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Reply

Applying cognitive psychology to education: Complexities and prospects☆

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We appreciate the thoughtful responses to our target article from the respondents. We even agree with (almost) all their points. Who could disagree with the argument that "more research in classrooms is needed" or that "we need to teach for transfer (if we can figure out how)"? Here we provide a few reflections aroused by the comments.

Mayer (2012) reminds us of the long history of psychologists being interested in applying their knowledge to education. Of course, when William James wrote his book on *Talks for Teachers* in 1891, there was not much of an empirical research base on which to draw. The book is still quite worth reading today for its inspiring ideas and possible nuggets for research. We agree with Mayer that the best avenue would be a two-way street between educators and researchers, but after 100 plus years of trying, the traffic both ways is infrequent. He points to the need for psychologists to use educationally relevant materials and to seek transfer. We agree, certainly, and will have a bit more to say on these matters below.

Daniel (2012) seems to think we are barely beyond where we were in James's time. He believes that we still do not have enough of an empirical base to apply psychologists' research to education today, and we will need dozens (hundreds?) of classroom experiments in many different fields and contexts before we should utter a word of advice (we paraphrase the argument). In the meantime, apparently we should just let educators use whatever methods they would want to use (even if based on no research at all) while psychologists stand mute by the sidelines. Or we could buy each student a computer and hope for the best, in the great American tradition of throwing money at a problem even if it is unlikely to have an effect.

Somehow we do not see the current situation as quite so grim. After all, Hermann Ebbinghaus discovered the spacing effect in 1885 (Ebbinghaus, 1885/1913), and it has been documented in hundreds of studies since then in all manner of species, paradigms, and, in humans, with children, college students and older adults. Further, the effect occurs with many sorts of materials, including educationally relevant ones. Is there really any doubt, in 2012, that spaced/interleaved practice would be better than massed practice for fostering long-term retention in classrooms? Do the principles governing learning stop when we switch from a lab to a classroom? All the evidence we know leads us to suspect that generalizations can be made, even though, yes, complexities will arise in the process and some pieces of advice will need to be revised as we learn more. Of course, the data base of research in classroom experiments is not zero, after all, and so far the returns seem promising. What is the downside of applying what we know now, even if the knowledge is not perfect?

The massed/spaced practice case is an interesting one, because teachers often use massed practice – and with good reason. When measuring learning, massed practice produces quicker learning of facts and procedures than does interleaved and spaced practice on an immediate test (see Schmidt & Bjork, 1992). Thus teachers and students might understandably be surprised to learn that this kind of practice leads to more rapid forgetting than does spaced/interleaved practice. The same principle often holds in research comparing repeated studying to repeated testing; cramming (repeated studying) may produce better performance on a criterial test after a short retention interval relative to testing of the information, yet testing produces better performance in the long term (e.g., Roediger & Karpicke, 2006a, among many others). Both the spacing/interleaving effect and the testing effect conform

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to Bjork's specification of desirable difficulties in learning: Although spacing/interleaving and testing may slow initial learning, they create better long-term retention (Bjork, 1994; Schmidt & Bjork, 1992). It can be hard for teachers (or students) to perceive such advantages of spacing or testing when their immediate experience seems to show the opposite. Thus, research is needed to document the point.

The other commentators seem more sanguine about applying cognitive research to educational practice in the present day, even if all questions cannot be answered now. We have to start with the knowledge base we have, which seems preferable to adopting whatever latest theory or fad sweeps through with no evidence base at all. Dunlosky and Rawson (2012) agree that evidence is firm enough to advocate spacing/interleaving and testing (relative to massed study in both cases) for long-term retention, with the ever-needed proviso that more studies in classroom would be a welcome addition. However, they think that we may be premature in recommending explanatory questioning and related techniques because a) there is not yet good evidence that this technique works in classroom settings and b) the technique requires great amounts of time (relative to others). They are right on both counts, but at least the lab evidence seems promising and the techniques seem to provide the benefits of elaborative processing that has been well established as beneficial in laboratory research.

Kornell, Rabelo, and Klein (2012) seem more sanguine about explanatory questioning, because they think testing should be compared against questioning and other techniques to establish the efficacy of testing. They raise many interesting points that should guide the way to further research. We would like to pick up on one comment they made about testing, viz., that "In the first author's experience, the biggest effect of daily quizzes may be to motivate effortful studying and punctual class attendance" (p. 5 of manuscript). We agree. Roediger and Karpicke (2006b) distinguished between direct and indirect effects of testing, and the qualities noted by Kornell represent the indirect effects of testing (as compared to direct effects of retrieval practice per se). In fact, Roediger, Putnam, and Smith (2011) pointed to ten benefits of testing, although not all would necessarily translate to the classroom. Kornell et al. worry that testing may displace other classroom activities that might be inherently more beneficial than testing. We suspect that their anxiety on this point is misplaced. Low-stakes quizzing produces so many benefits (increased studying prior to class, more attention paid in class, greater class attendance, retrieval practice, etc.) that it would be surprising if the few minutes needed for such quizzes could be replaced by some better technique. The results of Lyle and Crawford (2011) would seem to suggest as much in an actual classroom setting, because they compared quizzing to additional lecture time and found that quizzing produced greater performance on criterial tests. This research was conducted in a classroom setting, too, and the criterial tests were ones on which students grades were based.

Pellegrino (2012) takes a broader view, worrying about how even effective techniques would fit into a whole curriculum across several years. He is exactly right, and we paid too little attention to such matters in our target article. The first author grew up in Virginia, a state where (at least in the 1950s and early 1960s) educators took their state history seriously. Nearly every other year from 4th grade on was devoted to the rich history of Virginia, so that spacing was built into a biennial cycle. Although the first author went to high school in a different state, missing the high school course in Virginia history, he still knows the history of the state reasonably well (raise your hand now if you know where Jefferson Davis held his last full cabinet meeting on his retreat from Richmond in 1865). Pellegrino describes how key principles in elementary mathematics might be spaced for effective learning. His concerns dovetail nicely with Dunlosky and Rawson's (2012) prescription for successive relearning to occur at spaced intervals. They (and Harry Bahrick before them) have performed heroic experiments showing the benefits of successive relearning. The general point from both their results and Pellegrino's comment is that if we want students to know certain core facts, procedures and principles as adults, they should be repeatedly included in the curriculum during the years of education.

A theme running through several comments is that even research in the classroom (and nearly all research in the laboratory) has focused on the learning of basic facts, concepts, skills and procedures. Spacing/interleaving, testing and (probably) elaborative questioning are good for these sorts of learning, but will they create "deep learning" to use a phrase that Pellegrino employs? Deep learning implies great understanding, the development of what are variously called schemas or scripts or situation models. We are often asked this question and, besides mumbling about more research being needed, we can point to reasons why testing and other factors that enhance accessibility of information may be useful in fostering greater understanding in learning and even in creative problem solving. Often new learning requires retention and retrieval of previously learned concepts for deep understanding of the new material, and this is especially so in cases where new knowledge builds on prior knowledge. If a student is reading a new passage and can readily retrieve concepts and procedures presented earlier in the course, she will have a much better chance of deep learning of the new material. To the extent that spacing, testing and other techniques can foster rapid retrieval of relevant facts in new learning, understanding should be enhanced. Likewise, if a student is required to write an essay integrating several themes from a course, the ability to draw readily on facts and concepts already learned should help in creating a synthesis of the information. Of course, the argument in this paragraph is built on many "should" and "ought to" kinds of comments, because the evidence base is not yet available to strongly document these points (though relevant evidence has been produced by Butler (2010) and Carpenter (2012), among others).

Still, let us imagine for a moment that the techniques we recommended in the target article really are good just for learning basic concepts, facts, skills and procedures and for retaining these well. We still believe this would be an improvement in the knowledge base of many students. Dunlosky and Rawson (2012) point to the dismal rates of performance in grades 4, 8 and 12 on the National Assessment of Educational Progress in the United States. These exams are mostly testing for learning of basic facts, concepts, skills and procedures in which students are deficient. The techniques we advocate, if applied rigorously in schools, might at least give students a chance of acquiring basic knowledge and thereby at achieving deeper learning later. Without such basic educational tools, students will drop further behind. So even if the techniques did not create deep learning (assuming that can be measured), their use in the classroom is still needed in our view. We hasten to add that we suspect that the techniques will actually promote greater development of schemas and organization (e.g., Zaromb & Roediger, 2010), but the proviso to be kept in mind is that the forms of practice tests should transfer appropriately to final tests. If we want students to be able to reason with information and to write comprehensive essays about what they have learned, then practice tests given during the semester should require just these kinds of broad processes (see Thomas & McDaniel, 2007).

In sum, the points raised by the commentators are interesting and they rightly pinpoint various gaps in our knowledge, such as the need to know the "dosage" (as Dunlosky and Rawson call it) of even the effective techniques for long-term benefits. Even though there is much we do not yet know, we maintain that principles do exist that have been repeatedly established in research, and it is unlikely that when placed in classroom contexts that the effects will disappear or reverse (e.g., that massed practice will suddenly be superior

for long-term retention than spaced practice). We look forward to further developments in translational educational science from the lab to the classroom and, following the two-way street metaphor, of educators asking psychologists to evaluate ideas they may develop about teaching and learning.

References

Bjork, R. A. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe, & A. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 185–205). Cambridge, MA: MIT Press.

Butler, A. C. (2010). Repeated testing produces superior transfer of learning relative to repeated studying. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*, 1118–1133.

Carpenter, S. K. (2012). Testing enhances the transfer of learning. *Current Directions in Psychological Science*.

Daniel, D. B. (2012). Promising principles: Translating the science of learning to educational practice. *Journal of Applied Research in Memory and Cognition*.

Dunlosky, J., & Rawson, K. A. (2012). Despite their promise, there's still a lot to learn about techniques that support durable learning: Comment on Roediger & Pyc (2012). *Journal of Applied Research in Memory and Cognition*.

Ebbinghaus, H. (1913). *Memory: A contribution to experimental psychology*. New York: Teachers College, Columbia University. (translated by H.A. Ruger & C.E. Bussenius; original German work published 1885).

James, W. (1958/1899). *Talks to teachers*. New York: Norton.

Kornell, N., Rabelo, V. C., & Klein, P. J. (2012). Tests enhance learning—Compared to what? *Journal of Applied Research in Memory and Cognition*, *1*, 257–259.

Lyle, K. B., & Crawford, N. A. (2011). Retrieving essential material at the end of lectures improves performance on statistics exams. *Teaching of Psychology*, *38*, 94–97.

Mayer, R. E. (2012). Advances in applying the science of learning to education: An historical perspective. *Journal of Applied Research in Memory and Cognition*.

Pellegrino, J. W. (2012). From cognitive principles to instructional practices: The devil is often in the details. *Journal of Applied Research in Memory and Cognition*.

Roediger, H. L., & Karpicke, J. D. (2006a). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, *17*, 249–255.

Roediger, H. L., & Karpicke, J. D. (2006b). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science*, *1*, 181–210.

Roediger, H. L., Putnam, A. L., & Smith, M. A. (2011). Ten benefits of testing and their applications to educational practice. In J. Mestre, & B. Ross (Eds.), *Psychology of learning and motivation: Cognition in education* (pp. 1–36). Oxford: Elsevier.

Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science*, *3*, 207–217.

Thomas, A. K., & McDaniel, M. A. (2007). The negative cascade of incongruent generative study-test processing in memory and metacomprehension. *Memory & Cognition*, *35*, 668–678.

Zaromb, F. M., & Roediger, H. L. (2010). The testing effect in free recall is associated with enhanced organizational processes. *Memory & Cognition*, *38*, 995–1008.