Principles of Cognitive Science in Education

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There is a long history of eminent psychologists — Woodworth, Cattell, Thorndike, G. Stanley Hall, Skinner, Bruner, Piaget — devoted to human education. Ironically, cognitive scientists — who have perhaps the most to offer through well-researched principles of learning and memory — have, only recently, felt in position to contribute. Fortunately, for students who study ineffectively, who frequently neither know what they do not know nor how to remedy it, and who end discouraged by thwarted learning aspirations, there has, recently, been a surge of involvement from cognitive scientists, spurred by the IES program. Implementing principles of cognitive science in classroom situations seems obvious. But teaching children in a real environment how to study more effectively is, for a laboratory-based experimentalist, fraught with surprises. Even leaving overwhelming motivational issues aside, it is not clear that laboratory findings survive translation into the classroom.

The Columbia team's first effort was an attempt to demonstrate that applying such principles (Metcalfe, Son & Kornell, submitted) could result in learning enhancement. We conducted a six week computer-based study program with urban inner-city sixth grade children at high risk for academic failure and early school termination, at a school in the South Bronx. The study materials, informed by our teacher-collaborators, were science and advanced English vocabulary terms that the children needed to know for classroom subjects, and for improving state and aptitude test performance. Our computer programs were overdesigned to include as many learning-enhancing principles from cognitive science as possible: self-generation rather than reading (Slamecka & Graf, l978), multimodal and contextual variability, spaced practice (Bahrick & Hall, 2005, Pashler, Zarow, & Triplette, 2003), corrective feedback (Butterfield & Metcalfe, 2001), repeated testing both immediately and at a delay (Roediger & Karpicke, 2006), motivational game rather than ability-test framing (Steele & Aronson, l995) that emphasized an incremental-theory set towards learning (Dweck & Leggett, l988).

All participants engaged in both computer-based and self-study conditions (and a no-study control). The first ten minutes of each session were spent chatting, relaxing, and — insofar as many underprivileged children come to school hungry (undermining their ability to concentrate) — having a nutritious snack. The children then studied either with the cognitive-science-based computer program, or on their own, switching conditions 25 minutes later. There were five learning sessions, spaced a week apart; on the sixth, there was a test.

The results (Figure 1, Panel A) were dramatic: the cognitive-science-based computer program resulted in a 411 percent increase in strictly-scored performance. Results for a second study in which Spanish-speaking children learned English vocabulary are shown in Panel B. Even though these materials were easy, and drilled daily in class, the improvement with the cognitive-science-based program was impressive. Finally, we ran a study with English-speaking Columbia University undergraduates, using English to Spanish vocabulary. Panel C shows that they, too, benefited from the cognitive-science-based program, though less than did the children from the South Bronx.

Figure 1

In this initial investigation no holds had been barred: we used everything that might have helped. But we did not know which factors were responsible for benefits, or even if some were harmful. For example, the children had generated their answers, even though that meant they also generated errors (unlike in lab studies). But, we did not know whether the errors were harmful. Subsequent research by our team showed that as long as self-generated errors were corrected, they had little detrimental effect. We gave feedback immediately, without knowing whether feedback was beneficial. In five out of five follow-up experiments, feedback was shown to be beneficial. Surprisingly, it mattered little whether it was given immediately or (as many teachers may be relieved to hear) at a delay of a week—as long as it is thorough. We, like others (Winstanley, Bjork & Bjork, 1996) have sometimes had difficulty in showing the importance of self-generation. Follow-up experiments showed that this was because children often spontaneously generate even in the nominal 'read' conditions. Getting them to do so, though, is crucially important. Our follow-up experiments, like those of others, have shown consistent beneficial effects of testing, and of spacing practice.

These principles of cognitive science demonstrably make a sizable contribution to learning. This benefit obtains not only in the lab but also in a classroom setting. We are especially encouraged because implementation of these principles appears to have the greatest benefit for the children who are most in need.

References

- Bahrick, H. P., & Hall, L.K. (2005). The importance of retrieval failures to long-term retention: A metacognitive explanation of the spacing effect, *Journal of Memory and Language, 52,* 566-577.
- Butterfield, B. & Metcalfe, J. (2001). Errors made with high confidence are hypercorrected. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*, 1491-1494.
- Dweck, C.S., & Leggett, E. L. (l988). A social-cognitive approach to motivation and personality, *Psychological Review, 93*, 236-273.
- Metcalfe, J., Kornell, N. & Son, L. K. (under review). A cognitive-science based program to enhance study efficacy in a high and low-risk setting.
- Pashler, H. Zarow, G., & Triplett, B. (2003). Is temporal spacing of tests helpful even when it inflates error rates? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 1051-1057.
- Slamecka, N.J. & Graf, P. (l978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory, 4*, 592-604.
- Roediger , H. L., & Karpicke, J. D., (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science, 17*, 249-255.
- Steele, C. M., & Aronson, J. (l995). Stereotype threat and the intellectual test performance of African Americans, *Journal of Personality and Social Psychology, 69,* 797-811.
- Winstanley, P.A.D., Bjork E.L., & Bjork R. A. (l996). Generation effects and the lack thereof: The role of transfer-appropriate processing, *Memory, 4*, 31- 48.