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The Impact of Educational Technology on Student Achievement: Assessment *of* and *for* Learning

The author explores current efforts by educators and policy makers to harness the power of educational technology for both assessment *of learning* and assessment *for learning* in K-12 classrooms.

In this era of accountability brought about through international comparisons that pit the U.S. against other nations and testing requirements resulting from legislation such as No Child Left Behind (U.S. Department of Education (USDOE), 2001) educators, administrators and policy makers require more efficient and effective ways to measure and analyze student achievement data. Moreover, individuals at the local and state levels look to teachers and district leaders to use these analyses to benefit future outcomes. The pressure for accountability affects states and districts as well as classroom teachers. This article explores current efforts by educators and policy makers to harness the power of educational technology for both assessment *of learning* and assessment *for learning* in K-12 classrooms. The first section describes efforts to utilize technology for student achievement testing, an assessment *of learning*. Issues addressed include high-stakes and low-stakes testing, issues for classroom implementation, test preparation programs, special education populations, and adaptive testing. The second section outlines the responses of states, districts and schools to the accountability pressures related to data storage, analysis, reporting and data informed decision making. The last section focuses on the role of technology in networked science and mathematics classrooms where immediate feedback devices provide teachers with formative assessment information about student learning to guide instructional strategies. In a connected classroom, the assessment intends to help students learn. The critical difference between assessment *of learning* and assessment *for learning* lies at the heart of current educational technology use in science classrooms.

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Educational Technology for Testing

The increased testing requirements of the "No Child Left Behind" Act (2001) resulted in serious efforts to develop statewide computer-based testing programs to assess student learning. As of the 2004-2005 school year, 16 states have statewide computer-based testing programs in place while 4 additional states are piloting these programs (Fox, 2005). The rapid response, prompt retake possibilities for students close to the cut-off scores and easily captured data provided by computer-based testing programs provide school districts with several advantages. On a practical level, these programs allow schools to gather data to meet the requirements of federal mandates. More importantly they may provide educators necessary information to individualize learning plans for students. Unlike their more traditional predecessors that often require extensive time for scoring and data distribution, computer-based tests provide immediate feedback on student achievement.

However, statewide computer-based testing comes with a cost. While technology can streamline assessment and provide needed information for documentation related to accountability requirements, schools need computers for students to take electronic tests.

Budget deficits threaten to trump these initiatives. In addition to hardware and software costs, school systems must wrestle with issues of test security to limit potential for invalidating scores on high-stakes tests. Students across the state must take the test in a limited time frame and with similar testing conditions to ensure the fairness of the test. Variations in equipment across schools and districts further complicate the issue. Comparisons of test results from paper and pencil tests versus computer-based tests on modern or out-dated equipment introduce important variables into the evaluation process (Olson, 2003). As a natural consequence of these factors, some states have developed online test preparation programs to help improve student scores. As of 2003, twelve states already had computer-based practice exams available to help student prepare for state-mandated tests (Borja, 2003).

Low-stakes diagnostic computer-based tests offer possibilities for improving student performance without many of the issues related to their high-stakes counterparts. Some educators believe that success on low-stakes tests portends improved performance on high-stakes tests. Further, teachers are the recipients of several advantages of classroom computerized testing such as decreased time grading papers and efficient assessment of student learning. Limitations of this approach (many of which also apply to high stakes testing environments) include the need for classroom sets of computers, difficulties with test security (secure sites that cannot be hacked into by enterprising students), and test sites with easy visibility of computer screens for wandering student eyes. However, as test banks become more sophisticated several limitations have been effectively eliminated. Teachers can now prepare multiple versions of assessment instruments for standard multiple choice, true-false or fill in the blank type questions, but questions that require essay style answers or complex multi-step problem solving items continue to present difficulties for computer-based testing and evaluation systems. The efficiencies of time afforded teachers by computer evaluation of tests are lost for these higher level assessment items (Galley, 2003).

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Educational technology introduces both issues and advantages for measuring student achievement in special education classrooms. Advances such as assistive technologies have improved students with disabilities' opportunities to fully participate in the classroom (Hitchcock, Meyer, Rose, & Jackson, 2002; Rose, 2001). The use of computer-based testing technologies extends these possibilities by introducing tools such as spell-checkers or reading machines. For example, hearing impaired students in Oregon may select from English, American Sign Language or both in testing situations. Students with visual impairments or reading disabilities may take tests with text readers in Massachusetts, but the cost and limitations of text reading programs limits this possibility for general education students. Text readers still encounter problems with non standard symbols such as Greek letters or equations found in mathematics or science (Goldstein, 2003).

Exploration of new technology-based assessment systems with special education populations provides educators with insights that promise to benefit both regular and special education students. Indiana's use of annual videotapes of oral reading ability as part of an electronic portfolio assessment represents a creative use of educational technology to provide a unique and highly individualized view of student achievement over a multi-year period. The use of these electronic portfolios has the added benefit of greatly reducing the extensive paperwork needed to document student performance, a common grievance of special educators, and provides special educators the opportunity to easily share IDEA-mandated evidence of student progress with parents (Goldstein, 2003).

Another important area of research and test development is adaptive testing. In these situations, student's previous performance determines subsequent questions providing educators with useful diagnostic information. Adaptive testing allows students to self-pace, provides a suitable challenge for each learner, rewards student effort with immediate feedback, improves test security issues due to the differentiated nature of each sequence of items, and offers the advantage of multimedia options in question design such as the inclusion of text, graphs, images, video and animations (Dunkel, 1999). These forms of testing, however, do not meet the demands of NCLB to assess each student against state established grade level standards. South Dakota's adaptive online testing program, for example, serves as a voluntary resource for schools while educators administer a paper and pencil test to satisfy NCLB legislation (Olson, 2003; Trotter, 2003).

Educational Technology and Data Management

A critical advantage of computer-based testing programs is their readily accessible stores of data. Teachers and policy makers need to access, analyze, and interpret student achievement data if these resources are to guide decision making and strategy selection to improve student learning. Expensive and complex data management systems focused on meeting the reporting requirements of the NCLB legislation offer the promise of easily available student information including demographic information for reporting purposes and student achievement information. In a survey of state officials, 15 states responded that NCLB requirements influenced decisions to obtain more sophisticated data management systems (Hoff, 2005). The North Carolina Window of Information on Student Education or NC WISE represents an example of these new data management systems and the challenges of developing them. The NC-WISE implementation program for this $53 million project called for a two-phase approach over a multi-year time span, which was initially launched in 1999 and is scheduled to be fully operational in 2,264 public schools by 2007. When completed this data management system will capture a wide range of essential student data, integrate classroom, instructional and administrative tasks, provide information directly to teachers, and support school wide functions such as scheduling, transcript management, auditing and student services (Hoff, 2005; Reitz & Winter, 2004).

Similarly, educators anticipate a data management tool in Ohio to aid in preparation of individualized educational plans to help high-school students pass state mandated exit exams. Analysis of student's test results will point to areas of student's strengths and weaknesses and suggest strategies to help students improve their test scores. Another Ohio State data-management longitudinal project creates reports on individual students as they progress from grade 3 to grade 8 (Hoff, 2005). Similar projects have been proposed in both Arizona and Hawaii to expand current student data systems to improve the quality of data and teacher access to data (Hoff, 2005).

The demand for more transparent and student centered uses of data about every aspect of the educational process has increased the necessity for databases that talk easily to each other. In the past, data tended to flow upstream, from local schools to districts to states to the federal government. If schools and teachers expect to use these data to affect school wide or classroom decision making, the data must flow equally well in both directions. Disparate computer systems that do not communicate well with each other interfere with this data flow. In addition, the wide audience for educational data impacts choices about the type of data to collect and the method used for storage. Users representing varied constituencies such as the US Department of Education, state and district policy makers and educational agencies, school administrators, classroom teachers, students, parents and community and corporate partners complicate the situation due to their varying intended uses including meeting NCLB reporting requirements, informing parents and students regarding school choice, guiding administrators and teachers on school curriculum, tracking individual student progress, and helping each of these constituents determine how to invest their time and resources (Palaich, Good, & van der Ploeg, 2004).

As data needs continue to grow and become more complex, the standard issues of cost and available infrastructure are coupled with issues of making a wide variety of data available to many different audiences.

The type of data collected influences its potential impact for decision making. Many argue that the current infrequent standardized high-stakes test data collected by states offer insufficient detail to guide teacher classroom strategy choice (Seltzer, Bryk, & Frank, 1994; Seltzer, Choi, & Thum, 2003; Wainer, Hambleton, & Meara, 1999). The yearly grade or school improvement data mandated by NCLB provide volatile data that do not serve as a reliable indicator of school performance (Kane & Staiger, 2002; Linn & Haug, 2002). In addition, older databases often use events such as enrollment dates or testing schedules as organizational schemes which are not useful for classroom level decision making. Schools need access to individual student records to facilitate student-based decisions. Some states, including Michigan, Indiana, Illinois and Wisconsin have either already built statewide data bases or are in the process of doing so. Concerns about student privacy rights as spelled out in the Federal Educational Rights and Privacy Act (FERPA) (U.S. Department of Education, n.d.) have delayed this process in some cases (Palaich et al., 2004).

In summary, growing accountability pressures to collect, store, analyze and report educational data as well as to generate data-based educational policy provide the force behind the growing use of statewide computer-based testing programs and sophisticated data management systems.

As data needs continue to grow and become more complex, the standard issues of cost and available infrastructure are coupled with issues of making a wide variety of data available to many different audiences. Elected officials, policy makers and educators need sophisticated technical expertise to grapple with the challenges of compatibility and information flow in designing and implementing these data management systems. Evolving educational data needs require thoughtful solutions.

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Formative Assessment in Connected Classrooms

While the present focus on standardized testing and data collection and management offers both assistance and obstacles related to supporting student learning, standardized testing falls short of providing teachers with appropriate data to support daily decisions in the classroom. Teachers have long struggled to develop mechanisms for monitoring student progress toward understanding and are often frustrated by the quality of information gained through normal classroom processes.

Some have questioned whether the current interest and concern in school accountability can lead to improved student achievement. These issues may also overshadow more complex matters such as educators' efforts to motivate all students to want to learn or to increase students perceptions of their capability to learn (Stiggins, 2002). While the assessment community focuses on ever more sophisticated measures of student achievement and works diligently to ensure reliable and valid measures of student achievement, perhaps another worthy goal would be to maximize the positive impact of test scores on student learning. That is, perhaps these efforts should be dedicated to assessment *for* learning.

A different kind of educational technology use intended to support student achievement occurs in the connected classroom. Connected classroom technology refers to a networked system of personal computers or handheld devices specifically designed to be used in a classroom for interactive teaching and learning. These networked technologies include response systems, classroom communication systems, and newer systems included under the name CATAALYST (Classroom Aggregation Technology for Activating and Assessing Your Students' Thinking) (Roschelle, Penuel, & Abrahamson, 2004). Connected classroom systems offer opportunities for improved formative assessment through questioning and immediate feedback, which has the potential for affording teachers the necessary information to tailor instruction to meet student needs (Black & Wiliam, 1998; Fuchs & Fuchs, 1986). One mode of instruction in connected classrooms involves students beaming answers to a receiving station with an accompanying anonymous display of histograms of student answer choices. Data logs of student responses can be archived for later teacher analysis. Discourse that occurs in a safe environment through the public examination of problem solving and alternative conceptions helps students understand their role as critical listeners and thinkers in the classroom (Artzt & Yaloz-Femia, 1999). In the connected classroom, teacher adaptive expertise forms the critical foundation for formative assessment practices that provide needed information to monitor student's incremental progress and keep them oriented on the path to deep conceptual understanding.

The effectiveness of the connected classroom technology, as with all instructional tools, depends on the skill of the instructor.

Formative assessment coupled with well orchestrated classroom discourse informs teacher practice by providing a window into both what and how students are thinking. Unlike summative assessment that occurs after completion of instruction, formative assessment is ongoing and low stakes. The focus of this kind of assessment is often shifted from the right answer to the reasoning that led to the answer. In a connected classroom, students are informed about their classmates thinking processes, and students with a minority opinion see that they are not alone. Connected classroom environments support positive student thinking habits such as seeking alternative representations for problems, comparing and contrasting different solution strategies, and explaining and describing problem solving strategies. These habits support active engagement and intellectual growth (Dufresne, Gerace, Mestre, & Leonard, 2000).

In a traditional classroom, teachers collect student work, evaluate it by hand, and return the papers to students several days later (Figure 1). In many cases, students have forgotten the point of the assignment and teachers experience difficulty correcting conceptual problems days after instruction on the topic. With the pace of instruction continuing unabated, student naïve understandings accumulate resulting in increasing challenges for student achievement. In science and mathematics where conceptions build incrementally, delayed feedback proves particularly damaging. In connected classrooms, display of aggregated student results occurs shortly after students submit their individual work. Displays can give powerful clues to what students are doing, thinking, and understanding (Roschelle, Penuel, & Abrahamson, 2004). The teacher has immediate information and can use this to adjust instruction. Assignments can be smaller but more frequent—for example, requests to answer a question, solve a problem, state a position, write an equation, give a reason, participate in a simulation, or play a learning game (Stroup et al., 2002; Wilensky & Stroup, 2000, 2002). If the teacher chooses, aggregate class results can be displayed, students receive immediate private and non-threatening feedback in a way that encourages reflections and classroom discourse (Abrahamson, Davidian, & Lippai, 2002; Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996).

Researchers have found that in a connected classroom, students are more likely to actively engage in the learning process. Student attitudes and motivation improve as teachers focus on conceptual understanding. Quick attention to alternative understanding changes the student experience in science and mathematics from memorization of large quantities of facts to understanding the relationships between concepts (Dufresne et al., 1996).

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Present educational policy focuses on inputs to the educational system—students, teachers, resources, management, standards, and preparation for high stakes test. The assumption behind the input argument rests with the logic that changing these inputs will change the desired outputs—increased student achievement, strategic learners, highly qualified workers, and contented teachers. The pedagogy of the connected classroom addresses a significant component of what teachers and students do inside the black box of their classroom (Black & Wiliam, 1998). Inquiry and problem-solving approaches often leave unanswered the question of what students have learned from these experiences. Teachers need tools to better understand their students' learning *as they engage* their students in learning experiences. While classroom discourse processes have been examined as catalysts for fostering student active cognitive engagement and vehicles for assessing student understanding, the connected classroom offers tools for data collection and display that support these efforts. These tools provide a window into a learner's prior and present understandings and feedback loops that support teacher's instructional decision making and monitoring. Both teachers and students learn during instruction. Through constant observation and monitoring for understanding, teachers and learners may alter the course of the learning experience at critical junctures in the learning process and impact outcomes.

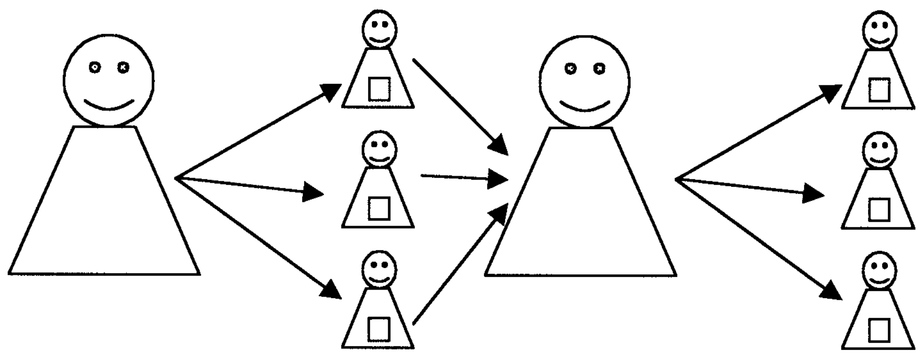
Two important research studies with connected classroom technology are currently underway in the United States: 1) the 5-year NSF-funded (TPC-0456124, 2005) *Teacher Learning of Technology-Enhanced Formative Assessment* project by Leonard, Gerace, Beatty and Feldman at the Scientific Reasoning Research Institute, University of Massachusetts Amherst, and 2) the 4-year, IES funded *Classroom Connectivity in Promoting Student Achievement in Mathematics and Science Achievement* project by Owens, Abrahamson, Pape, Irving, and Demana at The Ohio State University (R305K050045). The Massachusetts team hopes to better understand teacher learning of technology-enhanced formative assessment, to understand effective and efficient methods of teacher professional development for connected classrooms, and to develop tools and techniques for the evaluation of teacher pedagogy in connected classroom environments. The project at Ohio State is an interdisciplinary research study focused on teaching and learning of mathematics and science at the 7th to 10th grade levels with a national sample

Figure 1.
Traditional versus connected classroom

Traditional Classroom

Teacher assigns work. Students complete and submit. Teacher evaluates and returns. Students see individual work.

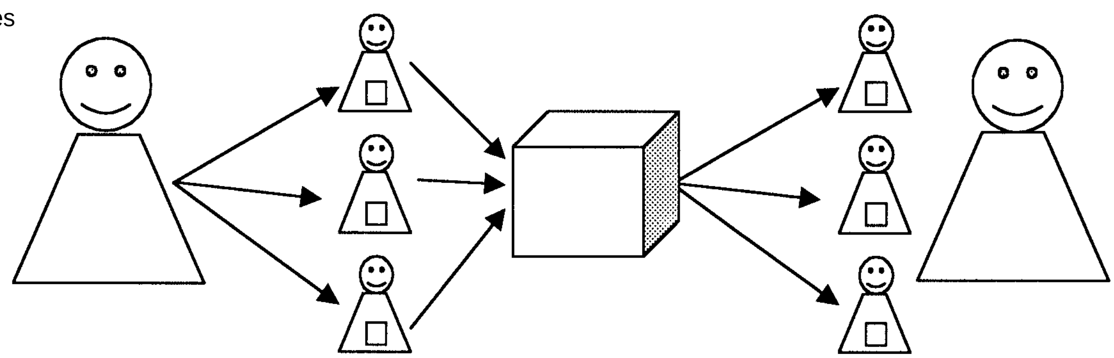
Time: several days



Networked Classroom

Teacher assigns work. Students complete and submit to connected classroom network. Computer aggregates and displays. Students and teacher see aggregated class data as well as individual work.

Time: minutes



of teachers using the TI-Navigator connected classroom hardware. This project includes a randomized cross-over trial design where the control group is sequentially exposed to the intervention. The project will measure student achievement in algebra 1 and physical science, student motivation, student dispositions toward mathematics and science and self-regulated learning over a four year period for up to 145 teachers and their students. Both of these projects promise to offer scientifically-based evidence to further support the claims made for increased student motivation, engagement, and achievement in connected classroom environments.

Conclusions

Educators, policy makers, parents, and community members wish to maximize student achievement in the United States in science, mathematics and many other disciplines. To achieve this goal, both assessment *of learning* and assessment *for learning* must play important roles. Computer-based statewide testing programs, reliable and valid measures of student learning, and comprehensive data management systems that facilitate the flow of information between stakeholders support the goal of assessment *of learning*. Assessment programs sensitive to the needs of students in both the regular and special education populations provide insight into student learning over time and begin our efforts toward assessment *for learning*. Innovations such as connected classroom technologies, however, offer greater potential for improved formative assessment for classroom teachers on the front lines of assessment *for learning*. In both cases the issue resolves to using reliable data to make decisions, whether at the state, district, or school level, or the classroom teacher level. Educational technology provides a powerful tool to gather, organize, and analyze data. Teachers and policy makers need the expertise to responsibly use these data to benefit all our students.

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