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COMMENTARY

Personal Reflections on Science Communication and Sharing Retrieval Practice Research with Teachers

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Abstract

Although research on retrieval practice—the process of bringing previously learned information to mind via quizzes, flashcards, etc.—dates back to the late 1800s, it took nearly 100 years to gain popularity among educators as a teaching strategy. This was due, in part, to the limited availability of practical recommendations on how to use retrieval practice to improve learning. Recently, there has been a rapid expansion in science communication of retrieval practice research in many forms, including books, blogs, podcasts, and engagement on social media. As one indication of growing interest among the general public, in 2019 the phrase "retrieval practice" became more frequently searched than "testing effect" on Google.

In this commentary, I reflect on my personal experience in the science communication of retrieval practice research, with a specific focus on a website (retrievalpractice.org), an email newsletter, and brief practice guides I developed for teachers over the previous decade. We currently lack empirical measurement of the impact of science communication on classroom implementation; thus, I offer five recommendations for translating research based on my own trials and errors. Looking forward to the next 100 years, I am optimistic that retrieval practice will be common knowledge as a valuable learning strategy and that teachers will leverage it to increase student achievement.

Keywords Retrieval practice · Classroom research · Implementation · Science communication · Teaching · Learning · Student achievement

A vast amount of research from cognitive psychology demonstrates that retrieval practice—the process of bringing previously learned information to mind via

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quizzes, flashcards, writing prompts, and classroom technology tools—significantly increases students' long-term learning. In a review of 50 classroom experiments, when teachers included question prompts during lessons, student learning consistently increased across a wide range of educational levels and content areas, compared to learning from lessons in which question prompts were not included (Agarwal et al., 2021). For example, Jones et al. (2016) found benefits from retrieval practice during spelling lessons in elementary school, Foss and Pirozzolo (2017) found benefits from retrieval practice in semester-long undergraduate psychology courses, and Kromann et al. (2010) found benefits from retrieval practice for medical students in Denmark who were learning how to administer cardiopulmonary resuscitation (CPR).

Historically, research on retrieval practice dates back to the late 1800s and early 1900s (e.g., Abbott, 1909; Ebbinghaus, 1885; Gates, 1917), but practical information about how to use retrieval practice in educational settings remained nearly nonexistent for more than 100 years (Roediger & Karpicke, 2006). For example, a book by cognitive scientist Daniel Willingham, *Why Don't Students Like School* (2009), became popular among teachers as a source of information about how to implement research-based cognitive strategies in the classroom. However, as Marsh and Eslick (2009) pointed out in their book review, there was no mention of retrieval practice as a learning strategy in Willingham's book. As further indication of limited information on the science of learning for a practitioner audience during this time period, prevalent social media platforms (e.g., Facebook, Twitter, and YouTube) weren't launched until the early 2000s. In addition, textbooks for educators rarely included retrieval practice as an instructional strategy (Pomerance et al., 2016), and both pre-service and in-service teachers lacked explicit instruction on evidence-based learning strategies (Halamish, 2018).

One of the first examples of science communication specific to retrieval practice research was a publicly available "practice guide" published by the Institute of Education Sciences (IES) within the US Department of Education, entitled "Organizing Instruction and Study to Improve Student Learning" (Pashler et al., 2007). In the extensive 63-page practice guide, a team of six cognitive scientists and a middle school teacher reviewed research on several evidence-based learning strategies, including retrieval practice, spacing, and interleaving. Six years later, another team of cognitive scientists published a 55-page review of ten research-based learning techniques (Dunlosky et al., 2013). These detailed reports have since become quite popular, with more than 1000 citations and nearly 4000 citations to date, respectively (Google Scholar, https://scholar.google.com).

2013–2023: a Decade of Rapid Science Communication of Retrieval Practice Research

More recently, public interest in applied research and implementation of retrieval practice has grown considerably, with a notable increase in peer-reviewed journal publications of experiments conducted in classroom settings (Agarwal et al., 2021; open access to the literature review is available from *Educational Psychology Review*

at https://rdcu.be/cgITe). In addition, the publication of accessible books for teachers and students has dramatically increased, each with practical recommendations for implementing retrieval practice to improve learning (e.g., Agarwal & Bain, 2019; Brown et al., 2014; Weinstein & Sumeracki, 2019; for a comprehensive list, see https://retrievalpractice.org/books).

Beginning in 2016, cognitive scientists Megan (Smith) Sumeracki and Yana Weinstein created a blog for teachers and students, aptly named The Learning Scientists (https://learningscientists.org; Sumeracki & Weinstein, 2017). They quickly expanded their website to create a wealth of resources and recommendations on how to implement six specific learning strategies: retrieval practice, spacing, interleaving, elaboration, concrete examples, and dual coding. Educators and teachers, spanning K–12 to medical school, began sharing resources and teaching ideas about retrieval practice strategies online, with Twitter threads becoming remarkably popular (Weinstein & Sumeracki, 2017). Currently, The Learning Scientists' resources include innovative YouTube videos, printable posters, infographics, and a podcast, reaching millions of people around the world.

From 2013 to 2023, the rapid increase in applied classroom research on retrieval practice, publication of books on the science of learning, and availability of online resources demonstrates significant growth in science communication of cognitive science. In surveying these combined efforts, a particularly meaningful theme emerges: scientists and educators have shifted away from using the phrases "testing effect" or "test-enhanced learning" in science communication, phrases which are typically found in the research literature to describe the act of recalling information to increase learning. In fact, in 2019, the phrase "retrieval practice" became more frequently searched than "testing effect" on Google (Fig. 1; data from Google Trends, https://trends.google.com).

Google search popularity data shown in Fig. 1 are from January 2013 to January 2023 (data retrieved from Google Trends on March 18, 2023). A score of 100

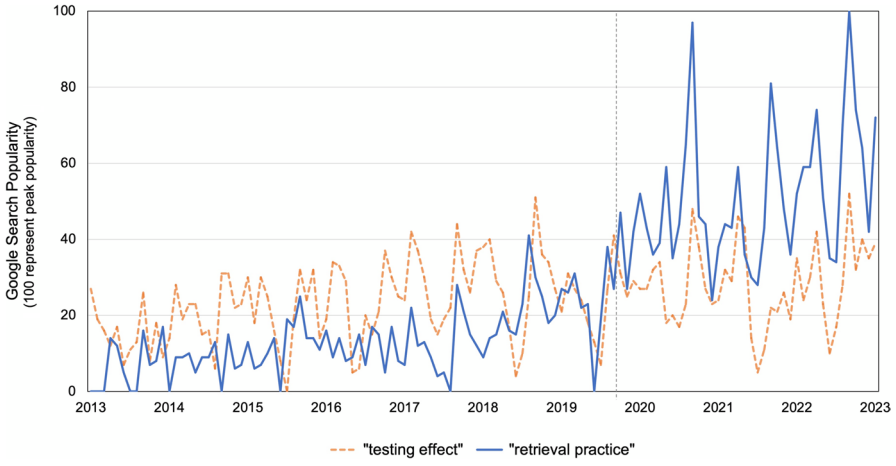

Fig. 1 Google search popularity for the terms "retrieval practice" and "testing effect"

represents peak popularity, and the dotted vertical line represents the inflection point in 2019 when the phrase "retrieval practice" became more frequently searched than "testing effect".

This recent shift in terminology from the "testing effect" to "retrieval practice" suggests a shared responsiveness among cognitive scientists and the general public, perhaps in consideration of two factors: (1) a need to acknowledge that the act of recalling information can be engaged using a wide range of activities, not just tests, and (2) an effort to distinguish between testing as a learning strategy vs. testing as an assessment strategy (i.e., to avoid an association with standardized testing; Agarwal et al., 2021). Although use of the phrase "testing effect" may continue in the academic literature for historical or technical reasons, use of the phrase "retrieval practice" places emphasis on the underlying cognitive process by which learning can be solidified. Hopefully, this shift in language will increase the likelihood that retrieval practice will be implemented by teachers and students, subsequently increasing long-term learning and achievement.

Personal Reflections on Sharing Retrieval Practice Research with Teachers

In the remainder of this commentary, I reflect on my personal experience in science communication of retrieval practice research with teachers. Research can be shared with teachers in a wide variety of formats (e.g., professional development workshops, articles in educator magazines, media interviews, and books); however, I focus my commentary on forms of online science communication, specifically a website (retrievalpractice.org), downloadable practice guides, and an email newsletter. Following discussion of measuring impact on classroom implementation, I offer five recommendations for researchers who are venturing into science communication.

I have chosen to focus on a website, practice guides, and an email newsletter for three particular reasons: (1) these are written forms of communication, with which scientists already have experience (i.e., compared to facilitating a workshop for a public audience); (2) they do not require financial resources for development or dissemination; and (3) they can be provided to educators free of charge. In addition, I include quantitative observational data resulting from the dissemination of these resources as a starting point for future research. Data on practitioner implementation following science communication are readily available in most STEM fields (Fischhoff, 2019), but there are few published studies of the impact of science communication specific to the field of cognitive psychology—a critical indicator in need of empirical investigation.

My hope is that by sharing my reflections on the development of resources for teachers, dissemination data as an initial indication of impact, and recommendations for scientists embarking on science communication, this singular case study can provide an informative perspective for readers.

Development of Practice Guides and a Website for Educators

While the availability of full-length books and detailed resources on the science of learning increased in the early 2000s, there was a lack of specific, simple recommendations for educators on how to implement retrieval practice in their schools and classrooms. To address this need, in 2012, my colleagues and I at Washington University in St. Louis (Henry L. Roediger, III, Mark A. McDaniel, and Kathleen B. McDermott) began to develop a brief practice guide for teachers, supported by grant funding from IES. In our initial conversations with K–12 teachers, it became clear that a short document—focused solely on retrieval practice as a teaching strategy, in ten pages or less—would be a valuable addition to the longer in-depth resources already available.

While drafting a ten-page guide might seem easy, simply deciding what to include (and what to exclude) was more difficult than we anticipated. For example, how fully should we discuss research on free vs. cued recall? Were the nuances of calibration and resolution from the judgment of learning literature relevant? What recommendations could we provide teachers for the provision of immediate vs. delayed feedback, taking into consideration that the research findings were mixed?

Ultimately, we decided to provide teaching tips based on our longitudinal classroom experiments on retrieval practice, which we conducted over the course of nearly 10 years with 1500 K–12 students in a public school district near St. Louis, MO. In brief, we found that teachers' lessons that included retrieval practice—compared to re-reading statements or lessons without retrieval practice—benefitted students' long-term learning and raised course grades from a C to an A level (Roediger et al., 2011). In follow-up experiments, lessons with three spaced opportunities for retrieval practice were optimal for increasing learning, even when measured 9 months later (McDaniel et al., 2011); retrieval practice was beneficial regardless of question format (i.e., multiple-choice and short answer questions; McDermott et al., 2014); and retrieval practice improved students' learning for higher order content and transfer of knowledge (Agarwal, 2019; McDaniel et al., 2013; for a synopsis of our researcher-teacher partnership and how we conducted research in K–12 schools, see Agarwal et al., 2012).

We spent an entire year drafting and refining the practice guide, facilitating teacher focus groups, distributing it to teachers in additional school districts, and observing daily classroom implementation. Originally, we referred to the document as a "manual," which teachers kindly recommended we reframe as a practice guide, to emphasize that the document served as a source of recommendations, rather than a precise list of directives or instructions. With iterative feedback from K–12 teachers and administrators, our final ten-page practice guide (a PDF) included accessible descriptions of research, practical tips for integrating retrieval practice strategies during existing lessons, a list of frequently asked questions, and an implementation checklist (Agarwal et al., 2013, 2020). We decided to omit graphs entirely, with the exception of a pie chart of survey data demonstrating that frequent retrieval practice *reduced* test anxiety for nearly 75% of students, in order to emphasize that retrieval practice is not a high-stakes assessment (Agarwal et al., 2014). We shared the practice guide via email with teachers who heard about it through the grapevine, and we

made it available for download on a new website created in 2014, retrievalpractice.org, marking the beginning of my experience with science communication.

From 2015 to 2021, I collaborated with a wider group of cognitive scientists to create six additional practice guides, spanning a range of research-based learning strategies: interleaving, transfer of knowledge, spaced retrieval practice, and metacognition, as well as retrieval practice research in early childhood education and information for teachers about how to interpret meta-analyses (Carpenter & Agarwal, 2019; Fazio & Agarwal, 2019; Pan & Agarwal, 2018; Rohrer et al., 2017; Son et al., 2020; Sundar & Agarwal, 2021, with translations in Spanish, Portuguese, Dutch, and Mandarin). With a commitment to public accessibility and open science, all materials available on my website are freely available for download under Creative Commons Licensing. As of this writing, the retrievalpractice.org website receives approximately 15,000 visitors per month, the practice guides have been downloaded by at least 250,000 educators around the world, and the website has had more than 1 million unique visitors since its inception (Google Analytics, https://analytics.google.com). Even with infinite advances in online resources since the release of our first practice guide in 2013, brief PDFs that are freely available to download, formatted for printing, and easy to forward via email continue to be a valuable resource for sharing research and practical classroom recommendations with teachers.

Development of an Email Newsletter

By 2016, I was eager to share research and tips with teachers beyond the practice guides. I began to add additional information to my website, including recommended research articles, a list of leading cognitive scientists, and links to related websites. Around the same time, a colleague observed that a static repository of information on a website would be insufficient for science communication; it would exist in a sea of "one and done" resources for teachers. If we are to have a lasting influence on the decisions teachers make in the classroom, my colleague advised that an ongoing form of communication would be valuable in sharing the most up-to-date research findings from cognitive and educational psychology.

With the help of scientists, educators, and bloggers to spread the word, I began sending an email newsletter to teachers via Mailchimp. The content for my initial newsletters focused on newly published research. Unexpectedly, the first newsletter in which I shared a specific teaching activity (free recall reframed as a "brain dump"; Agarwal, 2017) resulted in a significantly higher email "open rate" than previous content. To me, this suggested that educators were eager for *specific* teaching strategies, rather than broad classroom recommendations informed by newly published research. As much as my inner scientist winced at the idea of endorsing teaching strategies that had not been directly evaluated in classroom settings, I found some comfort in the consistent research findings that retrieval practice increases long-term learning beyond the traditional strategies readers may have been using, such as reviewing materials and infrequent high-stakes exams (Agarwal et al., 2021).

I began sending my newsletter on a weekly basis, with a focus on teaching activities to implement retrieval practice, spacing, interleaving, and metacognitive strategies. Currently, my newsletter has nearly 18,000 active subscribers, with approximately 250 new subscribers per month. The number of new subscribers peaked in 2019 at 400 subscribers per month, coinciding with the increase in Google search popularity of retrieval practice. On average, 9000 subscribers open each newsletter (a 50% open rate; in the marketing industry, the average open rate is 21%; Mailchimp, 2019). Based on survey data, 55% of my newsletter subscribers are K–12 teachers or administrators, 30% are higher education faculty or staff, and 15% are parents, students, or non-educators.

While the total number of subscribers and email open rates are important metrics for any newsletter, my definition of "success" for my newsletter has shifted over time. Early on, for example, I experimented with different types of content to find what yielded the highest open rate (e.g., teaching activities, research summaries, or links to resources). I found that the newsletters with the most engagement (i.e., open rates, click rates, number of website visitors, and sharing on social media) were the ones that included practical teaching activities and downloadable materials. I found it rewarding to observe growth in subscriber numbers and engagement, with tangible data points to inform my decision-making. My hope was that, with a growing number of subscribers and a high open rate, my newsletter was influencing classroom teaching and implementation of retrieval practice strategies.

At the same time, I learned that creating original content and new downloads on a weekly basis required a vast amount of time, energy, and unpaid labor, as well as unanticipated financial resources for website and newsletter platform expenses. After extensive consideration, I decided to pause the newsletter during the COVID pandemic and re-evaluate my goals for science communication. In 2022, I chose to focus less on the content that would yield the highest engagement rates. As a substitute, I decided to write about what was on my mind about teaching and research at the moment: how I addressed a recent challenge in my classroom, tips for teachers on how to conduct research in their classrooms, steps we can take to address inequities in STEM fields, and my thoughts on questions I receive from individual teachers.

Currently, I send my newsletter once per month. Following the shift in content and the reduced frequency of my newsletter, I have observed decreases in email open rates, speaking requests, and the sales rate of my book, *Powerful Teaching* (Agarwal & Bain, 2019). At the same time, I have found new energy in an unanticipated form, the fostering of a community of 40 diverse and underrecognized women, LGBTQ, and BIPOC scientists who conduct research on retrieval practice (more information about our group is available at https://retrievalpractice.org/scientists). On a near daily basis, we support and encourage each other in our collective teaching, research, and science communication efforts—which has been more personally and professionally rewarding than many of my science communication efforts over the years.

Measuring the Impact of Science Communication on Classroom Implementation

In an article published in the journal *PNAS*, Fischhoff (2019) stated, "Science communications succeed when recipients make better decisions" (p. 7674). This begs the question: Are teachers making better decisions based on cognitive and educational psychology research?

We know that retrieval practice consistently improves *student* learning in classrooms ranging from K–12 to medical school, with content ranging from world history to anatomy, across a wide variety of timing and formats (Agarwal et al., 2021). However, we have yet to establish a direct connection between *teachers'* learning about retrieval practice and their implementation of retrieval practice. In other words, it is currently unclear whether science communication efforts on the science of learning influence decision making in the classroom, a critical consideration as the number of blogs, books, social media posts, online courses, and professional development workshops for teachers continues to grow.

In pursuit of measuring the impact of science communication on teaching, it is critical that we include scientists and educators from a range of backgrounds. Human cognition is better understood when psychology research is conducted with race, context, and culture in mind (Roberts et al., 2020; Thomas et al., 2023). Furthermore, so-called universal patterns of human learning and memory—including benefits from retrieval practice and implementation by students as a study strategy—are frequently based on research with participant samples drawn from wealthy, highly educated countries (Ekuni et al., 2020). Collaborations with an inclusive representation of scientists, educators, and students will lead to a better understanding of if, when, and how science communication of retrieval practice research improves learning in modern classrooms.

In addition, we are in an opportune time to support educators in conducting research in their own classrooms. For example, when I shared a recommended reading list on the science of learning in my newsletter, the most frequently clicked link (by more than 2600 subscribers) was to an academic research article about students' test anxiety after engaging in retrieval practice (Agarwal et al., 2014). Numerous teachers emailed me requesting the survey we used in our research, with additional requests for more information on basic research methods and design. Although anecdotal, this was an indication that teachers are not only interested in reading about research; they are eager to conduct research themselves, even with all the daily responsibilities educators undertake. While there are many obstacles to building partnerships between scientists and educators in order to conduct research in applied settings (see Agarwal et al., 2012), it would benefit our understanding of teachers' learning to involve teachers in the research process.

As cognitive and educational psychologists, we have the expertise to develop both quantitative and qualitative approaches in this much-needed area of research, including experimental methods, standardized surveys, and focus group protocols, to directly examine teachers' learning about learning and their

subsequent classroom implementation. A growing area of research that is directly applicable is known as implementation science, which originated in the fields of medicine and public health (Bauer & Kirchner, 2020; Soicher et al., 2020). Doctors draw upon evidence-based strategies to improve the health of their patients, and classroom teachers are increasingly drawing upon retrieval practice research to improve the learning of their students. If the ultimate goal of science communication is to enhance decision making by practitioners, then as scientists, it's our responsibility to empirically investigate our own success.

Recommendations for Scientists Venturing into Science Communication

Drawing on a decade of experience in disseminating research, I offer five recommendations for scientists seeking to engage in science communication:

1. If you're hesitant to share your own work or research in progress, share the work from colleagues you admire, including their research, resources, and news and podcast interviews. This provides two benefits: you do not need to spend time creating original content, and the person whose work you are sharing will be appreciative (potentially increasing the likelihood that they will share your work in return).
2. Approach science communication like an experiment or pilot test: form a hypothesis, test out an approach, see what works, and adjust accordingly. Science communication can become time consuming, and there is no perfect design or procedure. While many people engage in science communication on social media, you do not need an active online presence or a large number of followers to influence teachers and students. Focus on an approach that is a better fit for you and your skills. For example, creating brief YouTube videos, practice guides, or infographics are all forms of science communication that may take less time with more impact when sharing evidence-based practices.
3. Aim to be credible *and* relatable. You can provide some basic graphs and research findings to demonstrate expertise, but make sure to include stories about challenges and solutions that you have personally encountered, too. Storytelling can feel uncomfortable—particularly for scientists—but keep in mind that people learn through stories. Relatable anecdotes and examples will increase the audience's interest and understanding of your research. In other words, share data so teachers believe you, but share a story so they care, too.
4. Get input and feedback from a friend or colleague who is not in your area of expertise. You may be surprised by how your language, tone, or explanations come across in a completely different way to someone else from what you intended. Like the peer-review process, receiving feedback is nerve wracking, but ultimately it strengthens how you communicate ideas that are important to you.
5. Contact a local school district or college and offer to give a virtual or in-person talk for teachers, students, and/or parents. Practitioners also appreciate concise informal interactions like Q&As (question and answer sessions), which can take

less preparation time than a formal presentation. With a brief presentation or a visit to a classroom, you can avoid adding burden on teachers or school leaders who are already overextended. In addition, sharing your expertise locally will help you build connections, while also refining your language and presentation skills.

To conclude, science communication can be deeply rewarding. Cognitive scientists have made great strides in the previous decade to share the science of learning in the form of books, videos, practice guides, newsletters, and blogs. In addition, educators are increasingly receptive to evidence-based teaching strategies, demonstrated by their engagement in written and online resources.

Looking forward to the next 10 years, I hope our fields pursue empirical examination of what works best when translating research to inform classroom practice. Additionally, in looking forward to the next 100 years, I am optimistic that retrieval practice will be common knowledge as a valuable learning strategy and that teachers will leverage it to increase student achievement. My hope is that, as scientists continue to develop an understanding of how learning works, they continue to share their knowledge with teachers and students, as well.

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Declarations

Conflict of Interest The author declares no competing interests.

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