of students are performing. High school principals also use the data warehouse to examine dropout rates and demographics of students dropping out to try and identify these students' needs.

Encouraging Teachers to Use Data for Instruction

Principals encourage their staff to use student data to inform instruction. Some principals ask teachers to select a few students and look at their data over a period of time to try to identify trends. They encourage teachers to log into TUSDStats to view individual student data. One principal said her goal was to help teachers respond to students' needs by encouraging them to develop individual plans for students based on data.

Discussing Test Scores with Students and Teachers

At some schools, teams made up of the principal, instructional coaches and counselors meet with every student individually at the beginning of the year to discuss the results of the student's test scores. During these "test talks", as one administrator referred to them, the team helps each student identify strengths and weaknesses and set goals for the year. At one school, the team also met with each teacher to review their class test scores and help them plan for instruction.

Challenges in Building-Level Data Use

Despite the district's focus on improving principal's ability to use data, actual use of data by principals varies building to building. District administrators that we interviewed recognized this as an issue and one commented, "Some principals are very astute at using data while others do it superficially." Additionally, district leaders were able to identify top data-using principals by name. Although principal supervisors are supposed to be working with principals to make sure data use is part of a principal's performance plan, district administrators were not sure if this was actually happening. One principal told us that she felt that while the message from the district on using data is clear, the accountability is not.

Classroom Level Use of Data

Using data for instructional decisions and planning is new to TUSD teachers. Among the problems created by the newness is that teachers have not received professional development from the district on how to use data in the classroom. Further, most teachers are influenced by the importance that their principal places on using data. Some principals have provided their own training to teachers on how to use data for instructional planning, while others fail to communicate to their teachers the importance of using data.

Teachers discussed the need to examine many sources of information when talking about using data. They recognize the importance of using multiple sources rather than relying on a sole data point from which to make decisions. This is a particularly salient issue when teachers examine standardized test scores along with classroom assessments. Teachers use aggregate class assessment data as well as individual student scores, grades, attendance, and contact information.

Differentiating Instruction

Most teachers who talked about using data to differentiate instruction were referring to using quarterly writing assessment scores. Quarterly writing prompts are scored by the teachers using the Six Trait Writing Model (NWREL; Bellamy, 2005; McMahon & Warrick, 2005) where each piece of writing receives six scores. Because teachers enter the writing scores into TUSDStats, they are able to view their class results immediately. Once the teachers have the visual organization of the data, they can see which students are falling below the standards in any writing trait. At one school we visited, cadres of teachers discuss the data as a group and together develop a plan on how to improve instruction and performance of the students. These teachers focus on the students that are falling below the standards in a trait and separate children into small groups to provide mini-sessions with those that need help in a certain writing skill. Teachers credited their ability to transform those data into actionable knowledge to the immediate aggregation of student scores that TUSDStats supports.

Assessment of Students

Some teachers use TUSDStats to examine assessment scores at the beginning of the year to gain an understanding of their students' level of academic performance. A few teachers said they develop assessments and curriculum based on the results of their students' scores. Teachers also reported that examining assessment data for new students that enter their class in the middle of the year was useful when they are trying to determine where new students are in relationship to their class. Additionally, some teachers look up assessment scores to see how their school compares to other schools in the district.

Other Uses of Data

Sharing student information with parents was another use of data that teachers mentioned. The data become points of conversation between the teacher and parents. Teachers use the data during parent conferences to show student attendance patterns, assessment scores, and grades.

Many teachers use the data warehouse to talk to students about their progress and how they are doing in other classes. Some middle and high school teachers mentioned logging into the data warehouse and viewing the data together with students. This process allows them to discuss test scores, attendance issues, and problems in other classes. In some cases, students ask their teachers to log into TUSDStats to view their own data.

Most teachers use the tool to look up student contact and background information. They credited the tool for helping them be more efficient since they don't have to go to the school office to obtain student information. As one teacher expressed, "It's like having a cum folder online."

Some teachers discussed using the Lesson Plan Builder section of TUSDStats to create their lesson plans. Teachers mainly look at the sample lesson plans available to get ideas for their own lessons.

Non Usage of the Data Warehouse

During interviews, teachers stated reasons for not using the data warehouse. Some teachers were not familiar with TUSDStats. Most of these teachers were either middle or high school teachers that were not required to use TUSDStats to enter quarterly writing scores. Of teachers that were familiar with the tool, most cited that they use their professional judgment to assess where students are academically and didn't feel the need to view test scores to confirm classroom sources of data. One teacher expressed that any good elementary school teacher knows where their students are within the first few weeks of a school year and questioned whether looking at the data would reveal anything new to her. Another reason for not using TUSDStats that teachers mentioned was their lack of expertise on using data. These teachers emphasized that

although they thought of themselves as technology-literate and had no problem accessing the tool, they didn't understand or know what to do with the assessment data. For example, a middle school math teacher felt that teachers at his school lacked the expertise to understand how to use data and feared that data might not be properly interpreted. Instead of using this data, some of these teachers prefer to generate their own data to monitor student learning usually through assessments they develop

Summary

These data only touch the surface of how three technology-based tools impact how educators use data to make informed decisions. It is clear that the characteristics of the tools, as well as a host of school variables affect use as can be seen in the variation across the systems maps. We have posited here the systems maps for the six districts as initial forays into the data we have collected. As we continue to mine the data, these maps will no doubt evolve. We have tried to depict the importance of each district's vision and the role of all levels of leadership. These factors directly influence and create a data culture that permeates throughout a district. Data and tool characteristics define the tool, while external factors such as accountability measures and policy mandates influence tool use. Also influencing the data culture and depicted in generic terms is the importance of educators' knowledge. We have identified three types of literacy that impact how teachers function in a data culture – data literacy, assessment literacy, and pedagogical data-driven decision making literacy. Teachers need to know about data and assessment, but they also need to understand how to how to apply this knowledge pedagogically in terms of instructional data-driven decision making. Other factors such as resources also affect the data culture.

The three frameworks posited here are works in progress based on two years of intensive data collection in six school districts. The systems-based methodological framework has attempted to capture the dynamics and interconnectedness of complex school systems. The conceptual framework provides a theoretical analysis of the cognitive processes that are engendered in data-driven decision making. Critical in this framework is the iterative nature of the feedback loops that transform data into information and ultimately to actionable knowledge. The third framework focuses on the structure and functions of the technology-based tools that either facilitate or impede their utility to end users.

As we continue to examine the data, we will continue to refine the systems models for each of the sites, attempting to draw parallels within and across tools. These data will help us to further refine the theoretical/conceptual model as well as the structural functionality framework. Our goal is to take our data and ultimately transform them to information and knowledge, just as we have posited in our theoretical framework.

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