Journal of Applied Research in Memory and Cognition 1 (2012) 242–248

Contents lists available at SciVerse ScienceDirect

Journal of Applied Research in Memory and Cognition

journal homepage: www.elsevier.com/locate/jarmac

Target Article

Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice

Henry L. Roediger III*, Mary A. Pyc

Washington University, St. Louis, MO, United States

ARTICLE INFO

Article history:
Received 6 July 2012
Received in revised form
12 September 2012
Accepted 14 September 2012

Keyword:
Inexpensive techniques to improve education

ABSTRACT

The need to improve the educational system has never been greater. People in congress and business argue for expensive technological applications to improve education despite a lack of empirical evidence for their efficacy. We argue that one inexpensive avenue for improving education has been largely ignored. Cognitive and educational psychologists have identified strategies that greatly improve learning and retention of information, and yet these techniques are not generally applied in education nor taught in education schools. In fact, teachers often use instructional practices known to be wrong (i.e., massing rather than interleaving examples to explain a topic). We identify three general principles that are inexpensive to implement and have been shown in both laboratory and field experiments to improve learning: (1) distribution (spacing and interleaving) of practice in learning facts and skills; (2) retrieval practice (via self testing) for durable learning; and (3) explanatory questioning (elaborative interrogation and self-explanation) as a study strategy. We describe each technique, provide supporting evidence, and discuss classroom applications. Each principle can be applied to most subject matters from kindergarten to higher education. Applying findings from cognitive psychology to classroom instruction is no panacea for educational problems, but it represents one helpful and inexpensive strategy.

A front-page article in the Sunday New York Times (Gabriel & Richtel, October 11, 2011) examined the role of technology in the classroom. Many products have been offered to improve education with an estimated annual cost of $2.2 billion. Yet a survey from the Department of Education in 2010 showed either no or only modest gains from expensive educational products compared to similar classes that used standard textbooks. Of course, new educational products are often not sold on the basis of solid research results showing their effectiveness, but on marketing, personal testimonials, small case studies and the like. The one guaranteed outcome is large profits for the companies that make the products; educational gains for students are more doubtful. Nonetheless, some companies (Intel) and some in the U.S. Congress argue that one goal should be to put a computer in every child's hands in the U.S. That step would be enormously costly. Would children be able to successfully use the computers to improve educational achievement? What studies show this to be the case? We suggest large-scale trial experiments should be undertaken before taking such expensive steps to show their effectiveness. Much more research is needed to show how and when computer-based education is effective so as not to waste funds. As it is, teachers are being laid off, schools are being closed, and so cost-effectiveness is at a premium.

The gold standard of educational innovation for any kind of new educational technique should be a strong research base showing that the new method produces positive results relative to standard practice (Whitehurst, 2010). We do not doubt that someday computer-based education will meet this criterion, but we do not seem to be there yet. Perhaps we should save our money until controlled field experiments produce strong results. We argue that there is much low-hanging fruit to collect before dreaming of sky-high bonanzas that may turn out to be false.

The turn to expensive educational interventions is in some ways not surprising: the problems confronting school officials are enormous, so educators seek help any place they can. Because the problem is huge, the assumption seems to be that all solutions will be correspondingly expensive. Referring to school administrators and teachers, Peter Cohen, a chief executive of Pearson School, commented in the New York Times article that "They want the shiny new. They always want the latest, when other things have been proven the longest and demonstrated to get results" (p. 22).

Below we discuss methods arising from the laboratories of cognitive and educational psychologists that have been shown to produce positive effects on learning. The three basic principles we recommend in this article are ones for which there is

* Corresponding author at: Department of Psychology, CB 1125, Washington University, One Brookings Drive, St. Louis, MO 63130-4899, United States. Tel.: +1 314 935 4307; fax: +1 314 935 7588.
E-mail address: Roediger@wustl.edu (H.L. Roediger III).

2211-3681/$ – see front matter © 2012 Society for Applied Research in Memory and Cognition. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.jarmac.2012.09.002

strong basic (laboratory) research but also research with educational materials and, in some cases, evidence from research in the classroom. The specific techniques that fall under each of the general principles are, for the most part, dirt cheap (little or nothing to buy) and can be incorporated into standard classroom practice without too much difficulty. Yet, outside of educational and cognitive psychology, the techniques are practically unknown. Some teachers and students hit upon these methods on their own through trial and error, but in our (admittedly haphazard) survey of teacher training programs and the curricula of education schools, new teachers are unlikely to be taught about these effective techniques.

Professors in schools of education and teachers often worry about creativity in students, a laudable goal. The techniques we advocate show improvements in basic learning and retention of concepts and facts, and some people have criticized this approach as emphasizing "rote learning" or "pure memorization" rather than creative synthesis. Shouldn't education be about fostering a sense of wonder, discovery, and creativity in children? The answer to the question is yes, of course, but we would argue that a strong knowledge base is a prerequisite to being creative in a particular domain. A student is unlikely to make creative discoveries in any subject without a comprehensive set of facts and concepts at his or her command. There is no necessary conflict in learning concepts and facts and in thinking creatively; the two are symbiotic. As Robert Sternberg and Elena Grigorenko have commented, "Teachers need to put behind them the false dichotomy between "teaching for thinking" and "teaching for facts," or between emphases on thinking or emphases on memory. Thinking always requires memory and the knowledge base that is accessed through the use of memory. . . .One cannot apply what one knows in a practical manner if one does not know anything to apply" (Sternberg & Grigorenko, 2003, p. 215). The techniques we advocate below aim to build this knowledge base. We firmly believe, and some empirical evidence shows, that students who can retrieve a variety of information when seeking to solve a problem will show better transfer on that problem than students without such information.

1. Cognitive strategies in enhancing learning

For many years educational and cognitive psychologists have studied factors that improve learning and retention, so that a solid factual basis has been achieved about which strategies work and which ones do not work. A recent review by Dunlosky, Rawson, Marsh, Nathan, and Willingham (in press) examined 10 promising strategies to improve learning in educational situations (see also Mayer's (2010) excellent book and the practice guides published by Pashler et al. (2007)). Based on an exhaustive review, Dunlosky et al. concluded that five strategies they examined were useful and five were not (or had not yet been proven to be useful based on empirical research – future research might change that state of affairs, of course).

In this article, we advocate five of the most useful techniques distilled from their exhaustive review, although we collapse their five strategies into three general principles (grouping closely related ones together). The three general principles we identify are the distribution (spacing and interleaving) of material and practice during learning; the frequent assessment of learning (direct and indirect positive effects of quizzing and testing); and explanatory questioning (elaborative interrogation and self explanation; having students ask themselves questions and provide answers or to explain to themselves why certain points are true). We grouped spacing and interleaving together because they usually go together naturally in practice (information that is interleaved necessarily involves spaced practice), and also consider elaborative interrogation and self explanation as related ideas, although we describe some differences below.

1.1. Distribution of material and practice

Repetition of information improves learning and memory. No surprise there. However, how information is repeated determines the amount of improvement. If information is repeated back to back (massed or blocked presentation), it is often learned quickly but not very securely (i.e., the knowledge fades fast). If information is repeated in a distributed fashion or spaced over time, it is learned more slowly but is retained for much longer. (When other types of learning are interspersed during the times between repetitions of the same information, this condition is referred to as interleaving of practice, as we discuss below.) Although spaced and interleaved presentations of information (or practice on problems) results in slower initial learning, a large body of research shows that it leads to more durable learning and retention.

The spacing effect is one of the oldest findings in experimental psychology (first reported by Ebbinghaus in 1885), and a huge volume of research since then has confirmed the point (see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). As noted, both spacing and interleaving impose a time delay between practice trials with the same (or same type of) repeated material. The primary difference between the two is the type of information that is practiced in between presentations of the same information (or practice on the same type of problems). For spacing paradigms, the target information to be repeated is simply spaced out in time (say a fact might be studied every 5 min) with irrelevant activity during the 5-min periods. For interleaving of practice, students study completely different examples of a given concept or topic that are spaced across time (e.g., in math, students would solve various types of problems all mixed up, so that practice on any one type of problem is spaced but with other types of problems occurring between examples of the same type). Both spacing and interleaving have positive effects, as we discuss below, and they are often used together (see Rohrer & Pashler, 2010).

Although the majority of research on spacing and interleaving has been conducted in laboratory settings, the utility of spacing has also been evaluated in classroom settings (e.g., Carpenter, Pashler, & Cepeda, 2009; Sobel, Cepeda, & Kapler, 2011). For example, in a study reported by Bloom and Shuell (1981), high school students learned 20 French–English vocabulary words. Students had 30 min to learn the vocabulary words. Half of the students spent 30 consecutive minutes studying (massed group), whereas the other half studied for 10 min across three consecutive days (spaced group). At the end of the learning phase students had a test to evaluate how much they had learned, and one week later they were given a surprise test to evaluate their long-term retention. The results are shown in Fig. 1, where it can be seen that on the initial test the groups performed similarly; however, on the final test recall was greater in the spaced versus massed group.

Translating this sort of question into the classroom, we can ask: Should students study all material from a given topic before moving on to the next one, or should topics be intermixed? The typical classroom procedure is to give students a new procedure (say second graders learning how to subtract) and then give them many example problems on this procedure to make sure they know it. This produces children who more quickly learn to subtract (if all they have to do is subtract). However, once they have finished studying the four basic procedures of arithmetic, they will have to use those procedures in many different contexts and it will be important to know how to subtract (or multiply or divide or add) in the right context. Blocked presentation may not help the student to pick which operation is needed for the problem at hand.