LIVESCRIBE IN K–12 EDUCATION: RESEARCH SUPPORT

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

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March 2009

livescribe

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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.
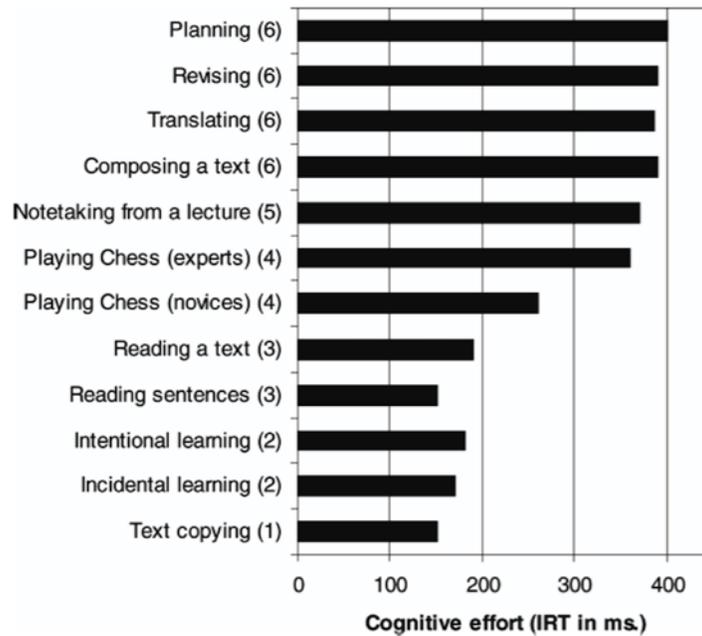

Figure 2: Cognitive effort required for various educational tasks. Note the position of "Notetaking from a lecture" – just above "Playing Chess (experts)" (Piolat, Olive, & Kellogg, 2005).

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 enhance-

ment 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).
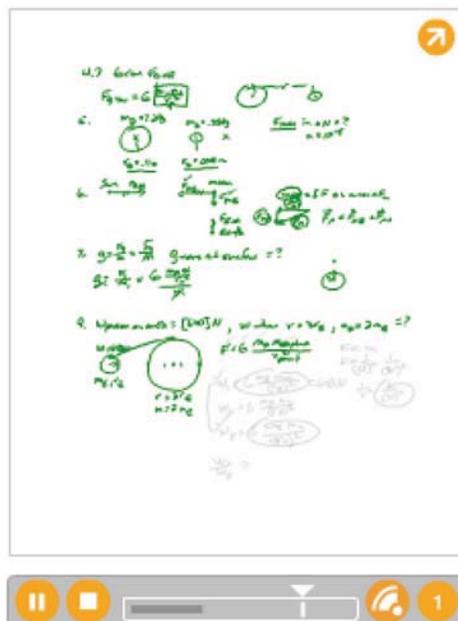

Figure 3: Pencast (audio-annotated animated diagram) playback through *Livescribe Desktop* software.

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