Breiter, A., & Light, D. (2006). Data for School Improvement: Factors for designing effective information systems to support decision-making in schools. *Educational Technology & Society*, 9 (3), 206-217.

Data for School Improvement: Factors for designing effective information systems to support decision-making in schools

Andreas Breiter
Institute for Information Management Bremen, Am Fallturm 1, 28359 Bremen, Germany
Tel: +49 421 218 7525
Fax: +49 421 218 4894
abreiter@ifib.de

Daniel Light
EDC/ Center for Children and Technology, 96 Morton St, New York NY 10014, USA
Tel: +1 (718) 237-5116
dlight@edc.org

ABSTRACT

National legislation that increased the role of accountability testing has created pressure to use testing data, along with other data, for instructional decision-making. Connected to this push for data-driven decision-making, is the increased interest in data delivery systems or Management Information Systems (MIS) in education. But, before administrators rush to build data and information systems, we argue for a careful review of existing knowledge about information systems in the education sector in light of what business and organizational research already knows about information systems. We draw on the considerable body of business and organizational research on MIS and a recent educational case study in New York City to introduce a theoretical framework to describe the process from data to decision-making in schools. Our exploration of how schools use information focuses on the potential of new technologies and new ways of analysis to meet the information needs of educators across different levels of the system. We conclude with a discussion about critical factors for the development and implementation of effective information systems for schools: 1) Build from the real needs of classroom and building educators; 2) Recognize teachers' wealth of tacit knowledge as a starting point; 3) Select appropriate data to include in the information system; 4) Effective testing requires close alignment between standards, teaching and testing; 5) Educators need professional development on instructional decision-making that considers the role of data; 6) Educators need expanded repertoires of instructional strategies; and 7) Further research on effective instructional decision-making and IS support is needed.

Keywords

Standard-Based Testing, Decision Support System, Data-Driven Decision-Making, Management Information Systems, Assessment Information Systems

Introduction

The shift in the funding and regulatory environment caused by the *No Child Left Behind Act* (NCLB) has prompted many district and school administrators to think differently about the potential that assessment data and information systems may have to inform instruction and decision-making aimed at raising student achievement. Increasingly the exploration of how data can inform instructional decisions is a main topic of educational policy (Salpeter, 2004; Secada, 2001) and building Management Information Systems (MIS) is a central concern for many administrators. But, before administrators rush to build data and information systems, we argue that educational decision-makers could benefit from a review of relevant work being done in business research and its application to an analysis of early experiences using technology to provide test data to classroom teachers. We draw on the considerable body of business organizational research on MIS and a recent educational case study in New York City to explore the question of how schools use information systems and the information needs of end users across different levels of the system. The case study examines the implementation of a web-based information system for student standardized test results to assist the educator's daily practice. Finally, the paper concludes with a discussion about critical factors for the development and implementation of information systems for schools and the meaning the data can have for school administration.

Support for Decision-Making

Research about using test data to support classroom-level decisions or building-level planning to improve learning is just beginning to emerge. In the U.S., the research from different design sites that are piloting educational data-systems are seen in: the Quality School Portfolio (QSP) developed at CRESST (Mitchell &

Lee, 1998), and IBM Reinventing Education data projects in Broward County Florida (Spielvogel et al., 2001), the Texas Education Agency, and the South Carolina Department of Education (Spielvogel & Pasnik, 1999). Research on the role of data systems and applications in practice is also being done in Minneapolis (Heistad & Spicuzza, 2003), Boston (Sharkey & Murnane, 2003), San Francisco (Symonds 2003) and on the implementation of QSP in Milwaukee (Thorn, 2002; Webb, 2002).

Additionally, there is a body of empirical research on the use of school information systems in other countries, like the case study in New Zealand (Nolan, Brown, & Graves, 2001), Visscher and Bloemen's (1999) examination of data-system in Dutch schools (Visscher & Bloemen, 1999), an examination of experiences with a widely used school information systems in Great Britain (Wild, Smith, & Walker, 2001) and in Hong Kong (Fung & Ledesma, 2001). In Germany, most studies primarily focus on test administration and feedback mechanisms (for an overview see e.g. Kohler & Schrader, 2004; Weinert, 2001). Nevertheless, most studies mainly focus on administrative data for school management. Less emphasis is given to the role of data for teachers in their instructional decision-making.

Although research on data-support systems is just beginning in the education field, such systems, known either as Management Information Systems (MIS) or Decision Support Systems (DSS), have been a focus since the early 70's in the field of organization and management research. Except for the work done by Thorn in Milwaukee (Thorn, 2001, 2002, 2003), the study on High School's continuous improvement process (Ingram et al., 2004) and the approach of Petrides and Guiney on knowledge management in schools (Petrides & Guiney, 2002), most of the above educational studies use case study methods and do not offer a theoretical model of data-driven decision making. Thorn used MIS theory to help understand data-support systems in schools. In this paper we follow his lead and present a review of MIS research and use our own research on a New York City educational data-system to highlight the application of an MIS framework to education.

Taking into account the increased significance of "information" as a prime resource in management contexts and its importance for the support of decision-making processes, various approaches to information management were developed in the beginning of the 70's. MIS are based on the assumption that availability of relevant information is a necessary condition for decisions. Simon (1977) suggested three phases of decision-making: intelligence (review the environment, analyze goals, collect data, identify problem, categorize problem, assess ownership and responsibility), design (develop alternative courses of action, analyze potential solutions, create model, test for feasibility, validate results) and choice (acceptability of solution, building normative models). In all three phases information has to be provided and/or searched for in different forms and levels of aggregation. Essentially, management decisions can be understood as information processing where information takes on a strategically important significance for the organization's development.

In the beginning of the 1970's, Gorry and Scott Morton (1971) recounted, in an empirical study, that the first MIS failed mainly because it was based on a flawed understanding of managerial work and a fundamental misunderstanding regarding the necessary information (Gorry & Scott Morton, 1971). The predominant perspective at that time, which is still common today among many system developers, is based on a naïve understanding of decision-making processes. It was thought that decisions can be exclusively rationalized and it took some years to understand the "bounded rationality" of decision-makers (Simon 1977). Built on this conception, company-wide projects collected data from every department and sub-department to be stored in a central data bank, which managers could use to make the "right" decisions. Through extensive case studies Gorry and Scott Morton (1971) showed that only a small portion of the collected data was relevant for decision-making and most of the data was totally worthless for decision-making.

Ackoff (1989) elaborates on the fundamental flawed assumptions that accompanied the development of MIS. The preconceptions underlying the design of early MIS presupposed that the crucial need of management was the availability of all relevant information. The early designers failed to realize that good management requires the reduction of irrelevant information to focus on relevant information when making a decision. The early MIS systems overloaded decision-makers with extraneous and irrelevant information, which merely complicated their task of selecting out the relevant data. This mistaken assumption was also exacerbated by actual managers who, when asked, in the abstract, would usually request all possible information but then get lost in data overload. It is important to bear in mind, however, that the definition of relevant information is often hard for managers as they usually act with unclear information. Feldman and March (1988), too, doubt that the provision of requested information should be sufficient to make good decisions. Their assumption is that, often, the necessary information only can be identified when the decisions have already been made. Even if essential information is already available to the decision-makers it is frequently ignored during the decision-making process.

Today, MIS literature has moved forward to what is called "business intelligence". The underlying assumption remains that enough efficient computers would be able to remove the problems of user-friendly data analysis. The latest approaches, like data warehousing, integrate multiple databases and promise the use special algorithms ("data mining") that will uncover hitherto unknown connections in big databases (see e.g. Laudon & Laudon, 2002; Marakas, 2003). But even these technologically complex systems do not meet the demands of decision-makers who expect more than simple predefined reports. In the end of the 90's the hardware still was not efficient enough to carry out the analyses. Longitudinal analyses were difficult because only limited historical data was available. OLAP ("On-Line Analytical Processing") brought the expectation that now complex, fast, and user-friendly data bank inquiries could be performed (see e.g. Connolly & Begg, 2002). Unlike earlier technologies, OLAP facilitates a more effective and efficient access to the core data, and the graphic visualization and the user interface have been improved.

In this brief review of research, we have identified a few key points as we move on to think about school information systems:

- Decision-making is a highly complex individual cognitive process influenced by various environmental factors. The classroom may be the example par excellence of an inter-subjective decision-making environment. Teachers constantly make decisions which may affect 20 or more children.
- Decision-makers often are not fully cognizant of the specific data they rely on for each decision. Identifying the information needs of the decision maker is a crucial step in designing an effective information system, although identifying the appropriate information to put into the system is a complex and time-consuming process. When making instructional decisions, teachers may need to consider their students' intellectual and physical abilities, developmental stages, personalities and their interpersonal skills.
- An effective information system needs to incorporate the logistical elements of time, quantity, quality and access. Schools are challenging organizations to work with: they lack professional staff for data processing and distribution; and teachers are often isolated in their classrooms, unable to absent the classroom to retrieve information.

Typology of School Information Systems

School information systems constitute a clear sub-group of management information systems that are used in educational organizations. In schools, distinct information systems support different types of decisions: administrative information systems, learning management systems and assessment information systems. In principle we must distinguish between systems that are focused directly on the support of the teaching and learning process and systems that serve for the administration and instructional decisions (see figure 1). An often cited definition for a school information system is given by Visscher: "[A]n information system based on one or more computers, consisting of a data bank and one or more computer applications which altogether enable the computer-supported storage, manipulation, retrieval, and distribution of data to support school management." (Visscher, 2001, p. 4). But this emphasizes only the aspect of administrative support.

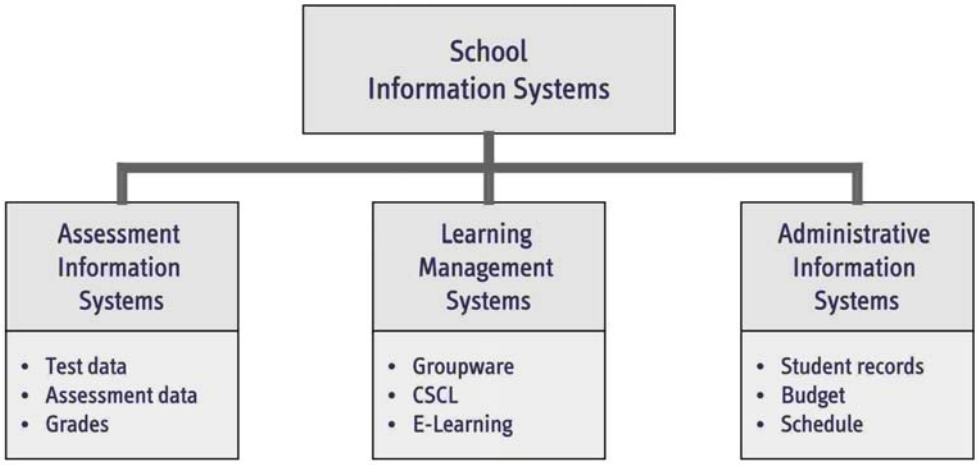

Figure 1: Typology of school information systems

Administrative information systems span the whole area of basic data – from addresses to scheduling and timetables, to accounting and financial planning. Usually, the school management must work with several systems for different purposes that are compatible in limited ways.

Learning management systems or Learning Content Management Systems aim at the direct support of the learning and teaching process (e-learning). Here, either learning processes are controlled individually or material is made available to students and teachers.

Independent of the content management systems, are assessment information systems (AIS) that make data about student test performance available. The assessment information can come from standardized tests, classroom-based assessments (i.e. teacher designed) or from portfolios of student work. The systematic analysis and use of AIS for instruction and school development will be a determining topic for schools and their management in the next years. Stronger accountability policies as well as school improvement processes will require the collection, analysis and reporting of data. Many systems are being combined into "data warehouses" since the database integration of multiple sources allows for multidimensional analyses and reduces the expense of inquiry and maintenance.

We can learn from the empirical research in MIS that decision-makers at different levels of the school system have different information needs, which first have to be identified and analyzed. The aspect of information logistics in the design of MIS raises the question of how accurate information can be provided to the right persons at the right time. In the school system four action levels with specific actor groups can be distinguished that each have different needs of information (see table 1).

Table 1: Model of levels of information needs in schools

Level	Stakeholders	Information needs
Classroom	Teachers Students	Disaggregated student data Grades and test scores / portfolios Tracking of attendance / suspensions
School	Principal Administrators	Aggregated longitudinal student data (i.e. by class, by subject) Grades and test scores Tracking of attendance / suspensions Aggregated longitudinal administrative data Coordination of class scheduling Special education and special programs scheduling Allocation of human resources Professional development Finance and budgeting
District	Superintendent Administrators	Aggregated longitudinal student data (i.e. by building, by grade) Aggregated longitudinal administrative data (i.e. by building, by grade) External data reporting requirements
School Environment	Parents Local community	Disaggregated student data Aggregated administrative data

Data-to-Knowledge Process Model

Most theories of information management draw distinctions among data, information, and knowledge. For example, knowledge is regarded in management literature as being embedded in people, and knowledge creation occurs in the process of social interaction about information (e.g. Brown & Duguid, 2000; Sveiby, 1997). Decision support systems have to be embedded in a larger context which is often described as knowledge management (e.g. Nonaka & Takeuchi, 1995) or organizational learning (Argyris & Schoen, 1978; Bhatt & Zaveri, 2001). The terms 'information' and 'knowledge' are often used as though they were interchangeable when in practice their management requires very different processes. At the core of knowledge management is the idea of systematizing and categorizing the variety of data and providing the resulting product in an appropriate using information technology. This, then, supports organizational learning (e.g. Alavi & Leidner, 2001; Earl, 2001). This perspective is supported by Nonaka and Takeuchi (1995): "information is a flow of messages, while knowledge is created by that very flow of information anchored in the beliefs and commitment of its holder. This […] emphasizes that knowledge is essentially related to human action". Likewise, Drucker (1989) claims that "[…] knowledge is information that changes something or somebody - either by becoming grounds for actions, or by making an individual (or an institution) capable of different or more effective action"

(Drucker, 1989). Therefore, data, prior to becoming information, is in a raw state and is not connected in a meaningful way to a context or situation.

Borrowing from Ackoff's (1989) work in the field of organization and management theory, we adapted a simplified version of Ackoff's conceptual framework that links data, information and knowledge (Breiter & Light, 2004a, 2004b). Within the framework, there are three "phases" of the continuum that begins with raw data and ends with meaningful knowledge that is used to make decisions. They are the following:

- Data exist in a raw state. They do not have meaning in itself, and therefore, can exist in any form, usable or not. Whether or not data become information depends on the understanding of the person looking at the data.
- Information is data that is given meaning when connected to a context. It is data used to comprehend and organize our environment, unveiling an understanding of relations between data and context. Alone, however, it does not carry any implications for future action.
- Knowledge is the collection of information deemed useful, and eventually used to guide action. Knowledge is created through a sequential process. In relation to test information, the teacher's ability to see connections between students' scores on different item-skills analysis and her classroom instruction, and then act on them, represents knowledge.

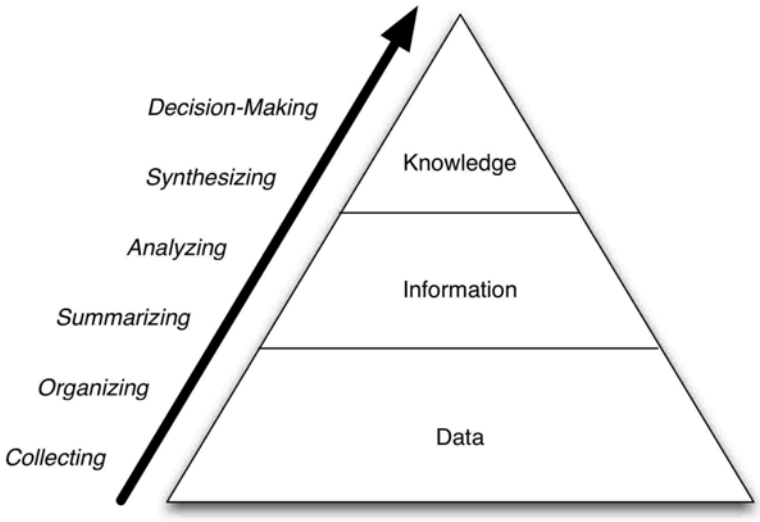

Figure 2: The process of transforming data into knowledge (see also Light, Wexlar and Heinze, 2004)

The literature identifies six broad steps (see Figure 2) through which a person goes in order to transform data into knowledge (Ackoff 1989; Drucker, 1989). The process entails collecting and organizing data, along with summarizing, analyzing, and synthesizing information prior to acting (making a decision). This is the process through which raw data are made meaningful, by being related to the context or situation that produced it; consequently, human action underlies all decision-making. This sequential process underlies our understanding of how teachers interact with data.

We can use an example of test scores to exemplify the underlying theoretical assumptions that distinguish among data, information and knowledge presented above. For example, the number 655 by itself means little. Test-data becomes information with the realization that the numbers indicate a measure of student test performance and the level of performance. A scale score of 655 on the third grade Language Arts test places that child below proficiency at Level 2 of the New York State Performance Levels. In relation to test scores, knowledge comes when the information can guide practice. The school must help a child achieve proficiency, therefore a Level 2 student might be enrolled in a supplemental program, or placed in cooperative groups with higher-level students (Level 3 or 4). Furthermore, 655 is right at the cut off to Level 3 – this provides even more knowledge about the significance of this child's score to the school's overall accountability process. Since schools must show a certain percentage of the students moving from Level 2 up to Level 3, a child whose score is right below the cut off is easier to move up than students scoring way below the cut offs. Achieving a certain level of knowledge about the test results is an important step in the decision-making process, for example.

Case study: New York City Department of Education and the Grow Network Data Reports

This paper draws on a research project of the implementation of an assessment information system in a large U.S. city. The research project *Linking Data and Learning* was funded by the Carnegie Corporation (Light et al., 2005). The New York City Department of Education (NYCDOE) is the largest education system in the USA with over a million students and 80,000 teachers. In 2001, NYCDOE contracted with the Grow Network to provide a data-driven decision-making tool at the third-grade through eighth-grade levels, where there are 30,000 teachers, 5,000 district and school instructional leaders, and 1,200 schools serving approximately 400,000 students. This represented an unprecedented effort to use standardized assessment data linked with supporting teaching resources to improve the quality of educational decision-making across multiple levels of the school system.

A number of factors of the larger context of New York City are often perceived as obstacles to improving student achievement. Among the total student population there are 423,694 children who are supported by public assistance, 153,134 receiving special education services and 127,099 English Language Learners (for all statistics see http://nycenet.edu/Offices/Stats). Other key complicating factors include:

- High levels of concentrated poverty, homelessness, isolation and addiction.
- High rates of teacher turn over create a constant cycle of novice teachers in need of training, mentoring, and support regarding content knowledge.
- High turn over of school leaders, 50% of school leaders hold their position for less than three years.
- Cultural disconnect: given the diversity of the school population and the challenge to effectively communicating philosophies, addressing learning needs of many different students and families is a challenge.
- Basic issues of ongoing maintenance and technical support are still concerns. Internet connectivity was still an obstacle in some districts.

NYCDOE introduced a system-wide data-support tool for its schools with the help of the Grow Network Company in 2001. The goal of Grow Network's NYCDOE Data Reports was to use paper and on-line reports to present relevant standardized test results to teachers, principals, and parents with specific recommendations for responsive action. Targeting students in grades 3-8, the objective was to use standardized assessment data, coupled with supporting resources and professional development, to improve the quality of instructional practice and student outcomes. By the end of the study, the Grow Network delivered four different data Reports reflecting different views for different target groups (table 2).

Table 2 Views of Grow Network Data Reports

View	Information Reported	Target group
School	Aggregated data, divided by subjects and grades	Principal, district, local community
Class	Students' test results, divided by subjects and by item-skills	Teachers, staff developers
Subject	Aggregated data, divided by grades	Teachers, subject coordinators
Students	Test data, divided by subjects	Students, teachers, parents

The Grow Network does a substantial amount of cleaning and manipulating to prepare the data for the Reports. Students are grouped by their current class, grade and school. They are grouped not just by score, but also according to the New York State standards across four levels, ranging from *Far Below Standards* (Level 1) to *Far Above Standards* (Level 4). Furthermore, the Grow Reports also present educators with student results on sub-sections of the test. For example, the teacher's Grow Report groups students in accordance with the state performance standards and provides an overview of class-wide priorities. For administrators, the reports provide an overview of the school, and present class and teacher-level data. For the parents, the reports explain the goals of the test, how their child performed, and what parents can do to help their child improve their score.

Soon after the beginning of the school year, educators receive a paper report with disaggregated data about their current students and they get a password-protected account on-line with access to complete test data for every student broken down by test areas. The on-line information system allows teachers to find and compare individual student data. Their class is ranked and grouped according to each sub-test and skill item.

In addition to the test reports, the Grow Network website supports teachers' analysis and instructional decision-making with two additional features. First, the website provides information on the state standards, definitions of the tested skills and concepts. Administrators and teachers often cited these materials as an important component

of the information provided. Second, the reported data is also linked to instructional materials and resources for teachers and administrators that suggest activities and teaching strategies to promote standards-based learning in the classroom. The reports also link to external resources approved by NYCDOE. The goal is to help teachers to collect more course material and rethink their classroom organization.

While most parts of the system rely on existing data from other sources, the analytical component offers aggregates of data (according to subject, item-skills). Additionally, the system suggests different models for classroom organization (e.g. heterogeneous or homogeneous grouping, additional material according to standards).

Research Methodology

The research project used a mixture of qualitative and quantitative methodologies. At the building and district level, the qualitative components focused on understanding the how educators (from classroom teachers to district administrators) understood the data presented in the Grow Reports and how they used that information to generate knowledge that could inform their decision-making. At the highest levels of the system, the findings are based on structured interviews with 47 educational leaders, including: central office stakeholders, superintendents, deputy superintendents, math coordinators, English Language Arts (ELA) coordinators, staff developers, district liaisons, technology coordinators, directors of research and curriculum. Additional interviews were conducted with representatives from non-governmental organizations working closely with the New York City schools on issues such as educational reform and professional development.

The research team also conducted ethnographic research in 15 schools across four school districts in New York City that represented various neighborhoods, student populations, and overall performance levels. This methodology is increasingly used in information systems research as hidden expectations, beliefs and usability concerns can be identified (e.g. Myers 1999; Trauth 2001). Research in the 15 schools produced 45 semi-structured and open-ended interviews with principals, assistant principals, staff developers, and teachers; and observations of ten grade-wide meetings and/or professional development workshops. To further explore the ways in which teachers think about using assessment information, the team conducted structured interviews using sample Grow Reports with 31 teachers in grades four, six and eight. The qualitative data was used to design two separate surveys for teachers and for administrators to explore how educators interpret data and conceptualize the use of the Grow Reports for instructional planning and the types of supports needed to fully leverage the use of data to improve instruction.

Use by Administrators

Linking Data and Learning found that administrator uses of the Grow Reports could be grouped into four main categories. However, depending upon the administrators' position (e.g. superintendent for curriculum, district math coordinator, school principal, or staff developer), they generated knowledge from the data organized by the Grow Reports and implemented their decisions into the school or district in slightly different ways.

- *Identifying areas of need and targeting resources*: Administrators explained that the Grow Reports helped them to identify class-, grade-, and school-wide strengths and weaknesses that could then be used to make decisions about planning, shaping professional development activities, and determining student performance and demographics. As one superintendent explained, "Grow allows you to combine test results and longitudinal analysis to diagnose a school's strengths. This helps make decisions about professional development and resource allocation" (Light et al. 2004, p.41)
- *Planning*: Once administrators identified which students, teachers, and resources they wanted to target, the data helped them to focus school or district planning activities. Administrators explained that they used the data on the Grow Reports to plan for setting school and district priorities and for instructional programs. However, administrators do not look to test data exclusively to make decisions because it is based on a single assessment. A superintendent reflected that, "You have to take into consideration how valid or current the data is when you are using the previous year's data. This is why you have to compare Grow with all of the other data sources" (Light et al. 2004, p. 42)
- *Supporting conversations*: Administrators considered that the reports and test data helped frame important conversations across the school system about student learning, professional development needs and school wide challenges. The reports provoked discussion about the role of testing in teaching and learning, as well as the (mis)alignments among standards, teaching and assessment. Specifically, the reports raise issues regarding standardized tests as diagnostics. Some respondents spoke of using standardized test data to move

principals', teachers' and parents' conversations about the determining factors of student achievement away from issues of socio-economic status or student behavior and toward a specific focus on students' strengths and weaknesses.

- *Shaping professional development*: The Grow Reports were used both as the focus of a professional development activity (typically in a workshop format) and to make decisions about other professional development activities, such as helping teachers to create differentiated instructional activities or learning about school or district-wide standards and goals through their close alignment to the Grow Reports.

Use by Teachers

Generally, the teachers considered the Grow Reports to be easy to read and informative. Teachers felt the report was self-explanatory. They compared them very favorably to all prior reporting formats they had seen. In particular, those teachers who had been using data as a planning tool felt the reports were a substantial improvement and time saving tool. The interviews with teachers also uncovered a core of "practitioner knowledge" about using the data which is what enabled them to use the Grow Reports to inform their instructional decisions. On the issue of teachers' background in psychometrics, teachers do not often have strong knowledge, but they did touch on many measurement and assessment issues and raised a number of concerns, although not phrased in psychometric terms. Some teachers raised concerns about the ways the data might have been transformed as it was turned into the Grow Report. Nearly all teachers touched on issues of validity and reliability in some way. Around validity, teachers had concerns about students who test poorly, or where having a "bad day" when they took the test. Teachers also raised concerns about students who test well – whose higher scores do not truly reflect their ability – and would be denied needed academic support because of it. Teachers also had reliability concerns linked to the difference between what they see as life skills and deeper learning, and the skills measured by the discrete, de-contextualized items on the test.

Teachers' concerns about reliability and validity were mediated by two factors – the level at which decisions were being made, and other "information" available. These two factors are closely interconnected. First, when referring to classroom-level decisions made by teachers, the interviewed teachers expressed less concern. At the classroom level, teachers understood that the test result, as a single measure, was insufficient for decision-making. Therefore, they always balanced the test data with other perspectives. Teachers have multiple sources of information about their students – teacher assessments, authentic assessments, observations, conversations and a shared experience. Teachers have a wealth of what sociologists of knowledge have called "tacit knowledge" (Polanyi, 1966) that they use in conjunction with test data. Teachers concerns about the validity of the test data increased when they spoke about decisions made at higher levels of the education system. They felt it was unwise to base student graduation or promotion decisions on one score. Their concerns were connected to a lack of other relevant information (i.e. insufficient data) available to decision-makers at higher levels.

The teachers' synthesis of information from the Grow Reports into their understanding of the classroom offered a springboard into a conversation about instructional decision-making. In the interviews teachers reported using the Grow Reports in myriad ways to meet their own varied instructional pedagogical needs, as well as their diverse students' academic needs. We grouped those 'areas of instructional practice' into the following five categories:

- *Targeting instruction*: When asked in interviews, several teachers and school administrators report, that they use the Grow Reports and instructional resources when doing broad level planning such as setting class priorities, creating a pacing calendar, or doing weekly or yearly lesson plans. Teachers report that the Grow Reports might help them decide on what standards to address and which skills to teach in daily lesson plans, mini-lessons, and even year-long pacing calendars. Many say that analyzing the information presented in the Grow Reports helps to show them where their overall class' strengths and weaknesses lie.
- *Meeting the needs of diverse learners*: Most teachers agree that because the data represented on the Grow Reports reveals that individual students perform at different levels, the tool helped them to differentiate instruction. Noting that the Grow Reports provided them with more information about student test performance than what they had access to previously, teachers said that they looked at the data mostly to know "where their students are." Classroom teachers commonly interpreted the test results in relative terms of their students' strengths and weaknesses. Teachers report different uses of the Data Report depending on the differentiation strategies they sought to implement. Teachers said that sometimes ideas for individualized instruction to meet student needs are derived from the reports, e.g. by modifying lesson plans, by providing different materials so that students have multiple entry points into the content; by varying homework and assignments and/or, by teaching in small groups or one-on-one.

- *Supporting Conversations:* Most of the teachers interviewed say the Grow Reports help bridge discussions about student learning. The teachers talked about using the Grow Reports in conversations with teachers, parents, administrators, and students as a starting point for conversations as well as something "concrete" to show parents, administrators, other teachers, or the students themselves when discussing where the class or the student was in terms of his or her learning and where he or she needs to go.
- *Shaping teachers' professional development:* In interviews and surveys teachers indicated that they use the opportunity to analyze the Grow Reports and their classes' strengths and weaknesses to also reflect upon their own teaching practice. Teachers explained that seeing, for example, that the majority students scored low on a skill, would cause them to reflect upon how they taught that specific skill. Some teachers reported that by looking at the Reports they realized that they weren't even teaching some of the standards and skills on which the students were tested (Light et al. 2004, p. 37). The reports helped teachers align their teaching to what the state standards expect children to be able to know and do.
- *Encouraging self-directed learning:* Another interesting use that emerged during the fieldwork was the dissemination of the data to students as a way to encourage them to take ownership of their own learning. A small but sizeable group of teachers talked about sharing the Reports (or the data from the reports) with their students so that students were not only aware of their performances on the test but were also encouraged to take responsibility in terms of their own academic progress. (Light et al. 2004, p. 38).

Rethinking the design of MIS for education

The findings from the research on Grow Reports offer an illuminating example for other districts that are starting to use test data for accountability and policy making. From the classroom-level perspective, the Grow Reports can be regarded as a useful data-tool since most teachers interviewed felt the data presented was clear and useful. Despite a noted lack of psychometric sophistication, teachers clearly demonstrated they could make sense of and use the data in the reports. Educators at the two levels of the school system closest to the students (i.e. classroom and building levels) felt that the student performance result on a single standardized test was not sufficient data to inform their instructional decision-making. The teachers and administrators who were using this data incorporated additional data from other sources to inform their decisions. In particular, teachers relied heavily on information gleaned from their daily interactions with their students. It was this tacit knowledge that enabled educators to use the MIS data effectively. Information technology has become widely available and its power and capacity is continuously increasing. This school case highlights the following seven factors of how data systems can support educators in making informed decisions:

- *Build from the real needs of classroom and building educators*. Most systems are built top-down, gathering as much data as possible and thinking about relevant data as information later – user-centered approaches would help. The Grow Network built the Grow Reports working closely together with the target audience – teachers. So much so that the tool may be more closely tailored to teacher needs than administrators;
- *Recognize teachers' wealth of tacit knowledge as a starting point*. Teachers using the Reports talked a lot about their holistic understanding of the students' needs and abilities, emphasizing their tacit knowledge as educators and how the data fit into their prior knowledge;
- *Select appropriate data to include in the information system*. Information systems are often flooded with data, offering more data than decision-makers can effectively synthesize and use. The Grow Reports present one specific and crucial data point – the standardized test scores. Because of the demanding accountability context in the United States, this is significant data to most teachers and administrators regardless of their concerns about the data's reliability and validity.
- *Effective testing requires close alignment between state standards, teaching and testing*. Alignment between what state standards expect students to know, what teachers are teaching and what the tests measure is often missing. The data tool can support a discussion about alignment by making the connections (or disconnections) explicit.
- *Educators need professional development on instructional decision-making that considers the role of data*. As U.S. teachers have long experience with standardized testing and state standards, they did not need specific professional development on standardized tests and standards. However, teachers working in systems that only recently have introduced standardized tests may need professional development around understanding the tests themselves.
- *Educators need expanded repertoires of instructional strategies*. Parallel to the needs for professional development, it is also important to provide access to resources, teaching materials and information about good practices. Although the data helps teachers identify the need to differentiate instruction, the teachers are often in need of an expanded repertoire of strategies and practices to be able to respond to the needs of individual children or groups of students.

- *Further research on effective instructional decision-making is needed*. Even if the support by information systems for decision-making is highly advanced, we will not be able to tell whether the decisions made are better than before – it depends on the context and is not reproducible. Neither the impact of the Grow Reports, nor the extent of its use in the district, has yet been evaluated.

Conclusion

We started this article by connecting research on MIS in corporate organizations to data-driven decision-making in schools and have found that research on the Grow Reports offers a school case that can illuminate MIS theory. Data-driven decision-making will be an important task for school administrators and teachers in the future; and more countries will follow the U.S. example. Our research on the Grow Reports suggests that the process for designing decision support systems has to be turned upside down from decision-making to data selection. Instead of starting with the available data, designers need to start from the source of the data – the students and their learning needs. The design needs to start from the information needs for decision support of different stakeholders, which are defined by their different relationships to the students. For example, the information needs of a third grade teacher planning a reading project are quite different from those of a school principal deciding on professional development programs to offer her teachers. From that premise, MIS designers should then consider which presentation formats and representations of data are relevant to meet those different needs. From this knowledge, an information system can then be built that houses the decision-relevant data that will help educators more effectively guide the students' learning.

References

Ackoff, R. L. (1989). From Data to Wisdom. *Journal of Applied Systems Analysis, 16*, 3-9.

Alavi, M., & Leidner, D. E. (2001). Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research issues. *Management Information Systems Quarterly, 25* (1), 107-136.

Argyris, C., & Schoen, D. A. (1978). *Organizational Learning: a Theory of Action Perspective*, Reading, MA: Addison Wesley.

Bhatt, G. D., & Zaveri, J. (2001). The enabling role of decision support systems in organizational learning. *Decision Support Systems, 32*, 297-309.

Breiter, A., & Light, D. (2004a). Decision Support Systems in Schools – from Data Collection to Decision Making. *Paper presented at the America's Conference on Information Systems (AMCIS)*, New York, NY.

Breiter, A., & Light, D. (2004b). Teachers in the "intelligent" school – From data collection to decision-making. *Paper presented at the ED-MEDIA*, Lugano, Switzerland.

Brown, J. S., & Duguid, P. (2000). *The Social Life of Information*, Boston, MA: Harvard Business School Press.

Connolly, T., & Begg, C. (2002). *Database Systems: A practical approach to design, implementation and management (3rd Ed.)*, Reading, MA: Addison-Wesley.

Drucker, P. F. (1989). *The New Realities: In Government and Politics. In Economics and Business. In Society and World View*, New York: Harper & Row.

Earl, M. J. (2001). Knowledge Management Strategies: Towards a Taxonomy. *Journal of Management Information Systems, 18* (1), 215-233.

Feldman, M. S., & March, J. G. (1988). Information in Organizations as Signal and Symbol. In March, J. G. (Ed.), *Decision and Organizations*, Oxford: Basil Blackwell, 409-428.

Fung, A. C. W., & Ledesma, J. (2001). SAMS in Hong Kong Schools: A Centrally Developed SIS for Primary and Secondary Schools. In Visscher, A. J., Wild, P. & Fung, A. C. W. (Eds.), *Information Technology in Educational Management. Synthesis of Experience, Research and Future Perspectives on Computer-Assisted School Information Systems*, Heidelberg: Springer, 39-53.

Gorry, G. A., & Scott Morton, M. S. (1971). A Framework for Management Information Systems. *Sloan Management Review, 13* (1), 55-70.

Heistad, D., & Spicuzza, R. (2003). Beyond Zip code analyses: What good measurement has to offer and how it can enhance the instructional delivery to all students. *Paper presented at the AERA Conference*, April, Chicago.

Ingram, D., Seashore Louis, K., & Schroeder, R. R. (2004). Accountability Policies and Teacher Decision Making: Barriers to the Use of Data to Improve Practice. *Teachers College Record, 106* (6), 1258-1287.

Kohler, B., & Schrader, F.-W. (2004). *Ergebnisrückmeldung und Rezeption. Von der externen Evaluation zur Entwicklung von Schule und Unterricht. Themenheft Empirische Pädagogik, 18* (1), Landau: Verlag Empirische Pädagogik.

Laudon, K., & Laudon, J. P. (2002). *Management information systems: managing the digital firm (7th Ed.),* Englewood Cliffs, NJ: Prentice-Hall.

Light, D., Honey, M., Heinze, J., Brunner, C., Wexlar, D., Mandinach, E., & Fasca, C. (2005). *Linking Data and Learning - The Grow Network Study - Summary Report*, New York: EDC's Center for Children and Technology.

Light, D., Wexlar, D., & Heinze, J. (2004). How Practitioners Interpret and Link Data to Instruction: Research Findings on New York City Schools' Implementation of the Grow Network. *Paper presented at the American Educational Research Association*, San Diego, CA.

Marakas, G. M. (2003). *Modern Data Warehousing, Mining, and Visualization - Core Concepts*, Upper Saddle River, NJ: Pearson.

Mitchell, D., & Lee, J. (1998). Quality school portfolio: Reporting on school goals and student achievement. *Paper presented at the CRESST Conference*, Los Angeles, CA.

Myers, M. D. (1999). Investigating Information Systems with Ethnographic Research. *Communications of the Association for Information Systems, 2* (23), 2-17.

Nolan, C. J. P., Brown, M. A., & Graves, B. (2001). MUSAC in New Zealand: From Grass Roots to System-Wide in a Decade. In Visscher, A. J., Wild, P. & Fung, A. C. W. (Eds.), *Information Technology in Educational Management. Synthesis of Experience, Research and Future Perspectives on Computer-Assisted School Information Systems*, Heidelberg: Springer, 55-75.

Nonaka, I., & Takeuchi, H. (1995). *The Knowledge Creating Company*, Oxford: Oxford University Press.

Petrides, L. A., & Guiney, S. Z. (2002). Knowledge Management for School Leaders: An Ecological Framework for Thinking Schools. *Teachers College Record, 104* (8), 1702-1717.

Polanyi, M. (1966). *The Tacit Dimension*, London: Routledge and Kegan Paul.

Salpeter, J. (2004). Data: Mining with a Mission. *Technology and Learning, 24* (8): 30-37.

Secada, W. (2001). From the Director. *Newsletter of the Comprehensive Center-Region VI, 6*, 1-2.

Sharkey, N., & Murnane, R. (2003). Helping K-12 Educators Learn from Student Assessment Data. *Paper presented at the AERA*, Chicago.

Simon, H. A. (1977). *The New Science of Management Decisions (revised edition),* Englewood Cliffs, NJ: Prentice-Hall.

Spielvogel, B., Brunner, C., Pasnik, S., Keane, J. T., Friedman, W., & Jeffers, L. (2001). *IBM Reinventing Education Grant Partnership Initiative - Individual Site Reports*, New York: EDC/Center for Children and Technology.

Spielvogel, B., & Pasnik, S. (1999). *From the School Room to the State House: Data Warehouse Solutions for Informed Decision-Making in Education*, New York: EDC/Center for Children and Technology.

Sveiby, K. E. (1997). *The New Organizational Wealth: Managing and Measuring Knowledge-Based Assets*, Berrett Koehler.

Symonds, K. W. (2003). *After the Test: How Schools are Using Data to Close the Achievement Gap*, San Francisco, CA, Bay Area School Reform Collaborative.

Thorn, C. A. (2001). Knowledge Management for Educational Information Systems: What is the State in the Field? *Education Policy Analysis Archives, 9* (47), retrieved June 30, 2006, from, http://epaa.asu.edu/epaa/v9n47/.

Thorn, C. A. (2002). Data Use in the Classroom: The Challenges of Implementing Data-based Decision-making at the School Level. *Paper presented at the American Education Research Association Convention*, New Orleans, Louisiana.

Thorn, C. A. (2003). Making Decision Support Systems Useful in the Classroom: Designing a Needs Assessment Process. In Selwood, I., Fung, A. & Paturi, T. (Eds.), *Information Technology in Educational Management*, Amsterdam: Kluwer Academic Publishers.

Trauth, E. M. (2001). *Qualitative Research in IS: Issues and Trends*, Hershey, PA: IDEA.

Visscher, A. J. (2001). Computer-Assisted School Information Systems: The Concepts, Intended Benefits, and Stages of Development. In Visscher, A. J., Wild, P. & Fung, A. C. W. (Eds.), *Information Technology in Educational Management: Synthesis of Experience, Research and Future Perspectives on Computer-Assisted School Information Systems*, Norwell, MA: Kluwer, 3-18.

Visscher, A. J., & Bloemen, P. P. M. (1999). Evaluation of the Use of Computer-Assisted Management Information Systems in Dutch Schools. *Journal of Research on Computing in Education, 32* (1), 172-188.

Webb, N. (2002). Assessment Literacy in a Standards-Based Urban Education Setting. *Paper presented at the AERA*, New Orleans.

Weinert, F. E. (2001). *Leistungsmessung in Schulen*, Weinheim: Beltz.

Wild, P., Smith, D., & Walker, J. (2001). Has a Decade of Computerization Made a Difference in School Management. In Nolan, C. J. P., Fung, A. C. W. & Brown, M. A. (Eds.), *Pathways to Institutional Improvement with Information Technology in Educational Management*, Norwell, MA: Kluwer, 99-120.