LIVESCRIBE IN K–12 EDUCATION: RESEARCH SUPPORT

A Review of Scienti c Evidence Demonstrating the Effectiveness of Smartpen Technologies for Improving Teaching and Learning

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livescribe™

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ENDORSEMENTS FROM EDUCATIONAL RESEARCHERS

I've had the chance to use the smartpen in a research project that I'm conducting with schoolchildren in Singapore. ***I think this smarpten is going to revolutionize learning.*** *Whether students have difficulty focusing on the material, or they're poor notetakers, the smartpen will compensate for all of these things and allow equal access to the content of the lectures.*

Scott Paris, Ph.D.
Professor of Education
University of Michigan

The Livescribe smartpen is an invaluable resource for use in classrooms if you are really trying to understand students' thinking. *In mathematics that's central to learning. So, I'm very excited about that prospect of having this smartpen the hands of students when I work with them.*

Kay McClain, Ph.D.
Associate Professor of Mathematics Education
University of Arizona

I'm excited about using the Livescribe smartpen as a part of the work I'm doing with preschool teachers who will use it for individualized assessment of the children in their classrooms. ***It could greatly facilitate the recording and tracking of children's performances on quick assessments called Curriculum Based Measures*** *that are delivered in preschool and elementary classrooms.*

David Dickinson, Ed.D.
Professor of Early Childhood Education
Vanderbilt University

In my work, I develop pen-based applications for both engineering and education and I've recently been working on educational applications for digital pen computers. I'm excited by the unique capabilities of the Livescribe product and I'm looking forward to using it in my research and teaching. ***This product has the potential to fundamentally change education in a very positive way.***

Tom Stahovich, Ph.D.
Associate Professor of Engineering
University of California, Riverside

I think the Livescribe smartpen has tremendous potential to help young people as they pursue their higher education*—certainly all forms of education—but particularly those young people who go to under-subscribed or under-resourced high schools that are going to need a little bit of a jumpstart in their educational experience as they make the transition to college.*

Rick Shaw
Dean of Admissions & Financial Aid
Stanford University

*I'm extremely excited about using the Livescribe smartpen to support much more natural systems for communication and collaboration***. Paper documents aren't going away—they are light to carry, easy to annotate, rapid to navigate, flexible to manipulate, and robust to use.*** *Some are attempting to simulate paper with tablet PCs. This approach suffers not only from limitations of current tablet computers, but also from the loss of invaluable paper affordances.*

Jim Hollan, Ph.D.
Professor of Cognitive Science and Computer Science
University of California, San Diego

INTRODUCTION

The Pulse smartpen, manufactured by Livescribe, Inc. of Oakland, California, is the first in a new category of low-cost, mobile computing platforms. It is an integrated system of smartpen, dot paper, applications, and development tools designed to enhance personal productivity, learning, communication, and self-expression.

Because of its low cost, ease-of-use, and built-in functionality, it is naturally appealing to teachers and students. This review of the literature will provide scientific evidence demonstrating the effectiveness of smartpen technologies for improving teaching and learning.

Livescribe Smartpen

The Livescribe smartpen is a Montblanc-size computer with advanced processing power, audio and visual feedback, as well as substantial memory for handwriting capture, audio recording, and additional applications.

Figure 1: Livescribe Pulse smartpen.

The Livescribe mobile computing platform includes:

- **Software Applications:** a breadth of solutions that leverage audio/ink capture, handwriting recognition, and Internet connectivity to enhance personal productivity, learning, communication and self-expression
- **Livescribe Desktop and Online Community:** allows users to backup, search, and replay notes from their computer. Users can also upload and convert notes to interactive Flash movies or PDF files and share them online.
- **Dot Paper with Dot Positioning System (DPS):** technology that enables interactive "live" documents using plain paper printed with microdots. The smartpen's high-speed infrared camera reads the dot-pattern and enables a wide range of paper-based applications.
- **Development Tools:** Livescribe is developing a suite of easy-to-use tools for creating, publishing, sharing, or selling new applications and content. The tools are designed for both end users and professionals

BENEFITS FOR STUDENTS: LEARNING SUPPORT

Notetaking

Notetaking practices can produce notes that are incomplete and ineffectively organized (Bretzing & Kulhavy, 1979; Kiewra & Benton, 1988) and can contribute to a students' failure to record many important lecture points (Baker & Lomardi, 1985; Hartley & Marshall, 1974; Kiewra, 1984; Kiewra, 1985a; Kiewra, Benton, & Lewis, 1987; Kiewra, DuBois, Christian, & McShane, 1988; Locke, 1977). These problems are underscored in research studies that have identified the cognitive requirements of successful notetaking. Kiewra and Benton (1988) found that good notetakers have sufficient working memory capacity to "attend, store, and manipulate information selected from the lecture simultaneously, while also transcribing ideas just presented and processed" (p. 35). Those with limited working memory capacity may experience cognitive overload attempting to execute these multiple tasks integrally. Although notetaking facilitates learning for notetakers with greater working-memory capacity, it may be detrimental for learners with more limited capacity (Berliner, 1969; Berliner, 1971; DiVesta & Gray, 1973; Kiewra, 1989). Regarding the challenges of writing the notes, researchers have shown that the act of writing previously mentioned ideas might cause critical information to be missed and/or be misinterpreted (DiVesta & Gray, 1973; Peters, 1972). Given the information processing challenges facing many students with learning disabilities, it is not surprising that they have trouble taking notes on lectures and learning from their notes.

Of course, a variety of approaches and technologies have been developed to help students take better notes. They all have shortcomings. For example, laptops and personal digital assistants (PDAs) have appeal for this application because they can input text and are ubiquitous on college campuses. Taking notes with a computer, however, actually takes twice as long, on average, as with pencil and paper (Ward & Tatsukawa, 2003); it is difficult to draw diagrams with a mouse or touchpad; and notes written on a handheld PDA device take 37% longer to read than notes handwritten on paper (Davis et al., 1999). Furthermore, when surveyed about their preferences, students preferred pen and paper to laptops. Van Schaack (2006) found that most students preferred paper notebooks to PCs for notetaking for such reasons as keyboard-based computers are too heavy to carry around all day; students write faster than they type; they cannot create graphs, tables, or other symbols easily; and the act of writing lecture notes helps them remember the material.

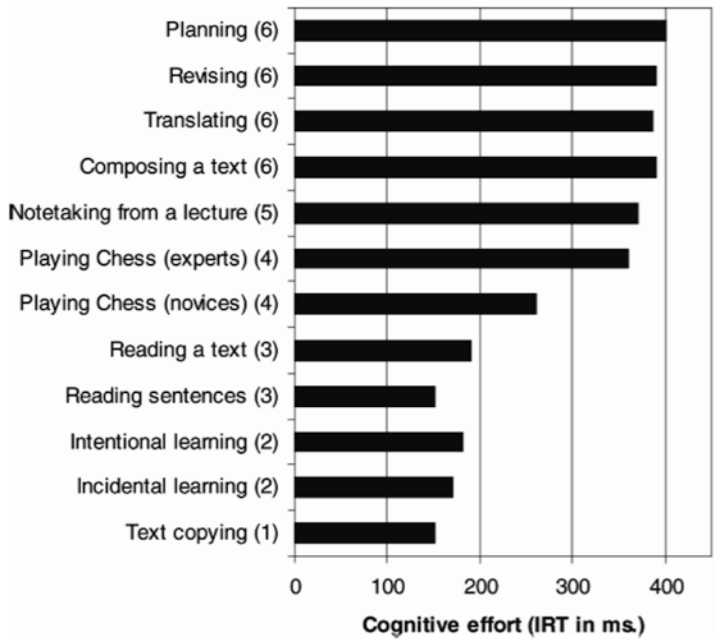

Figure 2: Cognitive effort required for various educational tasks. Note the position of “Notetaking from a lecture” – just above “Playing Chess (experts)” (Piolat, Olive, & Kellogg, 2005).

Two important features of the smartpen are the built-in microphone and speaker. Livescribe has developed an application called Paper Replay that synchronizes what is being recorded as handwriting with the audio recorded at the same moment, making it potentially valuable for students, with and without disabilities. Students with a Livescribe smartpen can record their instructor’s lecture while taking handwritten notes. Later, when they are reviewing their notes—while preparing for a test, for instance—they can tap on any written word or phrase to play back what the instructor was saying at the moment they wrote that phrase. The audio playback function can be sped up or slowed down. Previously, Kiewra (1989) demonstrated that low-achieving students who have the opportunity to rehear a lecture that they attended by viewing a videotape of it are able to annotate their notes (i.e., fill in the gaps), bringing the accuracy and completeness of the notes up to the level of the highest achieving students.

Other technologies exist that permit the recording and rehearing of lectures in relation to notes, but the Livescribe smartpen has unique advantages. Students can listen to podcasts when reviewing their notes, but the audio segments and notes are not synchronized as they are with the Livescribe smartpen. This synchronicity can exist with Tablet PCs with audio recording capability, but Tablet PCs are more expensive and less portable than smartpens and paper. Regular keyboard-based computers with audio recording capabilities are another alternative, but they also are much too expensive for many students. In addition, they lack the Livescribe Pulse's capabilities of capturing handwritten gestures, the audio/note synchronicity, and the option of speeding up or slowing down the audio playback.

Research suggests that good notetaking, coupled with review, can aid learning. In the general student population, notetaking helps the learner attend to and record important details of the lecture content during the class as well as during review (Tran & Lawson, 2001). For example, Kiewra et al. (1991) found that students who both write and review their notes perform better on synthesis tests that require generative processing (e.g., "cross-topical connections") than do students who either take notes and do not review them or review notes taken by a selected notetaker (an accommodation that some schools offer to students with learning disabilities). This suggests that if the taking of lecture notes is too demanding on a student's working memory to permit the student to carry out generative processing in real time, the needed generative processing of the content is still capable of occurring during the follow-up review of notes. This notion is particularly important for students with learning disabilities since, as noted by Swanson and Saez (2003), researchers have consistently found working memory deficits within this population.

Research has indicated that the bimodal experience provided by text-to-speech technologies can enhance the reading comprehension, fluency, accuracy, speed, endurance, and concentration of individuals with reading deficits (Elkind, Black, & Murray, 1996; Elkind, Cohen, & Murray, 1993; Higgins & Raskind, 1997; Leong, 1992; Lindstrom, 2007; Olofsson & Lundberg, 1993). Given the difficulties many students with learning disabilities face when reading—even reading their own writing—the bimodality of the synchronous juxtaposition of text and audio provided by the Livescribe smartpen should induce greater learning from the students reading their own notes during review time. This enhancement to note reviewing is critical because researchers have found that students, when reviewing their notes, can make connections with prior knowledge, with subsequent study material, or among parts of the lecture material. This strategic organization of lecture material can result in powerful knowledge representations that can be accessed in later problem solving (Tran & Lawson, 2001).

Figure 3: Pencast (audio-annotated animated diagram) playback through *Livescribe Desktop* software.

Use of the smartpen may allow students with learning disabilities in classes to better use their working memory capacities during lectures and review because the smartpen permits multiple revisits to the actual presentation of the lecture. Research suggests that these opportunities for multiple revisits reduce the burden of comprehension and attention that is imposed on the student in the typical lecture notetaking setting. There have been findings that students improve the depth and breadth of their notetaking when given multiple chances to view a lecture for which they took notes (Kiewra et al., 1991). Of particularly value for students is the fact that the Livescribe smartpen will free up the students' limited working memory capacities to process the typically dense visual and auditory information being presented in the classroom. It will also provide students with a more efficient system for taking notes because the students can limit their writing to major points that can be annotated with details at a later time when studying, without sacrificing their capture of all the information that they will eventually need. Lastly, we believe that this more rewarding notetaking and reviewing experience with the Livescribe Pulse will help the students learn and memorize the complex terminology, intricate chains of ideas, and mathematical notations associated with science and mathematics.

As mentioned previously, the audio recording of the lecture using the Livescribe smartpen as the student takes notes provides the student with multiple exposures to lecture content. Findings from general population studies on notetaking provide support for the beneficial effects of repeated exposure to lecture content that the smartpen. For example, studies evaluating the effects on community college academic learning with an earlier generation of a digital pen for note reviewing in conjunction with repeated viewings of lectures provided anecdotal evidence that students' use of the digital pen was associated with better performance in their courses (Kiernan, 2006). In the Kiewra-led repeated-lecture studies mentioned earlier, students who viewed a lecture multiple times scored better on recall tests than students who viewed the lectures only once (Kiewra, Mayer, Christensen, Kim, & Risch, 1991) and repeated viewing of a videotaped lecture significantly increased student idea capture (Kiewra, Mayer, Christian, Dyreson, & McShane, 1988). Other researchers have found that when given multiple opportunities to view videotaped lectures, students who took notes and subsequently reviewed their notes performed better on recall and synthesis test items about the lecture content than did students who either took notes but did not review them or skipped the lecture entirely and relied solely on reviewing someone else's notes to study for the test (DiVesta & Gray, 1972; Hartley, 1983; Kiewra, 1989). Other studies have supported these findings and extended them to assert that reviewing is the more powerful of the two contributors (Henk & Stahl, 1985; Kiewra, 1985b, 1985c).

Homework support. According to the U.S. Department of Education (2004), the average length of the school day—both public and private, across all grade levels—is 6.75 hours. (Approximately one hour each day is spent at lunch and passing between classes). The Department of Education (2007) also reported that 37% of high school sophomores spend more than 10 hours each week on homework, with an additional 26% spending between 5 and 10 hours per week.

Given these facts, a conservative estimate suggests that homework accounts for one-fifth of the time that students spend on academic activities. Yet students work on their homework in environments where their teachers have no control and are not available to support their students. Since many students experience learning difficulties, this creates a serious issue for concerned teachers and parents. Jayanthi, Sawyer, Nelson, Bursuck, and Epstein (1995) recommend that "Teachers and parents of students with disabilities must communicate clearly and effectively with one another and with students about homework policies, required practices, mutual expectations, student performance on homework, homework completion difficulties, and other homework-related concerns."

The Livescribe smartpen provides the means for students to capture a complete record of their teacher's in-class instruction as well as their teacher's directions for homework assignments. Without requiring any modifications to standard practice, or additional effort on the part of teachers, students, and parents, an effective and efficient means of communication and instructional support is provided.

Accelerated listening. Arons (1997) claims, "It is faster to speak than it is to write or type (Gould 1982); however, it is slower to listen than it is to read. Therefore, recording speech is efficient for the talker, but hearing recorded speech is usually a burden on the listener" (p. 3).

In a study conducted at Brigham Young University, Galbraith (2001) investigated the benefits associated with speeded playback of recordings of classroom lectures. One of the key measures of the study was the satisfaction of the software by its users. The usefulness of the software for the 256 participants who reported using is shown in Figure 4.

Figure 4: Self-reported usefulness of accelerated listening software by college students Galbraith (2001).

"The students were asked to rate usefulness on a scale from 1 (not useful) to 7 (very useful). The average reported usefulness measured 6.2. Only 4% of students (11) indicated that the plug-in was only moderately useful or less (by selecting a rating below 5). On the other hand, 61% of students (156) rated the usefulness at the top of the scale at 7 (very useful). The remaining 35% (89 students) rated the [software's] usefulness highly at 5 and 6 on the scale" (p. 6).

"Both intelligibility and comprehension improve with exposure to time-compressed speech. Beasley and Maki (1976) reported that, following a 30-minute exposure to time-compressed speech, listeners became uncomfortable if they were forced to return to the normal rate of presentation. They also found that subjects' listening rate preference shifted to faster rates after exposure to compressed speech" (Arons, 1997, p. 7)

Assistive Technologies

According to the Individuals with Disabilities Education Act (Public Law 105-17): "Assistive technology devices are any item, piece of equipment or product system, whether acquired commercially off the shelf, modified or customized, that is used to increase, maintain, or improve the functional capabilities of children with disabilities" (Section 300.5). This definition is rather narrow considering that all humans have inherent physical and psychological limitations. The Livescribe smartpen is designed, in particular, to support limitations of human information processing—for all users. Nevertheless, there are significant advantages to using it as a platform to facilitate learning and communication for individuals with disabilities.

Augmentative communication. Augmentative and alternative communication (AAC) devices are designed to facilitate communication among individuals who have difficulty in speech, writing, and sign language. Speech synthesis and digitally recorded speech provide a voice for these nonspeaking people.

Gorenflo and Gorenflo (1991) investigated three augmentative communication techniques on attitudes of nondisabled individuals toward nonspeaking persons with physical disabilities. In Condition 1, the nonspeaking individual used unaided communication techniques; in Condition 2, the nonspeaking individual using an alphabet board; in Condition 3, the nonspeaking individual used a computer-based voice output communication aid. Attitudes towards of nondisabled persons towards nonspeaking individuals increased with the sophistication of the augmentative communication technique.

Trembath, Balandin, and Togher (2007) reported that in their study of AAC devices used by schoolchildren, that the children use a small core vocabulary comprising frequently and commonly used words, together with large and highly individualized fringe vocabularies. Accordingly, the ideal AAC device would be one that provided a standard wordlist with the ability to easily and inexpensively append to it a much larger personalized word and phrase list.

Unfortunately, keyboards and other conventional input devices are difficult to use and sentence production is often slow. Commercial AAC devices are cumbersome and expensive—with many costing more than $1,000.

Commercial AAC devices come in many shapes and sizes, and use a variety of methods to program and use with them. The devices range from the simple 6-key GoTalk 4+ ($179; www.attainmentcompany.com) that provides 4.5 minutes of recording time, to the sophisticated 128-key Green Macaw 5 ($2,076; www.zygo-usa.com) that provides up to 78 minutes of recording time.

Figure 5: *GoTalk 4+* and *Green Macaw 5*.

The Livescribe smartpen provides the means for teachers, parents, and other caregivers to easily produce customized augmentative communication through low-cost, lightweight smartpen with paper.

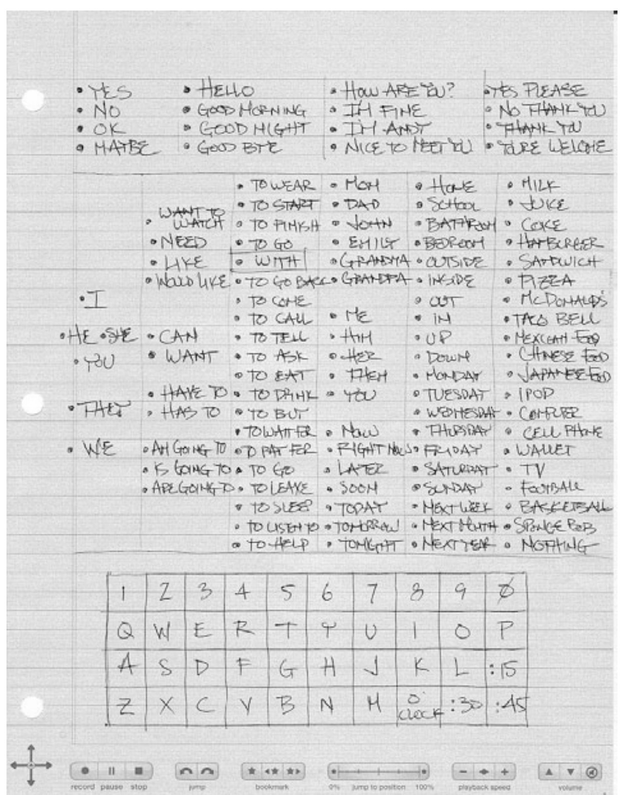

Figure 6: Example of a Livescribe AAC notebook page.

A simple word-based AAC page can be prepared using the built-in Paper Replay application follows:

1. Tap the Paper Replay *Record* button.
2. Speak a word while writing it. (Note: it is best to begin writing slightly before you begin speaking. That way, when you tap on the first letter of the word, the audio file will play back at the right moment.)
3. Tap the *Stop* button.
4. Repeat steps 1-3 for the list of words.
5. To use the page, the nonspeaking user simply taps on the beginning of each word to hear it spoken.

As can be seen through this simple example it is possible to provide all the benefits associated with conventional off-the-shelf AAC technologies—costing an order of magnitude more—using a low-cost, lightweight smartpen.

Audio-tactile graphics for blind students. Limited access to graphical materials has long been a problem facing blind and visually impaired students. With the development of the smartpen, many possibilities have opened for the rapid creation of portable, low-cost, high-quality accessible graphics. The smartpen can be used to create and explore audio/tactile graphics through interactive, raised-line figures that provide audio information about diagram elements. The smartpen is able to track its position on the page and play recorded labels when they are selected by tapping on them. For example, a visually impaired psychology student could learn neuroanatomy by exploring a diagram of the brain, with each lobe, gyrus, and sulcus's name spoken as the smartpen touches it.

Audio/tactile graphics have been available for some time, but the innovation of using smartpen technology will have a major impact on the usability, portability, cost, and ease of creating these accessible figures which have been clearly shown to improve science learning for blind and visually impaired students (Landau, Russell, Gourgey, Erin, & Cowan, 2003)

Audio/tactile graphics systems currently available suffer from a number of shortcomings. These include:

- **Lack of Portability:** Systems are bulky and require a computer to operate.

- **Frequent Recalibration:** Each time an overlay is placed on the touch tablet, the system must be recalibrated to be sure the positions of virtual and tactile elements match.
- **Overlay Identification:** An error-prone barcode-like system or other mechanism must be used to let the computer know which tactile figure overlays the touch tablet.
- **Multiple-Touch Errors:** Multiple, simultaneous contacts with a touch tablet's surface result in spurious location identification leading to incorrect audio output.
- **Creation:** The creation of audio/tactile diagrams is ill suited to the classroom, requiring time and special software tools.
- **Cost:** Supported touch tablets cost on the order of $500 and require a computer, putting the total price of a functional audio/tactile graphics system at a minimum of approximately $1,500.

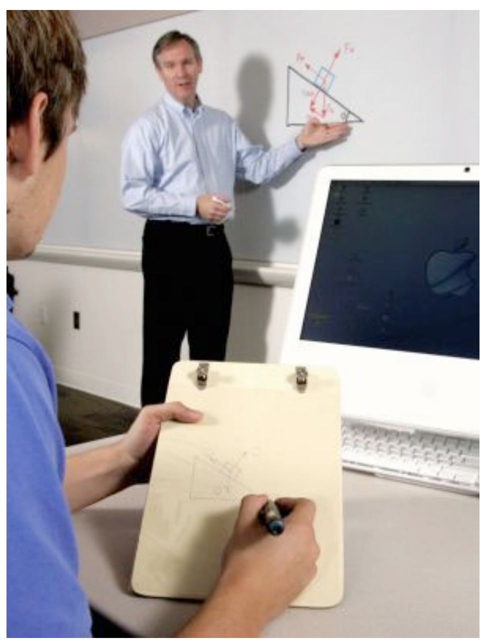

Figure 7: Livescribe smartpen used with a Sewell Raised Line Drawing Kit to produce ad hoc audio tactile graphics.

The use of the smartpen provides a simple approach to the creation and use of audio/tactile graphics while eliminating all of the difficulties associated with current, tablet-based approaches. The smartpen includes all the hardware and software necessary for both the position-sensitivity as well as digital audio recording and playback. With a single touch, the pen is capable of identifying a particular page, as well as its position on that page, thus simultaneously addressing the need for calibration and sheet identification. Since the pen's position sensitivity is optical, simultaneous haptic exploration does not interfere with its accuracy. This means the user can touch the tactile figure with both hands without impacting the accuracy of the pen's audio feedback. Audio/tactile graphics can be created dynamically in a classroom or other educational setting by using the digital pen in conjunction with an existing low-cost technique for creating tactile graphics—the Sewell raised-line drawing kit. In addition, the availability of such a low-cost audio/tactile graphics platform is likely to stimulate the authoring of third-party curricula for students with visual disabilities. These benefits promise to make graphics significantly more accessible to blind and visually-impaired students, ultimately translating to improved academic performance and careers in these key areas.

BENEFITS FOR TEACHERS: INSTRUCTIONAL SUPPORT

In-Class Data Capture: Assessing Class Participation

Teaching a class requires the instructor to manage a variety of activities at the same time. In many classes, teachers present new information while engaging learners in a dialog that enables them to process the information more deeply than they would in a traditional lecture. In order to help students develop competencies associated with a classroom dialog, teachers must deliberately monitor student performance and provide supportive and/or corrective feedback to each student. Unfortunately, presenting new information, coordinating a discussion, and managing classroom behavior—while keeping an eye on the clock—taxes even the most organized and experienced teachers. It would be too much to also ask that the teacher engage in a systematic process of assessing every individual on class participation according to a predefined rubric.

The Livescribe Pulse smartpen provides the means for teachers to record classroom discussions—linked to a system of simple marks on a seating chart—allowing them to return to the recording later for the explicit purpose of evaluating performance. Maintaining a record of in-class participation also allows teachers to share examples of in-class contributions with each student, fellow teachers, or parents, in order to demonstrate progress toward a goal.

"Class participation" should require more of students than to simply attend class or refrain from engaging in inappropriate behaviors. Teaching lessons that require student participation enhances motivation and improves learning and retention. According to Morgan and Saxton (1991), teachers ask questions for a variety of reasons:

1. the act of asking questions helps teachers keep students actively involved in lessons;
2. while answering questions, students have the opportunity to openly express their ideas and thoughts;
3. questioning students enables other students to hear different explanations of the material by their peers;
4. asking questions helps teachers to pace their lessons and moderate student behavior; and
5. questioning students helps teachers to evaluate student learning and revise their lessons as necessary.

Following their review of the scientific literature on effective questioning techniques, Wilen and Clegg (1986) recommended that teachers use these strategies to enhance engagement and achievement:

1. "phrase questions clearly;
2. ask questions of primarily an academic nature
3. allow three to five seconds of wait time after asking a question before requesting a student's response, particularly when high-cognitive level questions are asked;
4. encourage students to respond in some way to each question asked;
5. balance responses from volunteering and nonvolunteering students;
6. elicit a high percentage of correct responses from students and assist with incorrect responses;
7. probe students' responses to have them clarify ideas, support a point of view, or extend their thinking;
8. acknowledge correct responses from students and use praise specifically and discriminately" (p. 23).

In order for students to develop their question asking and answering skills, teachers must provide instruction, evaluate performance, and provide feedback. The most effective teachers will also track student performance over time to reveal trends toward a predetermined achievement level. And increasingly, teachers are expected to provide evidence—to administrators and teachers—of actual student work in order to justify instructional or behavioral interventions.

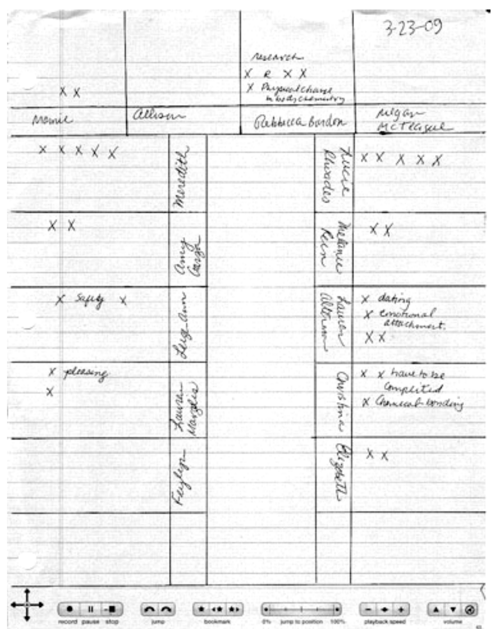

Figure 8: Example of a hand-drawn seating chart on Livescribe notebook paper with names and notations.

The technique described above would be useful for a variety of situations where data collection must, or should, be separated from the process of evaluation. These include:

- Behavior assessment/management observation (Figure 1 and Table 1)
- Classroom (teacher) observation
- Student presentation evaluation
- Team meeting observation

In many of these situations, the observer is provided with a form where they are to note the presence or absence of specified behaviors. Prior to the observation period, the observer can copy the key sections of the form into their notebook. Using the techniques above, the observer can not only capture a frequency count of each behavior, but also an audio recording associated with each behavior that will allow them to reliably and accurately report on the quality of the behavior—and to provide evidence to support their assessment should it be required.

As in the example presented previously, the seating chart may be drawn in advance on a page in the Livescribe notebook (or on dot pages printed from the Livescribe Desktop application.)

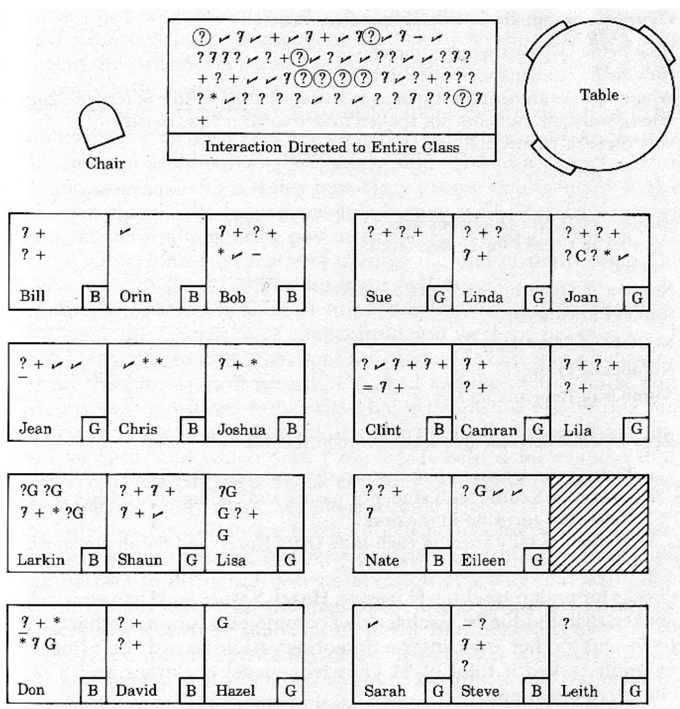

Figure 9: Sample seating chart with notations associated with behavioral observation (Stallings, Needles, & Sparks, 1987).

Code	Category	Description
?	Knowledge-level question	Require a right answer, simple recall of facts; include review questions
? (circled)	Higher cognitive question	Require students to think, apply, interpret, analyze, synthesize, create, or evaluate
? (slashed)	Checks for understanding	Require students to show understanding of content or procedures; call for summarizing, explaining,
+	Praise or acknowledgment	Students' academic responses, actions, or products are praised or acknowledged
C	Correction	Students' academic responses are wrong or incomplete, and teacher corrects them
G	Guided correction	Students' academic responses are wrong or incomplete, and teacher guides, probes, restates
(check)	Social comments	Teacher makes a social comment to a student. Even if stated as a question, a social comment is coded
–	Reprimand	Teacher reprimands behavior, this code always refers to behavior
*	Student initiates	Student initiates remarks or questions to the teacher. Be sure to code the teacher's response if there is one.

Source: Adapted from Stallings, Needles, & Sparks (1987).

Table 1: Codes, categories, and descriptions for a behavioral observation.

In-Class Assessments: Reading Fluency

Reading fluency is defined as the ability to read with sufficient ease and accuracy that the reader can focus their attention on understanding the meaning of the text. Because non-fluent readers devote much of their attention to decoding words, they have less cognitive resources available to apply to comprehension. Accordingly, effective teachers must apply systematic classroom-based instructional assessments to monitor student progress on both their reading rate and accuracy in order to modify instruction to suit individual student needs (Good, Simmons, & Kameenui, 2001).

The Livescribe smartpen addresses many of the limitations associated with data collection, analysis, and reporting of reading fluency.

Conventional Approach	Livescribe Approach
Paper record	Paper record w/automatic electronic copy
Separate timer; potential student anxiety	Unobtrusive timer built into pen display
One-time opportunity for data scoring	Recorded audio enables multiple reviews
Handwritten marks for future reference	Handwritten marks with audio record
Face-to-face training and practice	Smartpen-based training and practice

Table 2: Comparison of conventional and Livescribe fluency assessment.

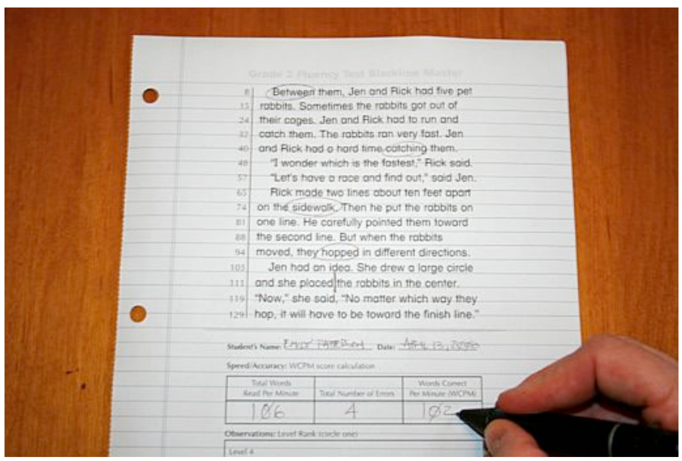

Figure 10: *Rigby Reads* fluency test printed onto Livescribe notebook.

CONCLUSION

Although the Livescribe Pulse smartpen has only been offered through the commercial market since April 2008, its value has been recognized by a variety of users—including teachers and students. Because it provides the means to easily capture handwriting and speech, it provides a universal platform for improving notetaking among students, accessing and communicating information more readily by individuals with disabilities, and conducting assessments by classroom teachers.

Researchers and practitioners are currently investigating many more applications of the smartpen to enhance the effectiveness, efficiency, and accessibility of teaching and learning.

FEDERALLY FUNDED SCIENTIFIC RESEARCH PROJECTS

2008 Funded Research Projects

Creating and Exploring Audio/Tactile Graphics with Digital Pen Technologies
National Science Foundation
- Josh Miele, Ph.D.; The Smith Kettlewell Eye Research Institute
- Andy Van Schaack, Ph.D.; Vanderbilt University

Creating Audio-Tactile Illustrated Digital Talking Books using a Digital Pen-Based Computing Platform
Department of Education, Small Business Innovation Research Grant
- Steven Landau; Touch Graphics

Scaling Up Smart Pen Technology for P1 Reading Assessment
Singapore, Ministry of Education
- Scott Paris, Ph.D.; National Institute of Education

2009 Submitted Research Proposals

Digital Pen-Based Supports for Notetaking and Summarizing of Notes Among Students with Learning Disabilities in Gateway Postsecondary Science
National Science Foundation
- Jose Blackorby, Ph.D.
- Dan Zalles, Ph.D.; SRI
- Andy Van Schaack, Ph.D.; Vanderbilt University

Using Paper-based Computing to Promote Teacher Learning for Inquiry-based Science Teaching
National Science Foundation
- David Kanter, Ph.D.; Temple University

Combining an Evidenced Based Treatment with a Measurement Feed-back System
National Institutes of Health
- Len Bickman, Ph.D.; Vanderbilt University
- Susan Kelley, Ph.D.; Vanderbilt University
- Thomas Sexton, Ph.D.; Indiana University

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