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ABSTRACT

With the growing need to adapt to external competitive demands and internal accountability mechanisms, schools and school systems have built up large-scale information systems with data from standardized tests and with administrative data. With reference to findings in research on management information systems, key aspects and constraints of data-driven decision-making in business are transferred to the education system. The limits and opportunities of data-driven analyses for school development are explained using results from a implementation study of an education information system targeted at teachers as a primary user group.

Keywords

Management Information Systems, Decision-making, Schools.

INTRODUCTION

There is growing pressure for teachers to adapt to external competitive demands (e.g. statewide assessments, student selection based on school profiles) as well as to respond to demands from a diffuse set of clients, such as the local community or taxpayers, who wish to see a return on their investment. The teachers' old tools of education like intuition, teaching philosophy and personal experience do not seem to be sufficient anymore. Schools need to be more flexible to changes in their environment. In the United States, new federal laws require every state to implement an assessment system intended to measure and validate student achievement and school performance. Data-driven decision-making, partly based on student test scores in large-scale achievement tests is far more developed than in other countries. In New York City school district data is reported specifically for teachers in order to support classroom decision-making to increase student learning. The data is obtained from state- and district-wide student achievement tests, which are conducted annually. This undertaking may help the city meet requirements of the new legal framework of the Elementary and Secondary Education Act – better known as the "No Child Left Behind (NCLB)" Act. NCLB requires all states and districts to increase their student test scores steadily to reach the targeted proficiency level for all students within 12 years. States which are not in compliance will face financial and other sanctions, therefore increasingly every education program is targeted on increasing student test scores.

The desire to collect data from students in order to measure their achievement and use this data to improve school quality closely resembles the introduction of data-driven decision-making processes in business in the 70s and 80s. The starting point is data – not decision-making. First, data are collected, stored in large databases, then "intelligent" ways of retrieving are applied, and at the end it is hoped that the decisions are better – or at least based on facts (= data). Yet, schools and their ultimate decision-makers, teachers, are ill-prepared in using data in order to change and improve classroom organizations:

> Yet, despite both the mandates and the rhetoric, schools are woefully under-prepared to engage in such inquiry. There may be a wealth of potential data available to schools, a growing number of tests mandated at the state, local, and school levels for various purposes: dropout statistics, attendance figures, course enrollments, SAT and ACT scores, and results of teacher and parent surveys. But such data are not easily accessible or available for comprehensive analysis. […] The practice of applying large-scale data to classroom practice is virtually nonexistent (Herman and Gribbons, 2001).

The key question is what should information systems look like to support informed decisions at the different levels of the school system, and how can diverse information needs of teachers, principals, administrators and politicians be identified and met. Our paper draws on Management Information Systems (MIS) research and the preliminary results of an implementation study of the Grow Network's Data Report tool designed for the New York City Department of Education. In order to

understand limits and constraints of computer support for decision-making in educational contexts, a theoretical model based on MIS research will be introduced first.

FROM DATA TO KNOWLEDGE: A MANAGEMENT INFORMATION SYSTEMS PERSPECTIVE

When dealing with human decision-making, it is important to distinguish between three key entities that are often used interchangeably: data, information and knowledge. Ackoff (1989) described a hierarchical model that reflects the classical semiotic interpretation of the terms *data*, *information* and *knowledge* (Nake, 2001): Raw *Data* simply exists without meaning in and of itself. Therefore, data can exist in any form, usable or not. In semiotics, this is the syntactic dimension. Whether or not data is *information* depends on the understanding of the person looking at the data. This is the first moment of interpretation. Information is data that is given meaning by being connected to a context. Information is used to comprehend and organize our environment; the semantic dimension. However, information generally does not indicate how data is likely to change over time or carry implications for future actions. *Knowledge* is information that builds connections between different bits of information. Knowledge provides causal connections and can be used to guide action, which is described as the pragmatic dimension.

There are obvious difficulties in defining knowledge bases for decision-making as long as we have no clear understanding about what are relevant data. Management information systems (MIS) try to fill the gap. Although primarily technology-driven, the idea of information systems as aids to managerial decision-making is based on the assumption that they can supply managers with the information necessary for making their decisions. It seems straightforward that a comprehensive analysis of the nature of managerial decisions should provide the basis for the development of information systems, but already in 1971, Gorry and Scott Morton identified that the failure of the early management information systems was linked to a misunderstanding of the nature of managerial decision-making (Gorry and Scott Morton, 1971). The predominant perspective today is still based on a naive understanding of tasks and decision-making processes. Then as now it is assumed that information should just be relevant, current, and reliable. This resulted in firm-wide activities to collect massive amounts of information from every department of the company. Gorry and Scott Morton (1971) demonstrated empirically that the information produced in simple transactions is relevant only for a few types of decisions. In other cases the information is completely useless. Gorry and Scott Morton developed a schematic to describe characteristics of 'good information' in relation to three different types of managerial decisions (strategic, tactical and operational, table 1).

	Operational Control	Tactical Control	Strategic Planning
Source	Largely internal	⇔	External
Scope	Well defined, narrow	⇔	Very wide
Level of Aggregation	Detailed	⇔	Aggregate
Time Horizon	Historical	⇔	Future
Currency	Highly current	⇔	Quite old
Required Accuracy	High	⇔	Low
Frequency of Use	Very frequent	⇔	Infrequent

Table 1. Characteristics of "good information" by category of managerial decision (Gorry & Scott Morton 1971)

This framework, still used in textbooks on decision-making and management information systems (Laudon and Laudon, 2002), draws attention to the question of information needs from the managerial perspective rather than data collection from the IT view of databases. While strategic decisions might be supported by aggregated prospective data with a very wide scope, operational control requires frequent access to detailed and current data. Newer models of MIS include advanced methods for data retrieval (like data mining, OLAP – On-Line Analytical Processing), and rely on more processing power. Although specialized OLAP tools do no more than other technologies, they do it better, and allow more effective work to be done in a short period of time (Connolly and Begg, 2002). Despite the technological advances, the open question during the development of MIS was how to determine the relevant information requirements. The work of Feldman and March (1988) cast doubt on the idea that providing information in itself is sufficient for managers to make good decisions (Feldman and March, 1988). They assume that decision-makers only realize the full range of relevant data and which data is available once they have actually made their decision. Furthermore, even if all pertinent data were available, a large share would be ignored because there are limitations to how much data managers can actually process. Likewise, there is always other data one might wish to have. Complaining about not having enough information coincides with neglecting other available data and facts. Managers often want to have all information they can get, but this leads to overload. If managers could define all required

information a priori to make informed decisions, managing wouldn't be a difficult job. But the procedural knowledge that is embedded in routines and experience, also referred to as tacit knowledge (Nonaka and Takeuchi, 1995, Polanyi, 1966), can hardly be modeled. In summary, MIS literature reveals that key areas of decision-making have to be identified first, the information needs of stakeholders have to be specified; and within this action space, the available and quantifiable data has to be selected.

Transferring these findings from MIS research to the school environment, it becomes obvious, that there is no single data need for decision-making but different data for different stakeholders at different levels of aggregation. The following table presents an approximation of data needs by the stakeholders at each level of the school system. Only with this degree of detail, the scope of a system for data-driven decision-making in schools can be described.

Level	Stakeholders	Information needs
Classroom	Teachers Students	Disaggregated instructional data (student) ▪ Grades and test scores / portfolios ▪ Tracking of attendance / suspensions
School	Principal Administrators	Aggregated longitudinal instructional data (class, subject) ▪ Grades and test scores ▪ Tracking of attendance / suspensions Aggregated longitudinal administrative data (class, subject) ▪ Coordination of class scheduling ▪ Special education and special programs scheduling ▪ Allocation of human resources ▪ Professional development ▪ Finance and budgeting
District	Superintendent Administrators	▪ Aggregated longitudinal instructional data (schools) ▪ Aggregated longitudinal administrative data (schools) ▪ External data demands
School Environment	Parents Local community	▪ Disaggregated instructional data (students) ▪ Aggregated data (schools)

Table 2. 4-level model of information needs in schools

In order to understand the limits and constraints of data-driven decision-making in schools, the following section will introduce a case study in which a web-based information system is set-up to support teachers and administrators.

DATA-DRIVEN DECISION-MAKING IN SCHOOLS

Urban districts in the U.S. have faced the intense external scrutiny of a high-stakes accountability climate for some time (Fullan, 2000), but the shift in the funding and regulatory environment represented by the *No Child Left Behind Act* (NCLB) is prompting district and school administrators to think differently about the potential that newly accessible data has to inform instruction and decision-making aimed at raising student achievement. Like their managerial counterparts in business, educators and school districts are expected to prove their bottom line with hard, solid data. In particular, since NCLB holds educators as well as students accountable, the exploration of how data can be used to make decisions for instructional purposes is increasingly becoming a main topic of educational policy (Salpeter, 2004, Secada, 2001). An on-going concern, as outlined above in the MIS literature, is that the critical aspects of information needs and relevant data for informed decision are often neglected under the weight of technological capabilities.

The new federal law now requires reporting on student test performance gains to be broken down by gender, race, disability, family income, migrant status and English fluency. Each state is also required to monitor how many students were not tested and provide detailed information about the professional qualifications of teachers. Although districts and states generate huge amounts of data that they report to the government, many remain ill equipped to utilize data effectively for policymaking.

Traditionally, using data for decision making at the school-wide level has been difficult, partly due to the inefficiency of paper file-and-folder tracking systems and partly due to a culture in which teachers and administrators who use data to solve problems are often perceived as instigators or troublemakers. Therefore, there is little incentive in many schools for faculty and administrative staff to base educational decision making on data. (Petrides and Guiney, 2002)

Furthermore, the data systems are usually designed for school and district administrators. Teachers might have access to data

but only few strategies attempt to connect this data to changes in the way they teach and organize their classrooms. Other factors complicate getting this data into the hands of teachers. Data from testing companies and states are often not disaggregated to a level useful for classroom decision-making, nor is the data available in a timely fashion, or organized in a way convenient to teachers. Additionally, data collection is distributed across different levels of the school system, sometimes even in incompatible proprietary formats that preclude linking to different data bases. There are also political and ethical issues around privacy and teachers' rights that complicate collection and reporting of data. There is only little research on the framework supporting effective data-driven decision-making in the school system (Thorn, 2001).

CASE STUDY: GROW NETWORK DATA REPORTS

In 2001, the New York City Department of Education (NYCDOE) introduced a system-wide data-support tool for its schools with the help of the Grow Network company. 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. Currently, the Grow Network's Data Reports deliver data in four different forms, reflecting different views for different target groups (Tab. 3).

View	Data	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

Table 3. Views on Grow Network Data Reports

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 Data Reports also present educators with student results on sub-sections of the test. Soon after the beginning of the school year, teachers 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. They can also get their class ranked and grouped each sub-test. The on-line reports for teachers, principals, staff developers and district leaders include links to state and district standards as well as to further teaching material. The data itself has been partially analyzed and synthesized. Aligned with state and district standards, the Data Reports also offer additional resources (teaching material) and links to external resources. The goal is to help teachers to collect more course material and rethink their classroom organization (especially reflecting individual students' needs) by using the examples provided (see fig. 1).

According to Alter's taxonomy of Decision Support Systems, the Data Reports can be described as in between data-oriented and model-oriented DSS (Alter, 1977). 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). Hence, the Data Reports can be understood as a simple DSS.

Research on use by administrators and teachers

This paper draws on the qualitative component of a larger research project funded by the Carnegie Corporation. The qualitative study focused on the organizational setting and how that shapes the interpretation of data. We interviewed a total of 47 educational leaders, including: central office stakeholders, superintendents, deputy superintendents, math coordinators, English language arts coordinators, staff developers, technology coordinators, directors of research and curriculum, and individuals who work with the union, the United Federation of Teachers. We also spoke with several people representing non-government organizations working closely with the New York City schools on issues like educational reform and professional development. We also conducted two sets of interviews with teachers. In the first set of semi-structured interviews (n=45), we sampled for teachers who were known to be using the Data Reports, and the second set of structured interviews (n=31) we selected a random sample of teachers in specific grades.
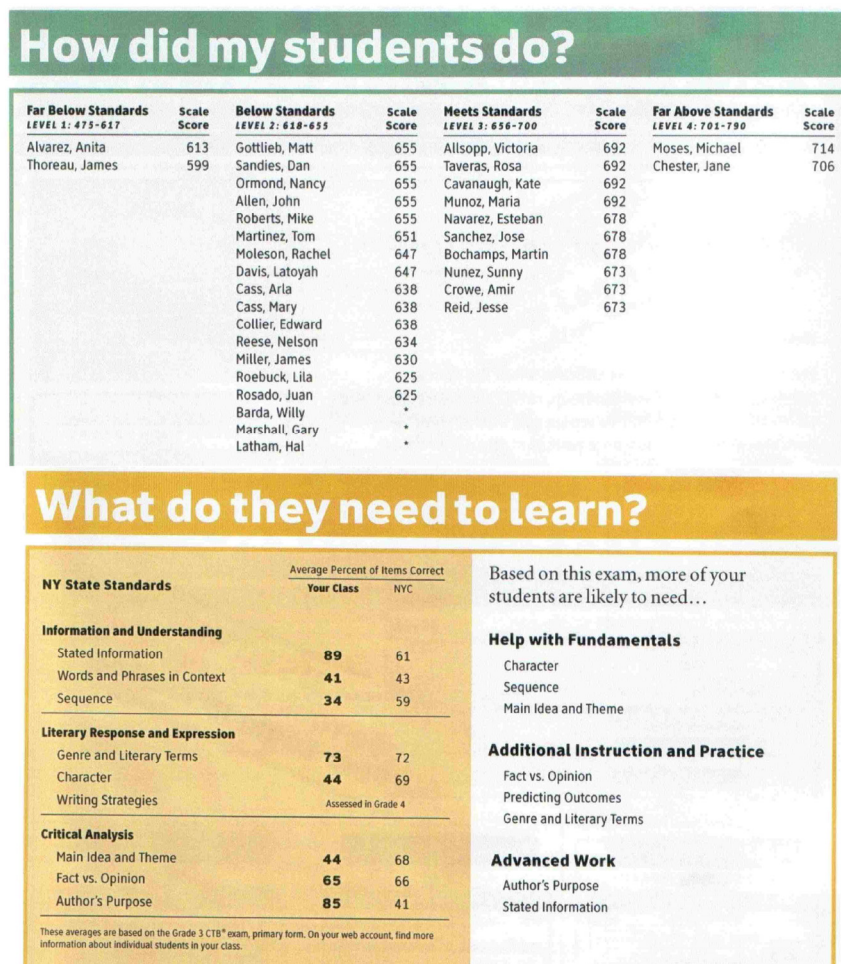
How did my students do?

Far Below Standards LEVEL 1: 475-617	Scale Score	Below Standards LEVEL 2: 618-655	Scale Score	Meets Standards LEVEL 3: 656-700	Scale Score	Far Above Standards LEVEL 4: 701-790	Scale Score
Alvarez, Anita	613	Gottlieb, Matt	655	Allsopp, Victoria	692	Moses, Michael	714
Thoreau, James	599	Sandies, Dan	655	Taveras, Rosa	692	Chester, Jane	706
		Ormond, Nancy	655	Cavanaugh, Kate	692		
		Allen, John	655	Munoz, Maria	692		
		Roberts, Mike	655	Navarez, Esteban	678		
		Martinez, Tom	651	Sanchez, Jose	678		
		Moleson, Rachel	647	Bochamps, Martin	678		
		Davis, Latoyah	647	Nunez, Sunny	673		
		Cass, Arla	638	Crowe, Amir	673		
		Cass, Mary	638	Reid, Jesse	673		
		Collier, Edward	638				
		Reese, Nelson	634				
		Miller, James	630				
		Roebuck, Lila	625				
		Rosado, Juan	625				
		Barda, Willy	*				
		Marshall, Gary	*				
		Latham, Hal	*				

What do they need to learn?

NY State Standards	Average Percent of Items Correct	
	Your Class	NYC
Information and Understanding		
Stated Information	89	61
Words and Phrases in Context	41	43
Sequence	34	59
Literary Response and Expression		
Genre and Literary Terms	73	72
Character	44	69
Writing Strategies	Assessed in Grade 4	
Critical Analysis		
Main Idea and Theme	44	68
Fact vs. Opinion	65	66
Author's Purpose	85	41

These averages are based on the Grade 3 CTB® exam, primary form. On your web account, find more information about individual students in your class.

Based on this exam, more of your students are likely to need...

Help with Fundamentals
Character
Sequence
Main Idea and Theme

Additional Instruction and Practice
Fact vs. Opinion
Predicting Outcomes
Genre and Literary Terms

Advanced Work
Author's Purpose
Stated Information

Figure 1. Detailed view on Grow Network Data Reports

We can use an example to situate the Data Reports within the underlying theoretical assumptions that distinguish among data, information and knowledge, which we presented above. For example, a test score of 655 by itself means little. Test-data becomes information with the realization that the numbers indicate 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. In relation to test scores, knowledge comes when the information can guide practice. 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 to this child's score to the school's overall accountability process. Achieving a certain level of knowledge about the test results is an important step in the decision-making process, for example. In addition, the value of this information is also subject to the educators' perceptions of validity and reliability.

The interviews with district and building level *administrators* identified the following four uses for the Data Reports at the administrative level.

- *Reports as a Conversation Starter*: Many respondents talked about the reports and test data more generally in terms of starting or facilitating important dialogue within the school system. 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, it raised issues regarding standardized tests as diagnostics. Some respondents spoke of using standardized test data to move principals', teachers' and parents' conversations about the determinants of achievement away from issues of socio-economic status or student behavior and toward a specific focus on students' strengths and weaknesses, especially in a large urban school district. Respondents among the principals and district leaders also spoke about the reports as helping to identify professional development need for teachers.

- *A Tool to Help Improve Teaching*: Some respondents believed that the Data Reports are helpful because it takes the examination data to the "next level" of helping teachers to plan lessons and group their students based on concrete evidence. Other respondents, however, offered the more cautious view that the reports are simply another form of data – to be interpreted and used wisely, and only in ways the educator seems relevant.

- *Providing Teachers with Access to Data*: Although the district has made test data available to administrators for a number of years, the Grow Network presents data in a format that respondents found to be easy to use and organized in useful groupings and accessible. Accessibility to the Data Reports, however, is still problematic as many respondents reported difficulties with basic computer and Internet access issues.

- *A Bridge Between Levels of the System:* The Data Reports may also be able to serve as a bridge between the generalized level at which the district functions and the concrete level at which schools function: (a) in helping align both district and school goals (systemic alignment); (b) alignment between assessments and classroom instruction, as well as between the content areas, school programs, and overall school pedagogy (instructional alignment).

Generally speaking, the *teachers* considered the Data 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 have also uncovered a core of "practitioner knowledge" about using the data. On the issue of teachers' background in psychometrics, teachers do not often have strong knowledge, but they did touch on many of measurement and assessment issues. They 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 Data 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 the test result was a single measure, which they took with a grain of salt. Teachers have multiple sources of information about their students – teacher assessments, authentic assessments, observations, conversations and a shared experience. Teachers have a wealth of "tacit knowledge" (Polanyi, 1966) that they use in conjunction with test data. Teachers became more concerned about the validity of the test data 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 available to decision-makers at higher levels.

The teachers' synthesis of information from the Data Reports into their understanding of the classroom, offered us a springboard into instructional decision-making. In the interviews teachers reported using the Data Reports in myriad ways to meet their own varied instructional pedagogical needs, as well as their diverse students' academic needs. We have grouped those different uses into three main categories: (1) planning; (2) differentiating instruction; and (3) supporting conversations.

- *Planning*: When asked in interviews, several teachers and school administrators report, that they use the Data 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 Data 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 Data Reports helps to show them where their overall class' strengths and weaknesses lie.

- *Differentiating Instruction*: Most teachers agree that because the data represented on the Data Reports reveals that individual students perform at various different levels, the tool helped them to differentiate instruction. Teachers report different uses of the Data Report depending on the differentiation strategies they sought to implement. Teachers said that sometimes individualized instruction to meet student needs 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 and school building administrators with whom we spoke say the Data Reports were useful in supporting conversations about students and learning. They speak of using the Data Reports in conversations with teachers, parents, administrators, and students. The respondents feel that the Data Report provided a starting point focused on student learning.

CONCLUSIONS

From the classroom-level perspective, the Data Reports can be regarded as a useful data-tool since most teachers we spoke to 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. In sum, in terms of usability, the Data Reports can be considered as successful. We started with the question on how research on MIS in corporate organizations can be transferred to data-driven decision-making in schools and have found that research on the Data Reports may offer a school case that can illuminate MIS theory. Although information technology has become widely available and its power and capacity is continuously increasing, the support for managers to make informed decisions is still under discussion. How can this school case inform that discussion? There are four conclusions that might be drawn:

- 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 Data 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;

- Decision-making is a highly complex individual cognitive process influenced by various environmental factors. The classroom may be the example *par excellence* of an intersubjective decision-making environment. Teachers constantly make decision affecting 20 or more individuals. 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;

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

- Information systems are often flooded with data, offering more data than decision-makers can effectively synthesize and use. The Data 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.

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. What our research on the NYCDOE Data Reports suggests is that the process for designing decision support systems has to be turned upside down, from decision-making to data selection. First of all, information needs for decision support for different stakeholders in different situations with different forms of visualization and complexity have to be identified. From this, an information system can be built and then decision-relevant data can be defined and stored in databases.

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