

Educational Reports That Scale Across Users and Data

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ABSTRACT

The field of education is undergoing fundamental change with the growing use of data. Fine-scale data collection at the item-response level is now possible. Xerox has developed a system that bridges the paper-to-digital divide by providing the well-established and easy-to-use paper interface to students, but digitizes the responses for scoring, validating, reporting, and managing data using a range of digital technologies. The Ignite™ system supports written responses, shading, connecting lines, multiple choice selections, and other question types. For some users, monitoring is at a very fine-grain level in both time and skill, while for others the data is used for more summative evaluations and strategic planning; one user's details may be another user's overview. All the reports presented in this document use the same basic atomic data elements and associated meta-data. The hierarchical nature of the organization of users requires that these atomic elements be combined in different ways for specialized visual representations, dependent upon the needs of the user.

Keywords

Visualization in Education, Application, Data Transformation and Representations, Field Studies, Ethnography.

1. INTRODUCTION

Technology and regulations regarding education have increased the availability of student data as well as the need to track student performance over time. No Child Left Behind [7], Race-to-the-Top [9], and the Common Core State Standards [3] are all efforts within the United States that have endeavored to make the tracking of student learning growth more measurable. Despite the increase in the access to, and need for data and data analysis, the abilities for many educators to make use of available data has not kept pace with the need [5]. Data analysis requires knowledge and tools to which not all educators have easy access [13]. Enabling data to be visualized in ways that are familiar to educators will help encourage the use of student data to inform student learning and instruction. This paper provides one example of how reporting student data in a user friendly form, for many levels of users, can help educators to find more effective uses for their student data.

2. BACKGROUND

2.1 Teachers Changing Their Instruction and Their Needs

Teachers have begun transitioning from curriculum-based instruction to student-centered instruction, which shifts the focus to assessing students at the beginning, middle and end of an instructional unit. In this way, teachers learn what the students already know about a particular subject from the start, where to focus needed instruction, and collect data throughout the process of their learning growth.

To help support the shift to utilizing student data to inform day-to-day instruction in ways that fit more closely into educator's current

work processes, Xerox has created the Xerox Ignite™ Educator Support System [16]. Ignite™ is a web-based teacher tool for printing, scanning and scoring a variety of hand-marked student work and also manages the student data and produces personalized reports. Student work is generally an assessment (e.g. a quiz or test).

The item-response level of information is defined as an atomic unit: "A student is presented an item on a date by a teacher and provides some type of response." Each part of the atomic element contains additional metadata. All the reports present views of the same underlying data, but with differing levels of aggregation, dependent upon the needs of the user. This paper describes these differing user requirements and how a set of consistent and connected graphical reports can scale across the needs of these different users and their needs for data.

3. RELATED WORK

Data and data mining usage in the education domain (educational data mining or EDM) is relatively new. The field has grown rapidly for just over a decade [1].

There is a desire that the use of data will foster improvements at all levels of education. The desire for data-driven improvement in learning is countered by a concern that the use of data by itself will lead to too much of a focus on testing rather than teaching [5]. Over the years the focus of research has moved more into the field of prediction [2], and it may be that the real value will come over time when enough longitudinal data is available.

Public educational institutions have a hierarchical nature. In the United States primary schools there is a hierarchy of superintendents, principals, team leaders, and classroom teachers all making decisions. This hierarchy of users share common tasks including the analysis and visualization of data, providing feedback to support instructors, recommendations for students, and grouping of students, among others. The hierarchical nature of the users within the educational organization presents interesting challenges in both EDM [2] and in the use of the data. Teachers want easy-to-use systems, with a "desire to see assessment results at the level of subscales (groups of test items) related to specific standards and at the level of individual items in order to tailor instructions." [6] "Decisions are made at all levels of school organization. The superintendent makes decisions concerning a school district's goals and strategies. Then principals make tactical decisions concerning those goals and strategies to accomplish them in relation to their own buildings. Department heads and team leaders then make curricular and operational decisions to carry out the day-to-day activities of a department or unit. And, finally, classroom teachers make decisions in their classrooms".

Others have investigated the use of visualization in higher education situations with limited success [8]. The use of on-line learning tools has led to visualizations of curriculum [4], the design of models of student learning [10], the use of graph structures to understand

patterns of student enrolment [14] and the use of a small set of static and interactive visualizations of user data [11].

4. USERS AND USER REQUIREMENTS

4.1 Ethnographic Study of Pilot Deployment

During a technical pilot of the Xerox Ignite™ application, four elementary schools in two school districts participated. An ethnographic study was conducted to observe teachers’ processes to identify challenges with using the pilot tool, and to collect user requirements and needs for the system. Observations and open-ended interviews [12] were the primary data collection methods to study teachers’ assessment practices. Many teachers expressed a desire to know how their students were performing in the skills being taught, and wanted to understand how well the students understood the skills.

Talks with principals and school district administrators, including district data specialists, uncovered another level of requirements [29] relating to trend analysis, student growth over time, class-to-class and school-to-school comparisons, and progress monitoring. Principals and administrators expressed a need to see student data at the grade level, reaching from single classrooms, to all classrooms for a single grade in a single building, to entire buildings or the entire district.

Just as the assessments are used for different purposes, the users of reports have different needs. The users have been segmented into three major groups: A single teacher & class, principal or lead teacher with several classes within a school, and a district administrator looking across multiple schools in the district.

4.2 Single Teacher / Class

A teacher working with a class, or a single student in a class, is the lowest level of granularity within the current scenario. In this situation a teacher has one of two major goals: assessing the success or direction of a lesson or helping a single student.

To assess the success of a lesson plan, a teacher needs to see the class average, but also details about the mastery of different skills within that teaching unit. In Ignite™, the teacher can group and sort the questions on an assessment report according to the metadata related to the skills connected to each question.

To help an individual student, the teacher, student, and often parent need fine-scale information about specific mastery of skills. The teacher must be able to communicate with the student and parent on specific problem areas that need immediate work.

The data markers for this type of user must reveal information about the individual student, and the specific question or skill. Reports must reveal the data at the level of the basic atomic data unit, to the level of every item and response by a student to that item.

4.3 Several Classes within a Grade or School

A school principal or lead teacher within a grade or subject area needs a middle level of data aggregation. A principal is in charge of an entire school building, typically covering several grades. A lead teacher is typically focused on a single grade, or a single subject within a grade. Users at this level are typically looking at the overall progress of a cohort and the management of class or group affiliations of students. The goal is to best assign students to classes or groups and to insure that these classes or groups are on track to meet marking period and yearly goals.

The data markers for this type of user need to reveal information about the class statistics and summary information about individual students. Reports for this level can also reveal the data so that cohorts can be compared, and individual outliers within classes or groups can be identified. Skill proficiency can be shown across time and across multiple classes within a given group giving a wider view of proficiency trends. The skills are grouped at the larger unit or quarterly time intervals, and not at the individual skill code level.

4.4 Across Schools within a District

District administrators analyse data to determine long-term trends and comparisons, to report to state agencies, and to evaluate curriculum. Users at this level are more focused on summative and high-stakes assessments. These users look across schools, and compare their own district with other districts in the area and those with similar social and economic demographics.

The data markers for this class of user need to reveal information about the overall aggregate status of a district or school, with visual markers at the grade, teacher, or building level. Information about individual students is not identified or required. Trends for skills are most often limited to subject and grade level expectations.

5. DESIGN CONSIDERATIONS

Design choices were made in response to the user requirements discussed above. These design choices fell into two major areas: The general usability or workflow, and the visual attributes of the reports.

5.1 Report Selection Workflow

To produce a report, the user needs to select both a data set and a report type. These selections are not independent; as not all data can be rendered as any report, and each report needs an appropriate set of data. A linear sequential method was developed to guide the user through the report selection process.

The logical concept of the selection process is shown in Figure 1. The first step is the top row of the selection space where the user specifies “Who?” i.e. the target user and student aggregation level of the report. The second step is the left most column of the selection space where the user specifies “What?” i.e. how many assessments are to be viewed in the report. The third step of the selection process defines “When?” i.e. is this report for a single instance, or does it cover multiple recurrences. These three linear sequential steps allow the user to navigate simply through a three-dimensional specification space ending with a choice of just a few different eligible reports.

| | (1)Who? | | Principal or Lead Teacher / Several Classes | District/ Multiple Schools |
|--------------------------|-----------|--|--|--|
| (2)What? | (3)When? | Teacher / Class | | |
| Single Assessment | Once | <ul style="list-style-type: none"> • Matrix • Table • Image | <ul style="list-style-type: none"> • Matrix • Bar | <ul style="list-style-type: none"> • Distribution |
| | Over Time | <ul style="list-style-type: none"> • Matrix • Line | <ul style="list-style-type: none"> • Grouped Bar • Lines | <ul style="list-style-type: none"> • Lines |
| Portfolio of Assessments | Once | <ul style="list-style-type: none"> • Bar | <ul style="list-style-type: none"> • Bar/ Scatter | <ul style="list-style-type: none"> • Distribution |
| | Over Time | <ul style="list-style-type: none"> • Lines | <ul style="list-style-type: none"> • Lines | |

Figure 1 - Report selection table

The layout of the report selection table shown in Figure 1 also aids in understanding the automatic aggregation of data according to user and data selection. The different user views for the case of aggregating data about a single assessment given once are shown in Figure 2. In all cases, that same single assessment is chosen, but the report is different depending upon the scope of classes selected. A teacher meeting with a single student is most interested in the report

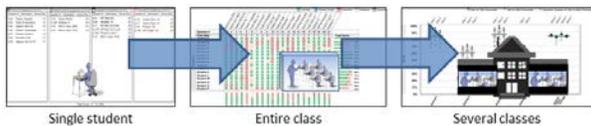


Figure 2 Flow of data aggregation and report type for a single assessment given once. In moving from left to right the question detail is lost and the higher level averages are presented.

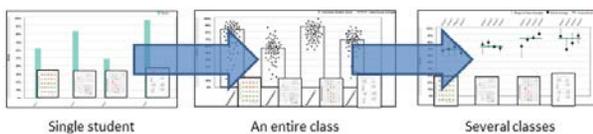


Figure 3 Flow of data aggregation and report type for a portfolio of four assessments. In moving from left to right the student specific information is lost and higher level distributions are presented.

on the left; a table report that provides detailed information about each question. A teacher assessing the progress of an entire class is most interested in the report in the middle; a matrix heat map. A district administrator, looking at several classes is most interested in the report on the right; a distribution report that provides information about school and class averages, and some notion of the distribution of scores within each class and range of scores within each school.

The different user views for the case of aggregating data about a portfolio of assessments are shown in Figure 3. In all cases, the same set of assessments is chosen, but the reports are different depending upon the scope of classes selected. A teacher meeting with a student and parent is most interested in the report on the left; a single bar chart report that provides a student's performance across a range of skills, at a single point in time. A group of teachers meeting to discuss the grouping of students is most interested in the report in the middle; a bar chart report that provides information about the class average, but also the score of each student. A district administrator, looking at several classes is most interested in the report on the right; a distribution report that provides information about school and class averages, and some notion of the range of scores within a class.

6. REPORT DESIGNS

There are 6 different basic report styles: (1) image, (2) table, (3) matrix heat map, (4) line, (5) bar, and (6) distribution. Where appropriate, report styles were customizable to properly display the defined data set selected by the user.

6.1 Image

The image report is an image of the scanned and validated assessment. This report is the only portrait mode report, and has no header or footer information to maximize the actual assessment image region. Two examples of this report type are in Figure 4.

The visual representation exactly matches the physical paper version of the assessment.

The green highlight areas are those questions that were validated by the teacher as correct. Responses that were validated as incorrect were shown with a red overlay, skipped responses with a yellow

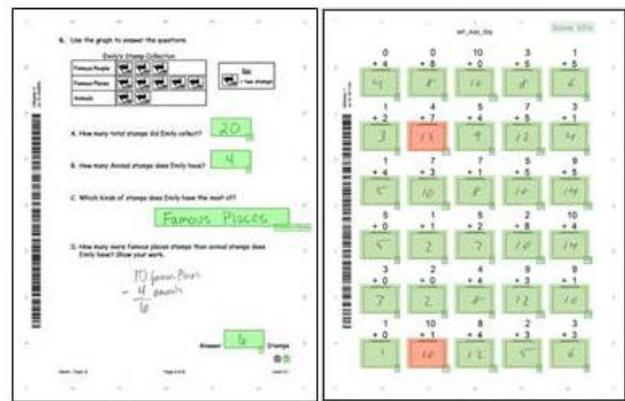


Figure 4 - Image reports where green indicates the area of a correct answer and red is an incorrect answer

overlay, and those validated for partial credit were shown in blue. The color coding served as a pre-attentive signal to the correctness of the student's answer.

This report is used by a teacher in individual consultations with a student and/or parent. It is a record of the marks the student made on the assessment, and how the teacher validated each question.

6.2 Table

The table report is a listing of the correct, partial, skipped, and incorrect responses to a single assessment, by a single student. The questions are placed in the column corresponding to the scored and validated response and include the question number, the question description (obtained from metadata), the number of points the student earned for the question, and the total number of points possible on the question. The data is presented at the fine-scale atomic level, with the use of metadata. By using the metadata about the question, the report is applicable to any type of question. If the question description metadata is used to encode specific skill information, then a quick visual scan down the list reveals common skills that have appeared in a single column, or the columns could be sorted according to some value(s) in the metadata.

This report is used by teachers with students and parents. It is easy for students to understand that their goal is to make all the questions appear in the left-most (correct) column.

6.3 Matrix heat map

The matrix heat map report is a visual summary of the responses to each question on an assessment, by each student. The data for each student appears in a row, and the data for each question appears in a column. At each intersection point there is a graphical representation of the student's response to that question.

Sorting the rows and columns of the matrix provides the user with a quick visual assessment of several different stories [15]. By sorting the rows in order of student score, the teacher is able to quickly discern who has mastered the skills, and who has not as well as identifying which areas where most students are struggling. By sorting the columns in order of the correct number of student responses, or sorting by the metadata associated with questions, the teacher can quickly see what groups of questions or skill sets were successfully mastered by the class and which were not. If a particular set of question were not mastered by the class, the teacher now has this additional piece of information and can decide upon the need to re-teach a particular set of skills to that subgroup of students.

6.4 Bar

The Bar Chart is used in several instances. For consistency, all bar charts use the vertical axis to represent score. The horizontal axis can be categorical values of assessments, students, classes, or dates. The

bars can be singular or grouped, depending upon the amount of data to be displayed.

6.4.1 Comparing Students or Classes over time

The collection of scores for a single assessment repeated over time can be represented using a bar chart. In this case, the x-axis is a categorical list of students or classes. There is a group of bars for each student or class, and a bar of each instance in time.

6.4.2 Portfolio of Assessments

The portfolio of assessment scores for a single student, a single class, or all the classes within a school all use similar representation. The common representation provides users with a common mental model for scaling across such aggregations. In all these cases, the x-axis is a categorical list of assessments.

For the case of a single student, there is one bar for each assessment.

For the case of a single class, there is one bar for each class average score, and the distribution of student scores are overlaid as a jittered scatter plot, where the x-jitter is bounded to the width of the corresponding bar

6.5 Line

The line chart is used only for trends over time. For consistency, all line charts use the vertical axis to represent score. For a single assessment, the score can be absolute or percentage, and may be aggregated at the student, class, or school level. In all cases, the x-axis is a categorical list of times, e.g. the date each assessment was given. These reports are used to view the progress over time of one or more assessments.

When viewing the portfolio of results over time, each line represents a different assessment. The points on the line are the relative score achieved on the given assessment at that point in time. The score can be a single student, aggregated over a class, or over a school.

6.6 Distribution

Reports showing a statistical summary of distributions typically are used only by district level users. These types of reports use the greatest amount of aggregation of atomic data elements. For consistency, all distribution charts use the vertical axis to represent score. The x-axis is a categorical list of assessments or schools. The markers are groupings of box and whisker plots.

7. CONCLUSION

We designed and deployed a system that implements a large and comprehensive set of reports for use by educators at different levels. The system was designed based on ethnographic studies and iterative participatory feedback from users, as well as subject matter experts on staff. The novel aspect of this work was the creation of a complete system that bridges the paper-digital divide, offers views into the data at different levels of granularity and aggregation, and scales to match a user's needs and work processes while preserving similarity in the selection workflow and report design.

The reports all used the same underlying fine-grain data element at the item-response level by each student, but aggregate the data differently dependent on the user's needs. Users included teachers-students-parents, lead teachers or principals, and district level administrators. These users had needs that required scalability through several levels of data aggregation.

Report designs focused on the re-use of basic design concepts across the different visual representations, thus allowing users to more easily traverse the report space by learning a common set of patterns and styles. The report selection process follows a linear progression of selecting the collection of students, the collection of item-responses, the time, and finally any visual representation options for the data.

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