Rozložené opakování a vybavování z paměti ve vzdělávání

March 31, 2026

Research Goal: Hledám přehled akademického výzkumu o rozloženém opakování a vybavování z paměti ve vzdělávání v běžné školní výuce napříč všemi stupni škol. Mým cílem je porozumět tomu, jak tyto přístupy ovlivňují dlouhodobé zapamatování, přenos učení a studijní výsledky. Prioritou je kauzální evidence o účincích, zejména experimentální studie a meta-analýzy. Jednou z hlavních os rešerše má být také srovnání prvků zavedení do výuky, zejména načasování, četnosti, zpětné vazby a podoby kvízů.

Found 115 papers · March 31, 2026

Topic Breakdown

Rozložené opakování a vybavování z paměti ve výuce: Kauzální evidence z běžné školní výuky napříč stupni a srovnání implementačních prvků (načasování, četnost, zpětná vazba, formát kvízů) pro dlouhodobé zapamatování, transfer a studijní výsledky

- *Meta-analýzy a systematické přehledy pro školní a vysokoškolské prostředí*
- *Rozložené opakování v reálných třídách a kurikulu (K-12 a podobné)*
- *Vybavování z paměti formou kvízů v běžné výuce a jeho kauzální dopady (K-12 a vysoká škola)*
- *Implementační volby ve výuce: načasování, četnost, rozmístění úloh, zpětná vazba a formát kvízů*
- *Dlouhodobé zapamatování, transfer a širší studijní výsledky: kdy a proč efekty přecházejí na nové úlohy*

Paper Catalog (115 papers)

	Year	Cit/yr	Title	Authors	Journal
1	2021	50	Testing (quizzing) boosts classroom learning: A systematic and meta-analytic review. (link)	Chunliang Yang, Liang Luo, M. Vadillo, Rongjun Yu, and D. Shanks	Psychological bulletin
2	2025	4.8	The Distributed Practice Effect on Classroom Learning: A Meta-Analytic Review of Applied Research (link)	Rhys D. Mawson and Sean H. K. Kang	Behavioral Sciences
3	2018	32	Transfer of Test-Enhanced Learning: Meta-Analytic Review and Synthesis (link)	Steven C. Pan and T. Rickard	Psychological Bulletin
4	2020	7.6	A Meta-Analytic Review of the Benefit of Spacing out Retrieval Practice Episodes on Retention (link)	Alice Latimier, H. Peyre, and F. Ramus	Educational Psychology Review

	Year	Cit/yr	Title	Authors	Journal
5	2019	22	Retrieval Practice Consistently Benefits Student Learning: a Systematic Review of Applied Research in Schools and Classrooms (link)	P. Agarwal, Ludmila D. Nunes, and Jane Blunt	Educational Psychology Review
6	2011	24	Test-Enhanced Learning in a Middle School Science Classroom: The Effects of Quiz Frequency and Placement. (link)	M. McDaniel, P. Agarwal, Barbie J. Huelser, K. McDermott, and H. Roediger	Journal of Educational Psychology
7	2011	26	Test-enhanced learning in the classroom: long-term improvements from quizzing. (link)	H. Roediger, P. Agarwal, M. McDaniel, and K. McDermott	Journal of experimental psychology. Applied
8	2014	15	Both multiple-choice and short-answer quizzes enhance later exam performance in middle and high school classes. (link)	K. McDermott, P. Agarwal, L. Dantonio, H. Roediger, and M. McDaniel	Journal of experimental psychology. Applied
9	2009	16	Using tests to enhance 8th grade students' retention of U.S. history facts (link)	Shana K. Carpenter, H. Pashler, and N. Cepeda	Applied Cognitive Psychology
10	2011	13	Spacing Effects in Real-World Classroom Vocabulary Learning (link)	H. Sobel, N. Cepeda, and Irina V. Kapler	Applied Cognitive Psychology
11	2007	18	The effect of type and timing of feedback on learning from multiple-choice tests. (link)	A. C. Butler, Jeffrey D. Karpicke, and H. Roediger	Journal of experimental psychology. Applied
12	2016	3.7	On the placement of practice questions during study. (link)	Y. Weinstein, Ludmila D. Nunes, and Jeffrey D. Karpicke	Journal of experimental psychology. Applied
13	2018	5.2	Distributing mathematical practice of third and seventh graders: Applicability of the spacing effect in the classroom (link)	Katharina Barzagar Nazari and M. Ebersbach	Applied Cognitive Psychology
14	2021	4.7	Spaced mathematics practice improves test scores and reduces overconfidence (link)	William Emeny, Marissa K Hartwig, and D. Rohrer	Applied Cognitive Psychology

	Year	Cit/yr	Title	Authors	Journal
15	2019	3.6	Putting evidence-based claims to the test: A multi-site classroom study of retrieval practice and spaced practice (link)	R. Gurung and K. Burns	Applied Cognitive Psychology
16	2023	0.8	A pilot randomized controlled trial comparing the effectiveness of different spaced learning models used during school examination revision: the SMART Spaces 24/10 model (link)	Liam O'Hare et al.	Frontiers in Education
17	2013	13	Quizzing in Middle-School Science: Successful Transfer Performance on Classroom Exams (link)	M. McDaniel, Ruthann C. Thomas, P. Agarwal, K. McDermott, and H. Roediger	Applied Cognitive Psychology
18	2014	76	The effect of testing versus restudy on retention: a meta-analytic review of the testing effect. (link)	Christopher A. Rowland	Psychological bulletin
19	2020	9.8	Regarding Class Quizzes: a Meta-analytic Synthesis of Studies on the Relationship Between Frequent Low-Stakes Testing and Class Performance (link)	Lukas K. Sotola and M. Credé	Educational Psychology Review
20	2017	48	Rethinking the Use of Tests: A Meta-Analysis of Practice Testing (link)	Olusola O. Adesope, Dominic A. Trevisan, and N. Sundararajan	Review of Educational Research
21	2006	83	Distributed practice in verbal recall tasks: A review and quantitative synthesis. (link)	N. Cepeda, H. Pashler, E. Vul, J. Wixted, and D. Rohrer	Psychological bulletin
22	2019	0.6	Retrieval practice can improve classroom review despite low practice test performance (link)	Jack M. I. Leggett, J. S. Burt, and A. Carroll	Applied Cognitive Psychology
23	1981	5.1	Effects of Massed and Distributed Practice on the Learning and Retention of Second-Language Vocabulary (link)	Kristine C. Bloom and T. Shuell	Journal of Educational Research

	Year	Cit/yr	Title	Authors	Journal
24	2019	22	Retrieval Practice & Bloom's Taxonomy: Do Students Need Fact Knowledge Before Higher Order Learning? (link)	P. Agarwal	Journal of Educational Psychology
25	2007	31	Testing the testing effect in the classroom (link)	M. McDaniel, Janis L. Anderson, Mary H. Derbish, and Nova Morrisette	European Journal of Cognitive Psychology
26	2009	17	Optimizing distributed practice: theoretical analysis and practical implications. (link)	N. Cepeda et al.	Experimental psychology
27	2022	31	The science of effective learning with spacing and retrieval practice (link)	Shana K. Carpenter, Steven C. Pan, and A. C. Butler	Nature Reviews Psychology
28	2019	9.6	Retrieval Practice in Classroom Settings: A Review of Applied Research (link)	Bruna Fernanda Tolentino Moreira, Tatiana Salazar Silva Pinto, D. Starling, and Antônio Jaeger	Frontiers in Education
29	2005	1.7	Distributed and massed practice: from laboratory to classroom (link)	Rachel Seabrook, G. D. Brown, and J. Solity	Applied Cognitive Psychology
30	2014	4.4	Spacing Simultaneously Promotes Multiple Forms of Learning in Children's Science Curriculum (link)	M. Gluckman, Haley A. Vlach, and Catherine M. Sandhofer	Applied Cognitive Psychology
31	2019	2.0	Judging credibility: Can spaced lessons help students think more critically online? (link)	Vanessa Foot-Seymour, J. Foot, and M. Wiseheart	Applied Cognitive Psychology
32	2014	5.3	The Effect of Retrieval Practice in Primary School Vocabulary Learning (link)	Nicole A. M. C. Goossens, Gino Camp, P. Verkoeijen, and H. Tabbers	Applied Cognitive Psychology
33	2025		A Meta-analytic Review of the Effectiveness of Spacing and Retrieval Practice for Mathematics Learning (link)	Ewan Murray, Aidan J. Horner, and Silke M. Göbel	Educational Psychology Review

	Year	Cit/yr	Title	Authors	Journal
34	2018	3.3	Testing Encourages Transfer Between Factual and Application Questions in an Online Learning Environment (link)	Ruthann C. Thomas, C. Weywadt, Janis L. Anderson, Brenda Martinez-Papponi, and M. McDaniel	Journal of Applied Research in Memory and Cognition
35	2010	3.6	The testing effect: The role of feedback and collaboration in a tertiary classroom setting (link)	Marija Vojdanoska, J. Cranney, and B. Newell	Applied Cognitive Psychology
36	2020	0.4	Improving retention by placing retrieval practice at the end of class: a naturalistic study (link)	Roberta Ekuni and S. Pompéia	Revista Latinoamericana De Psicologia
37	2018	0.5	Optimizing the Use of Interpolated Tests: The Influence of Interpolated Test Lag (link)	É. Lavigne and Evan F. Risko	Scholarship of Teaching and Learning in Psychology
38	2017	3.4	Timing of Quizzes During Learning: Effects on Motivation and Retention (link)	A. Healy, Matt Jones, L. A. Lalchandani, and Lindsay Anderson Tack	Journal of Experimental Psychology: Applied
39	1995	1.2	Distributed Versus Massed Practice in High School Physics (link)	Michael Grote	School Science and Mathematics
40	2015	0.2	On the Robustness of the Quizzing Effect under Real Teaching Conditions (link)	Tilmann Betsch, Nancy Quittenbaum, and Manfred Lüders	Zeitschrift Fur Padagogische Psychologie
41	2013		The Lag Effect in Secondary School Classrooms 1 (link)	Carolina E. Küpper-Tetzel, E. Erdfelder, and O. Dickhäuser	
42	2020	2.6	Implementing Distributed Practice in Statistics Courses: Benefits for Retention and Transfer (link)	M. Ebersbach and Katharina Barzagar Nazari	Journal of Applied Research in Memory and Cognition
43	2019		How the Amount and Spacing of Retrieval Practice Affect the Short- and Long-Term Retention of Mathematics Knowledge (link)	K. Lyle, Campbell R. Bego, Robin F. Hopkins, Jeffrey L. Hieb, and Patricia A. S. Ralston	Educational Psychology Review

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44	2022	3.8	Spaced Retrieval Practice Imposes Desirable Difficulty in Calculus Learning (link)	K. Lyle, Campbell R. Bego, Patricia A. S. Ralston, and J. Immekus	Educational Psychology Review
45	2023	4.6	Systematic review of distributed practice and retrieval practice in health professions education (link)	Emma Trumble, J. Lodge, A. Mandrusiak, and R. Forbes	Advances in Health Sciences Education
46	2010	16	Spacing and Testing Effects: A Deeply Critical, Lengthy, and At Times Discursive Review of the Literature (link	Peter F Delaney, P. Verkoeijen, and Arie S. Spirgel	Psychology of Learning and Motivation
47	2020	1.6	Should You Use Frequent Quizzing in Your College Course? Giving up 20 Minutes of Lecture Time May Pay Off (link)	A. Thomas, Amy M. Smith, Kanika Kamal, and Leamarie T. Gordon	Journal of applied research in memory and cognition
48	2016	1.3	The Testing Effect and Far Transfer: The Role of Exposure to Key Information (link)	Gerdien G. van Eersel, P. Verkoeijen, M. Povilenaite, and R. Rikers	Frontiers in Psychology
49	2022	0.5	Judging the credibility of websites: an effectiveness trial of the spacing effect in the elementary classroom (link)	Vanessa Foot-Seymour and M. Wiseheart	Cognitive Research: Principles and Implications
50	2019	1.8	Distributed Learning in the Classroom: Effects of Rereading Schedules Depend on Time of Test (link)	Carla E. Greving and Tobias Richter	Frontiers in Psychology
51	2020	1.2	Retrieval practice and retention of course content in a middle school science classroom (link)	T. Rowley and Matthew T. McCrudden	Applied Cognitive Psychology
52	2021	1.7	Adaptive Practice Quizzing in a University Lecture: A Pre-Registered Field Experiment (link)	Svenja Heitmann et al.	Journal of Applied Research in Memory and Cognition
53	2018	7.5	Examining the Testing Effect in University Teaching: Retrievability and Question Format Matter (link)	Sven Greving and Tobias Richter	Frontiers in Psychology

	Year	Cit/yr	Title	Authors	Journal
54	2020	3.1	Adaptive retrieval practice with multiple-choice questions in the university classroom (link)	Sven Greving, W. Lenhard, and Tobias Richter	J. Comput. Assist. Learn.
55	2014	7.2	Effectiveness of clickers: Effect of feedback and the timing of questions on learning (link)	Michael E. Lantz and Angela Stawiski	Comput. Hum. Behav.
56	2019	2.0	Optimizing the Spacing of Retrieval Practice to Improve Pharmacy Students' Learning of Drug Names (link)	James Terenyi, H. Anksorus, and A. Persky	American Journal of Pharmaceutical Education
57	2011	12	Retrieving Essential Material at the End of Lectures Improves Performance on Statistics Exams (link)	K. Lyle and N. Crawford	Teaching of Psychology
58	2012	4.4	A Controlled Study of Clicker-Assisted Memory Enhancement in College Classrooms (link)	A. Shapiro and Leamarie T. Gordon	Applied Cognitive Psychology
59	2021	9.8	A Meta-Analysis of Ten Learning Techniques (link)	Gregory M. Donoghue and J. Hattie	Frontiers in Education
60	2019	4.2	Enhancing the Quality of Student Learning Using Distributed Practice (link)	Melody Wiseheart Carolina E. et al.	The Cambridge Handbook of Cognition and Education
61	2015	9.1	The effect of distributed practice: Neuroscience, cognition, and education (link)	Emilie Gerbier and Thomas C. Toppino	Trends in Neuroscience and Education
62	1999	24	A meta-analytic review of the distribution of practice effect: Now you see it, now you don't. (link)	John J. Donovan and D. Radosevich	
63	2021	6.4	Interleaving Retrieval Practice Promotes Science Learning (link)	Faria Sana and Veronica X. Yan	Psychological Science
64	2019	2.6	The Forward Testing Effect is Reliable and Independent of Learners' Working Memory Capacity (link)	Bernhard Pastötter and C. Frings	Journal of Cognition
65	2018	1.7	The testing effect and analogical problem-solving (link)	Daniel Peterson and Kathryn T. Wissman	Memory

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66	2019	4.9	The forward effects of testing transfer to different domains of learning. (link)	Chunliang Yang, S. Chew, Bukuan Sun, and D. Shanks	Journal of Educational Psychology
67	2007	5.6	Examining the efficiency of schedules of distributed retrieval practice (link)	M. Pyc and Katherine A. Rawson	Memory & Cognition
68	2011	15	Spaced retrieval: absolute spacing enhances learning regardless of relative spacing. (link)	Jeffrey D. Karpicke and Althea Bauernschmidt	Journal of experimental psychology. Learning, memory, and cognition
69	2012	2.3	Effect of uniform versus expanding retrieval practice on the recall of physiology information. (link)	John L. Dobson	Advances in physiology education
70	2014	6.8	Retrieval practice over the long term: Should spacing be expanding or equal-interval? (link)	Sean H. K. Kang, Robert V. Lindsey, M. Mozer, and H. Pashler	Psychonomic Bulletin & Review
71	2016	5.6	A comparison of adaptive and fixed schedules of practice. (link)	Everett Mettler, Christine M. Massey, and P. Kellman	Journal of experimental psychology. General
72	2007	20	Expanding retrieval practice promotes short-term retention, but equally spaced retrieval enhances long-term retention. (link)	Jeffrey D. Karpicke and H. Roediger	Journal of experimental psychology. Learning, memory, and cognition
73	2013	3.0	Retrieval practice is an efficient method of enhancing the retention of anatomy and physiology information. (link)	John L. Dobson	Advances in physiology education
74	2016	11	Spaced Retrieval Practice Increases College Students' Short- and Long-Term Retention of Mathematics Knowledge (link)	Robin F. Hopkins, K. Lyle, Jeffrey L. Hieb, and P. Ralston	Educational Psychology Review
75	2013	5.0	Making long-term memories in minutes: a spaced learning pattern from memory research in education (link)	Paul Kelley and T. Whatson	Frontiers in Human Neuroscience
76	2019	2.5	Distributed practice in mathematics: Recommendable especially for students on a medium performance level? (link)	Katharina Barzagar Nazari and M. Ebersbach	Trends in neuroscience and education

	Year	Cit/yr	Title	Authors	Journal
77	2025		The impact of spaced learning within physics lessons in secondary schools (link)	Yuxi Zhou, R. Hartley, Alessio Bernardelli, and Andrew K Tolmie	PLOS One
78	2013	7.3	Strengthening concept learning by repeated testing (link)	Carola Wiklund-Hörnqvist, B. Jonsson, and L. Nyberg	Scandinavian Journal of Psychology
79	2014	3.2	Understanding the distributed practice effect : Strong effects on weak theoretical grounds (link)	Carolina E. Küpper-Tetzel	
80	1988	12	The spacing effect: A case study in the failure to apply the results of psychological research. (link)	Frank N. Dempster	American Psychologist
81	2017	3.2	Prequestions do not enhance the benefits of retrieval in a STEM classroom (link)	Jason Geller et al.	Cognitive Research: Principles and Implications
82	2017	3.4	Does Retrieval Practice Enhance Learning and Transfer Relative to Restudy for Term-Definition Facts? (link)	Steven C. Pan and T. Rickard	Journal of Experimental Psychology: Applied
83	2018	5.1	Input spacing and the learning of L2 vocabulary in a classroom context (link)	J. Rogers and Anisa Cheung	Language Teaching Research
84	2019	2.3	Applying spaced practice in the schools to teach math vocabulary (link)	Shawna Petersen-Brown et al.	Psychology in the Schools
85	2017	2.5	Spacing effects in vocabulary learning: Young EFL learners in focus (link)	A. Lotfolahi and Hadi Salehi	Cogent Education
86	2018	2.4	Distributed Practice: Rarely Realized in Self-Regulated Mathematical Learning (link)	Katharina Barzagar Nazari and M. Ebersbach	Frontiers in Psychology
87	2009	4.3	The testing effect, collaborative learning, and retrieval-induced facilitation in a classroom setting (link)	J. Cranney, Mi-ri Ahn, Rachel D McKinnon, Sue Morris, and K. Watts	European Journal of Cognitive Psychology

	Year	Cit/yr	Title	Authors	Journal
88	2012	13	Using quizzes to enhance summative-assessment performance in a web-based class: An experimental study (link)	M. McDaniel, Kathleen M. Wildman, and Janis L. Anderson	Journal of applied research in memory and cognition
89	1982	1.3	Testing Effects Measured with Alternate Test Forms (link)	P. Duchastel and R. Nungester	Journal of Educational Research
90	2024		The Learning Benefits of Mastery Quizzing Versus Other Quizzing Methods (link)	Lauren E. Bates, Sarah J. Myers, Edward L. Delosh, and Matthew G. Rhodes	Psychology Learning & Teaching
91	2020	0.3	Adaptive vs. Fixed Spacing of Learning Items: Evidence from Studies of Learning and Transfer in Chemistry Education (link)	Everett Mettler, Amina K. El-Ashmawy, Christine M. Massey, and P. Kellman	CogSci ... Annual Conference of the Cognitive Science Society. Cognitive Science Society (U.S.). Conference
92	2000	10	Untangling the benefits of multiple study opportunities and repeated testing for cued recall ([link](https://doi.org/10.1002/(SICI%291099-0720(200005/06%2914:3<215::AID-ACP640>3.0.CO;2-1))	W. Cull	Applied Cognitive Psychology
93	2003	4.6	Is temporal spacing of tests helpful even when it inflates error rates? (link)	H. Pashler, G. Zarow, and B. Triplett	Journal of experimental psychology. Learning, memory, and cognition
94	2013	4.5	Relearning attenuates the benefits and costs of spacing. (link)	Katherine A. Rawson and J. Dunlosky	Journal of experimental psychology. General
95	2014	4.0	Contracting, equal, and expanding learning schedules: The optimal distribution of learning sessions depends on retention interval (link)	Carolina E. Küpper-Tetzel, Irina V. Kapler, and M. Wiseheart	Memory & Cognition
96	2024	0.7	A grain of truth in the grain size effect: Retrieval practice is more effective when interspersed during learning. (link)	Hilary J. Don, Shaun Boustani, Chunliang Yang, and David R. Shanks	Journal of experimental psychology. Learning, memory, and cognition
97	2024	0.5	Retrieval Practice Improves Exam Performance as a Function of Review Question Number and Format (link)	Jason Pitt and Bethany Huebner	Journal of Physical Therapy Education

	Year	Cit/yr	Title	Authors	Journal
98	2018	2.3	Level of initial training moderates the effects of distributing practice over multiple days with expanding, contracting, and uniform schedules: Evidence for study-phase retrieval (link)	Thomas C. Toppino, H. Phelan, and Emilie Gerbier	Memory & Cognition
99	2015	11	EFFECTS OF EXPANDING AND EQUAL SPACING ON SECOND LANGUAGE VOCABULARY LEARNING (link)	T. Nakata	Studies in Second Language Acquisition
100	2022	2.6	Using Spacing to Promote Lasting Learning in Educational Contexts (link)	M. Ebersbach, A. Lachner, K. Scheiter, and Tobias Richter	Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie
101	2020	2.4	Distributed Practice or Spacing Effect (link)	Shana K. Carpenter	
102	2020		Distributed Practice or Spacing Effect-Oxford Research Encyclopedia of Education (link)	Shana K. Carpenter	
103	2015	7.4	TEACHER-READY RESEARCH REVIEW Practice Tests, Spaced Practice, and Successive Relearning: Tips for Classroom Use and for Guiding Students' Learning (link)	J. Dunlosky and Katherine A. Rawson	
104	1990	1.7	The Spacing Effect: Research and Practice. (link)	Frank N. Dempster and R. Farris	Journal of research and development in education
105	2022	2.6	Heterogeneity and Publication Bias in Research on Test-Potentiated New Learning (link)	Shaun Boustani and D. Shanks	Collabra: Psychology
106	2019		The role of retrieval type and feedback in test-potentiated new learning (link)	Mateja Pavlic, Denis Vlašiček, and D. Ivanec	Journal of applied research in memory and cognition
107	2014	7.6	Attempting to answer a meaningful question enhances subsequent learning even when feedback is delayed. (link)	Nate Kornell	Journal of experimental psychology. Learning, memory, and cognition
108	2006	14	The effects of overlearning and distributed practise on the retention of mathematics knowledge (link)	D. Rohrer and Kelli M. Taylor	Applied Cognitive Psychology

	Year	Cit/yr	Title	Authors	Journal
109	2018		Applying the Spacing Effect in the Classroom: The SMART Spaces program (link)	L. O'Hare	
110	2018	0.8	Distributed practice in classroom inquiry science learning (link)	Vanessa Svihla, M. Wester, and M. Linn	Learning: Research and Practice
111	2023	0.7	Applying distributed practice in the schools to enhance retention of spelling words (link)	Shawna Petersen-Brown, Abbey M. Riese, M. Schneider, Jannine E. Ray, and Hannah R. Clonkey	Psychology in the Schools
112	2012	0.1	Distributing Practice: Challenges and Opportunities for Inquiry Learning (link)	Vanessa Svihla and M. Linn	International Conference of the Learning Sciences
113	2010	0.1	Improving student learning through the use of classroom quizzes: Three years of evidence from the Columbia Middle School project. (link)	P. Agarwal, H. Roediger, M. McDaniel, and K. McDermott	Society for Research on Educational Effectiveness
114	2013	0.2	The effect of frequent quizzing on student learning in a high school physical science classroom (link)	C. B. Norton	
115	2017	2.1	Ecological validity of the testing effect : The use of daily quizzes in introductory (link)	A. Schwartz, C. Shane-Simpson, P. J. Brooks, and R. Obeid	

Paper Details

1. · 2021 · 50 cit/yr

Testing (quizzing) boosts classroom learning: A systematic and meta-analytic review. (link)

Chunliang Yang, Liang Luo, M. Vadillo, Rongjun Yu, and D. Shanks

Psychological bulletin · Mar 8, 2021 · 252 citations

> Over the last century hundreds of studies have demonstrated that testing is an effective intervention to enhance long-term retention of studied knowledge and facilitate mastery of new information, compared with restudying and many other learning strategies (e.g., concept mapping), a phenomenon termed the testing effect. How robust is this effect in applied settings beyond the laboratory? The current review integrated 48,478 students' data, extracted from 222 independent studies, to investigate the magnitude, boundary conditions, and psychological underpinnings of test-enhanced learning in the classroom. The results show that overall testing (quizzing) raises student academic achievement to a medium extent (g = 0.499). The magnitude of the effect is modulated by a variety of factors, including learning strategy in the control condition, test format consistency, material matching,

provision of corrective feedback, number of test repetitions, test administration location and timepoint, treatment duration, and experimental design. The documented findings support 3 theories to account for the classroom testing effect: additional exposure, transfer-appropriate processing, and motivation. In addition to their implications for theory development, these results have practical significance for enhancing teaching practice and guiding education policy and highlight important directions for future research. (PsycInfo Database Record (c) 2021 APA, all rights reserved).

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2. · 2025 · 4.8 cit/yr

The Distributed Practice Effect on Classroom Learning: A Meta-Analytic Review of Applied Research (link)

Rhys D. Mawson and Sean H. K. Kang

Behavioral Sciences · Jun 1, 2025 · 4 citations

There is extensive evidence that distributed practice produces superior learning to massed practice, predominantly from laboratory studies often featuring decontextualized learning. A systematic review of applied research was undertaken to assess the impact of distributed practice on classroom learning. Inclusion criteria were classroom studies with learning materials and timescales relevant to curriculum-based learning. The screening of over 3000 articles resulted in 22 reports containing 31 effect sizes (N > 3000). A meta-analysis found a moderate effect in favor of distributed over massed practice (d = 0.54, 95% CI [0.31, 0.77]). Although a comprehensive quantitative moderator analysis was not possible due to the number of studies, generally larger effect sizes were associated with studies that featured longer retention intervals, had learners at higher education levels, and had fewer re-exposures to the materials.

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3. · 2018 · 32 cit/yr

Transfer of Test-Enhanced Learning: Meta-Analytic Review and Synthesis (link)

Steven C. Pan and T. Rickard

Psychological Bulletin · May 7, 2018 · 256 citations

Attempting recall of information from memory, as occurs when taking a practice test, is one of the most potent training techniques known to learning science. However, does testing yield learning that transfers to different contexts? In the present article, we report the findings of the first comprehensive meta-analytic review into that question. Our review encompassed 192 transfer effect sizes extracted from 122 experiments and 67 published and unpublished articles (N = 10,382) that together comprise more than 40 years of research. A random-effects model revealed that testing can yield transferrable learning as measured relative to a nontesting reexposure control condition (d = 0.40, 95% CI [0.31, 0.50]). That transfer of learning is greatest across test formats, to application and inference questions, to problems involving medical diagnoses, and to mediator and related word cues; it is weakest to rearranged stimulus-response items, to untested materials seen during initial study, and to problems involving worked examples. Moderator analyses further indicated that response congruency and elaborated retrieval practice, as well as initial test performance, strongly influence the likelihood of positive transfer. In two assessments for publication bias using PET-PEESE and various selection methods, the

moderator effect sizes were minimally affected. However, the intercept predictions were substantially reduced, often indicating no positive transfer when none of the aforementioned moderators are present. Overall, our results motivate a three-factor framework for transfer of test-enhanced learning and have practical implications for the effective use of practice testing in educational and other training contexts.

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4. · 2020 · 7.6 cit/yr

A Meta-Analytic Review of the Benefit of Spacing out Retrieval Practice Episodes on Retention (link)

Alice Latimier, H. Peyre, and F. Ramus

Educational Psychology Review · Mar 5, 2020 · 46 citations

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5. · 2019 · 22 cit/yr

Retrieval Practice Consistently Benefits Student Learning: a Systematic Review of Applied Research in Schools and Classrooms (link)

P. Agarwal, Ludmila D. Nunes, and Jane Blunt

Educational Psychology Review · Oct 29, 2019 · 144 citations

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6. · 2011 · 24 cit/yr

Test-Enhanced Learning in a Middle School Science Classroom: The Effects of Quiz Frequency and Placement. (link)

M. McDaniel, P. Agarwal, Barbie J. Huelser, K. McDermott, and H. Roediger

Journal of Educational Psychology · May 1, 2011 · 359 citations

Typically, teachers use tests to evaluate students' knowledge acquisition. In a novel experimental study, we examined whether low-stakes testing (quizzing) can be used to foster students' learning of course content in 8th grade science classes. Students received multiple-choice quizzes (with feedback); in the quizzes, some target content that would be included on the class summative assessments was tested, and some of the target content was not tested. In Experiment 1, three quizzes on the content were spaced across the coverage of a unit. Quizzing produced significant learning benefits, with between 13% and 25% gains in performance on summative unit examinations. In Experiments 2a and 2b, we manipulated the placement of the quizzing, with students being quizzed on some content prior to the lecture, quizzed on some immediately after the lecture, and quizzed on some as a review prior to the unit exam. Review quizzing produced the greatest increases in exam performance, and these increases were only slightly augmented when the items had appeared on previous quizzes. The benefits of quizzing (relative to not quizzing) persisted on cumulative semester and end-of-year exams. We suggest that the present effects reflect benefits accruing to retrieval practice, benefits that are well established in the basic literature.

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7. · 2011 · 26 cit/yr

Test-enhanced learning in the classroom: long-term improvements from quizzing. (link)

H. Roediger, P. Agarwal, M. McDaniel, and K. McDermott
Journal of experimental psychology. Applied · Nov 14, 2011 · 374 citations

Three experiments examined whether quizzing promotes learning and retention of material from a social studies course with sixth grade students from a suburban middle school. The material used in the experiments was the course material students were to learn and some of the dependent measures were the actual tests on which students received grades. In within-subject designs, students received three low-stakes multiple-choice quizzes in Experiments 1 and 2 and performance on quizzed items was compared to that on items that were presented twice (Experiment 2) or items that were not presented on the initial quizzes (Experiments 1 and 2). We found that students' performance on both chapter exams and semester exams improved following quizzing relative to either not being quizzed or relative to the twice-presented items. In Experiment 3, students were given one multiple-choice quiz in class and encouraged to quiz themselves outside of class using a Web-based system. The assessment in this experiment was a short answer test in which students had to produce answers, but we also used multiple-choice tests. Once again, we found that quizzing of material produced a positive effect on chapter and semester exams. These results show the robustness of retrieval practice via testing as a learning mechanism in a classroom setting using the subject matter of the course and (in most cases) the tests on which students received grades as the dependent measures. Our results add to a growing body of evidence that retrieval practice in the classroom can boost academic performance.

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8. · 2014 · 15 cit/yr

Both multiple-choice and short-answer quizzes enhance later exam performance in middle and high school classes. (link)

K. McDermott, P. Agarwal, L. Dantonio, H. Roediger, and M. McDaniel
Journal of experimental psychology. Applied · Mar 1, 2014 · 182 citations

Practicing retrieval of recently studied information enhances the likelihood of the learner retrieving that information in the future. We examined whether short-answer and multiple-choice classroom quizzing could enhance retention of information on classroom exams taken for a grade. In seventh-grade science and high school history classes, students took intermittent quizzes (short-answer or multiple-choice, both with correct-answer feedback) on some information, whereas other information was not initially quizzed but received equivalent coverage in all other classroom activities. On the unit exams and on an end-of-semester exam, students performed better for information that had been quizzed than that not quizzed. An unanticipated and key finding is that the format of the quiz (multiple-choice or short-answer) did not need to match the format of the criterial test (e.g., unit exam) for this benefit to emerge. Further, intermittent quizzing cannot be attributed to intermittent reexposure to the target facts: A restudy condition produced less enhancement of later test performance than did quizzing with feedback. Frequent classroom quizzing with feedback improves student learning and retention, and multiple-choice quizzing is as effective as short-answer quizzing for this purpose.

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9. · 2009 · 16 cit/yr

Using tests to enhance 8th grade students' retention of U.S. history facts (link)

Shana K. Carpenter, H. Pashler, and N. Cepeda
Applied Cognitive Psychology · Sep 1, 2009 · 262 citations

Laboratory studies show that retention of information can be powerfully enhanced through testing, but evidence for their utility to promote long-term retention of course information is limited. We assessed 8th grade students' retention of U.S. history facts. Facts were reviewed after 1 week, 16 weeks or not reviewed at all. Some facts were reviewed by testing (Who assassinated president Abraham Lincoln?) followed by feedback (John Wilkes Booth), while others were re-studied. Nine months later, all students received a test covering all of the facts. Facts reviewed through testing were retained significantly better than facts reviewed through re-studying, and nearly twice as well as those given no review. The best retention occurred for facts that were reviewed by testing after a 16-week time interval. Although the gain in item was numerically small, due to floor effects, these results support the notion that testing can enhance long-term retention of course knowledge. Copyright © 2008 John Wiley & Sons, Ltd.

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10. · 2011 · 13 cit/yr

Spacing Effects in Real-World Classroom Vocabulary Learning (link)
H. Sobel, N. Cepeda, and Irina V. Kapler
Applied Cognitive Psychology · Sep 1, 2011 · 189 citations

Summary: As a primary goal, educators often strive to maximize the amount of information pupils remember. In the lab, psychologists havefoundefficient memory strategies forretainingschool-related materials.Onesuch strategyis thespacingeffect, a memory advantage that occurs when learning is distributed across time instead of crammed into a single study session. Spaced learning is not often explicitly utilized in actual classrooms, perhaps due to a paucity of research in applied settings and with school-aged children. The current study examined the spacing effect in real-world fifth-grade classrooms. We taught 39 children unfamiliar English words using both massed and spaced learning. Five weeks later, we tested vocabulary recall. One-week spacing produced superior long-term retention compared to massed learning. This finding demonstrates that the spacing effect can be generalized to vocabulary learning in applied settings and middle-school-aged children. Copyright # 2010 John Wiley & Sons, Ltd.

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11. · 2007 · 18 cit/yr

The effect of type and timing of feedback on learning from multiple-choice tests. (link)
A. C. Butler, Jeffrey D. Karpicke, and H. Roediger
Journal of experimental psychology. Applied · Dec 1, 2007 · 328 citations

Two experiments investigated how the type and timing of feedback influence learning from a multiple-choice test. First, participants read 12 prose passages, which covered various general knowledge topics (e.g., The Sun) and ranged between 280 and 300 words in length. Next, they took an initial six-alternative, multiple-choice test on information contained in the passages. Feedback was given immediately for some of the multiple-choice items or after delay for other items. Participants were either shown the correct answer as feedback (standard feedback) or were allowed to keep answering until the correct answer was discovered (answer-until-correct feedback). Learning from the test was

assessed on a delayed cued-recall test. The results indicated that delayed feedback led to superior final test performance relative to immediate feedback. However, type of feedback did not matter: discovering the correct answer through answer-until-correct feedback produced equivalent performance relative to standard feedback. This research suggests that delaying the presentation of feedback after a test is beneficial to learning because of the spaced presentation of information.

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12. · 2016 · 3.7 cit/yr

On the placement of practice questions during study. (link)

Y. Weinstein, Ludmila D. Nunes, and Jeffrey D. Karpicke

Journal of experimental psychology. Applied · Mar 1, 2016 · 37 citations

Retrieval practice improves retention of information on later tests. A question remains: When should retrieval occur during learning-interspersed throughout study or at the end of each study period? In a lab experiment, an online experiment, and a classroom study, we aimed to determine the ideal placement (interspersed vs. at-the-end) of retrieval practice questions. In the lab experiment, 64 subjects viewed slides about APA style and answered short-answer practice questions about the content or restudied the slides (restudy condition). The practice questions either appeared 1 every 1-2 slides (interspersed condition), or all at the end of the presentation (at-the-end condition). One week later, subjects returned and answered the same questions on a final test. In the online experiment, 175 subjects completed the same procedure. In the classroom study, 62 undergraduate students took quizzes as part of class lectures. Short-answer practice questions appeared either throughout the lectures (interspersed condition) or at the end of the lectures (at-the-end condition). Nineteen days after the last quiz, students were given a surprise final test. Results from the 3 experiments converge in demonstrating an advantage for interspersing practice questions on the initial tests, but an absence of this advantage on the final test.

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13. · 2018 · 5.2 cit/yr

Distributing mathematical practice of third and seventh graders: Applicability of the spacing effect in the classroom (link)

Katharina Barzagar Nazari and M. Ebersbach

Applied Cognitive Psychology · Nov 20, 2018 · 38 citations

Summary We examined the effect of distributed practice on the mathematical performance of third and seventh graders (N = 213) in school. Students first received an introduction to a mathematical topic, derived from their curriculum. Thereafter, they practiced in one of two conditions. In the massed condition, they worked on three practice sets in 1 day. In the distributed condition, they worked on one practice set per day for 3 consecutive days. Bayesian analyses of the performance in two follow - up tests 1 and 6 weeks after the last practice set revealed a positive effect of distributed practice as compared with massed practice in Grade 7. In Grade 3, a positive effect of distributed practice was supported by the data only in the test 1 week after the last practice set. The results suggest that distributed practice is a powerful learning tool for both elementary and secondary school students in the classroom.

14. · 2021 · 4.7 cit/yr

Spaced mathematics practice improves test scores and reduces overconfidence (link)

William Emeny, Marissa K Hartwig, and D. Rohrer

Applied Cognitive Psychology · Mar 9, 2021 · 24 citations

Correspondence Doug Rohrer, University of South Florida, Psychology PCD4118G, Tampa, Florida 33620. Email: drohrer@usf.edu Abstract The practice assignments in a mathematics textbook or course can be arranged so that most of the problems relating to any particular concept are massed together in a single assignment, or these related problems can be distributed across many assignments–a format known as spaced practice. Here we report the results of two classroom experiments that assessed the effects of mathematics spacing on both test scores and students' predictions of their test scores. In each experiment, students in Year 7 (11–12 years of age) either massed their practice into a single session or divided their practice across three sessions spaced 1 week apart, followed 1 month later by a test. In both experiments, spaced practice produced higher test scores than did massed practice, and test score predictions were relatively accurate after spaced practice yet grossly overconfident after massed practice.

15. · 2019 · 3.6 cit/yr

Putting evidence-based claims to the test: A multi-site classroom study of retrieval practice and spaced practice (link)

R. Gurung and K. Burns

Applied Cognitive Psychology · Sep 1, 2019 · 24 citations

16. · 2023 · 0.8 cit/yr

A pilot randomized controlled trial comparing the effectiveness of different spaced learning models used during school examination revision: the SMART Spaces 24/10 model (link)

Liam O'Hare et al.

Frontiers in Education · Sep 19, 2023 · 2 citations

The main aim of this pilot study was to compare the efficacy of using different spaced learning models during school examination revision on pupil attainment. Spaced learning is using intervals between periods of learning rather than learning content all at one time.Three spaced learning models with different inter-study intervals (ISI's) were co-designed by teachers and researchers using research evidence and practice knowledge. A pilot randomized controlled trial compared the three ISI models against control groups in 12 UK secondary schools' science classes (pupil n = 408). The effects on attainment of each model were assessed using pre and post-tests of science attainment.The results showed that all three models were feasible for use in a classroom. The spacing model using ISI of 24-h spaces between and 10-min spaces within revision sessions was the only significant one for improving attainment against a control group (effect size d = 0.19, p = <0.05). The study also found that student engagement with the spaced learning program was a statistically significant predictor of increased pupil attainment.The study demonstrates the potential benefits of applying spaced learning to exam revision, with the most optimal ISI model found to be the SMART Spaces 24/10 model.

17. · 2013 · 13 cit/yr

Quizzing in Middle-School Science: Successful Transfer Performance on Classroom Exams (link)

M. McDaniel, Ruthann C. Thomas, P. Agarwal, K. McDermott, and H. Roediger

Applied Cognitive Psychology · May 1, 2013 · 174 citations

Summary: We examined whether learning from quizzing arises from memorization of answers or fosters more complete understanding of the quizzed content. In middle-school science classes, we spaced three multiple-choice quizzes on content in a unit. In Experiment 1, the class exams included questions given on quizzes, transfer questions targeting the same content, and content that had not been quizzed (control content). The quizzing procedure was associated with significant learning benefits with large effect sizes and similar effect sizes for both transfer items and identical items. In Experiment 2, quiz questions focused on definitional information or application of the principle. Application questions increased exam performance for definitional-type questions and for different application questions. Definition questions did not confer benefits for application questions. Test-enhanced learning, inaddition toother factors inthe present quizzing protocol (repeated, spaced presentationofthe content), may createdeeper understanding that leads to certain types of transfer. Copyright © 2013 John Wiley & Sons, Ltd. The use of summative testing to evaluatestudents' acquisition, retention, and transfer of instructed material is a fundamental aspect of educational practice and theory. However, a substantial literature has established that testing is not a neutral event—the act of retrieving answers to questions during testing can also enhance and modify memory for the tested information (Carpenter & DeLosh, 2006; Hogan & Kintsch, 1971; McDaniel & Masson, 1985; see Roediger & Karpicke, 2006a, for a review). Such findings suggest that educators might exploit testing as a technique to promote learning, not

18. · 2014 · 76 cit/yr

The effect of testing versus restudy on retention: a meta-analytic review of the testing effect. (link)

Christopher A. Rowland

Psychological bulletin · 923 citations

Engaging in a test over previously studied information can serve as a potent learning event, a phenomenon referred to as the testing effect. Despite a surge of research in the past decade, existing theories have not yet provided a cohesive account of testing phenomena. The present study uses meta-analysis to examine the effects of testing versus restudy on retention. Key results indicate support for the role of effortful processing as a contributor to the testing effect, with initial recall tests yielding larger testing benefits than recognition tests. Limited support was found for existing theoretical accounts attributing the testing effect to enhanced semantic elaboration, indicating that consideration of alternative mechanisms is warranted in explaining testing effects. Future theoretical accounts of the testing effect may benefit from consideration of episodic and contextually derived contributions to retention resulting from memory retrieval. Additionally, the bifurcation model of the testing effect is considered as a viable framework from which to characterize the patterns of results present across the literature.

19. · 2020 · 9.8 cit/yr

Regarding Class Quizzes: a Meta-analytic Synthesis of Studies on the Relationship Between Frequent Low-Stakes Testing and Class Performance (link)

Lukas K. Sotola and M. Credé

Educational Psychology Review · Aug 14, 2020 · 55 citations

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20. · 2017 · 48 cit/yr

Rethinking the Use of Tests: A Meta-Analysis of Practice Testing (link)

Olusola O. Adesope, Dominic A. Trevisan, and N. Sundararajan

Review of Educational Research · Feb 1, 2017 · 439 citations

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21. · 2006 · 83 cit/yr

Distributed practice in verbal recall tasks: A review and quantitative synthesis. (link)

N. Cepeda, H. Pashler, E. Vul, J. Wixted, and D. Rohrer

Psychological bulletin · 1670 citations

The authors performed a meta-analysis of the distributed practice effect to illuminate the effects of temporal variables that have been neglected in previous reviews. This review found 839 assessments of distributed practice in 317 experiments located in 184 articles. Effects of spacing (consecutive massed presentations vs. spaced learning episodes) and lag (less spaced vs. more spaced learning episodes) were examined, as were expanding interstudy interval (ISI) effects. Analyses suggest that ISI and retention interval operate jointly to affect final-test retention; specifically, the ISI producing maximal retention increased as retention interval increased. Areas needing future research and theoretical implications are discussed.

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22. · 2019 · 0.6 cit/yr

Retrieval practice can improve classroom review despite low practice test performance (link)

Jack M. I. Leggett, J. S. Burt, and A. Carroll

Applied Cognitive Psychology · Sep 1, 2019 · 4 citations

Review is often more effective when it involves deliberate memory retrieval. However, this advantage may depend on a high rate of retrieval success; students who are less capable with the material may be better served by another activity. In our study, year 9 geography students listened to factual information, then reviewed some of it with a retrieval practice and feedback activity, some with a reading activity and left some unreviewed. We also manipulated the presence of hints during review—hints can affect the rate of retrieval success during practice and are relatively easy for teachers to provide. When tested 1 week later, most students showed a benefit of retrieval practice, even those who had performed poorly during review. There was also some evidence that hints improved learning when they made retrieval practice easier. Our findings suggest that retrieval practice, properly implemented, is advantageous for students of all ability levels.

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23. · 1981 · 5.1 cit/yr

Effects of Massed and Distributed Practice on the Learning and Retention of Second-Language Vocabulary (link)

Kristine C. Bloom and T. Shuell

Journal of Educational Research · Mar 1, 1981 · 229 citations

AbstractHigh school students enrolled in a French course learned vocabulary words under conditions of either massed or distributed practice as part of their regular class activities. Distributed practice consisted of three 10-minute units on each of three successive days; massed practice consisted of all three units being completed during a 30-minute period on a single day. Though performance of the two groups was virtually identical on a test given immediately after completion of study, the students who had learned the words by distributed practice did substantially better (35%) than the massed- practice students on a second test given 4 days later. The implications of the findings for classroom instruction and the need to distinguish between learning and memory are discussed.

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24. · 2019 · 22 cit/yr

Retrieval Practice & Bloom's Taxonomy: Do Students Need Fact Knowledge Before Higher Order Learning? (link)

P. Agarwal

Journal of Educational Psychology · Feb 1, 2019 · 155 citations

The development of students' higher order learning is a critical component of education. For decades, educators and scientists have engaged in an ongoing debate about whether higher order learning can only be enhanced by building a base of factual knowledge (analogous to Bloom's taxonomy) or whether higher order learning can be enhanced directly by engaging in complex questioning and materials. The relationship between fact learning and higher order learning is often speculated, but empirically unknown. In this study, middle school students and college students engaged in retrieval practice with fact questions, higher order questions, or a mix of question types to examine the optimal type of retrieval practice for enhancing higher order learning. In laboratory and K-12 settings, retrieval practice consistently increased delayed test performance, compared with rereading or no quizzes. Critically, higher order and mixed quizzes improved higher order test performance, but fact quizzes did not. Contrary to popular intuition about higher order learning and Bloom's taxonomy, building a foundation of knowledge via fact-based retrieval practice may be less potent than engaging in higher order retrieval practice, a key finding for future research and classroom application.

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25. · 2007 · 31 cit/yr

Testing the testing effect in the classroom (link)

M. McDaniel, Janis L. Anderson, Mary H. Derbish, and Nova Morrisette

European Journal of Cognitive Psychology · Jul 1, 2007 · 577 citations

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26. · 2009 · 17 cit/yr

Optimizing distributed practice: theoretical analysis and practical implications. (link)

N. Cepeda et al.
Experimental psychology · May 13, 2009 · 284 citations

More than a century of research shows that increasing the gap between study episodes using the same material can enhance retention, yet little is known about how this so-called distributed practice effect unfolds over nontrivial periods. In two three-session laboratory studies, we examined the effects of gap on retention of foreign vocabulary, facts, and names of visual objects, with test delays up to 6 months. An optimal gap improved final recall by up to 150%. Both studies demonstrated nonmonotonic gap effects: Increases in gap caused test accuracy to initially sharply increase and then gradually decline. These results provide new constraints on theories of spacing and confirm the importance of cumulative reviews to promote retention over meaningful time periods.

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27. · 2022 · 31 cit/yr
The science of effective learning with spacing and retrieval practice (link)
Shana K. Carpenter, Steven C. Pan, and A. C. Butler
Nature Reviews Psychology · Aug 2, 2022 · 115 citations

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28. · 2019 · 9.6 cit/yr
Retrieval Practice in Classroom Settings: A Review of Applied Research (link)
Bruna Fernanda Tolentino Moreira, Tatiana Salazar Silva Pinto, D. Starling, and Antônio Jaeger
Frontiers in Education · Feb 1, 2019 · 69 citations

Tests have been vastly used for the assessment of learning in educational contexts. Recently, however, a growing body of research have shown that the practice of remembering previously studied information (i.e., retrieval practice) is more advantageous for long-term retention than restudying that same information; a phenomenon often termed “testing effect”. The question remains, however, whether such practice can be useful to improve learning in actual educational contexts, and whether in these contexts specific types of tests are particularly beneficial. We address these issues by reviewing studies that investigated the use of retrieval practice as a learning strategy in actual educational contexts. The reviewed studies adopted from free-recall to multiple-choice tests, and involved from elementary school children to medical school students. In general, their results are favorable to the use of retrieval practice in classroom settings, regardless of whether feedback is provided or not. Importantly, however, the majority of the reviewed studies compared retrieval practice to repeated study or to “no-activity”. The results of the studies comparing retrieval practice to alternative control conditions were less conclusive, and a subset of them found no advantage for tests. These findings raise the question whether retrieval practice is more beneficial than alternative learning strategies, especially learning strategies and activities already adopted in classroom settings (e.g., concept mapping). Thus, even though retrieval practice emerges as a promising strategy to improve learning in classroom environments, there is not enough evidence available at this moment to determine whether it is as beneficial as alternative learning activities frequently adopted in classroom settings.

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29. · 2005 · 1.7 cit/yr
Distributed and massed practice: from laboratory to classroom (link)

Rachel Seabrook, G. D. Brown, and J. Solity
Applied Cognitive Psychology · 37 citations

The benefit to memory of spacing presentations of material is well established but lacks an adequate explanation and is rarely applied in education. This paper presents three experiments that examined the spacing effect and its application to education. Experiment 1 demonstrated that spacing repeated presentations of items is equally beneficial to memory for a wide range of ages, contrary to some theories. Experiment 2 introduced 'clustered' presentations as a more relevant control than massed, reflecting the fact that massed presentation of material is uncommon in education. The scheduling of clustered presentations was intermediate between massed and distributed, yet recall was no different than for massed. Experiment 3, a classroom-based study, demonstrated the benefit of distributed over clustered teaching of reading through modification of the scheduling of everyday lessons. Thus, the effectiveness of teaching may be improved by increasing the degree to which lessons are distributed.

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30. · 2014 · 4.4 cit/yr

Spacing Simultaneously Promotes Multiple Forms of Learning in Children's Science Curriculum (link)

M. Gluckman, Haley A. Vlach, and Catherine M. Sandhofer
Applied Cognitive Psychology · Mar 1, 2014 · 53 citations

Summary: The spacing effect refers to the robust finding that long-term memory is promoted when learning events are distributed in time rather than massed in immediate succession. The current study extended research on the spacing effect by examining whether spaced learning schedules can simultaneously promote multiple forms of learning, such as memory and generalization, in the context of an educational intervention. Thirty-six early elementary school-aged children were presented with science lessons on one of three schedules: massed, clumped, and spaced. At a 1-week delayed test, children in the spaced condition demonstrated improvements in both memory and generalization, significantly outperforming children in the other conditions. However, there was no observed relationship between children's memory performance and generalization performance. The current study highlights directions for future research and contributes to a growing body of work demonstrating the benefits of spaced learning for educational curriculum. A long history of research on human memory has sought to identify the conditions of the learning environment that promote the ability to retain information. A central finding from this work is that the timing of learning events may be central in supporting memory. The most robust and highly replicable observed timing phenomenon is often termed the 'spacing effect' (dating back to Ebbinghaus, 1885/1964). The current study sought to extend research on the spacing effect by (i) grounding our investigation in an educational intervention in order to further bridge psychological science and educational practices and (ii) examining if and how spaced learning schedules simultaneously support multiple forms of learning, such as memory and generalization, within the context of an educational intervention.

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31. · 2019 · 2.0 cit/yr

Judging credibility: Can spaced lessons help students think more critically online? (link)

Vanessa Foot-Seymour, J. Foot, and M. Wiseheart
Applied Cognitive Psychology · Nov 1, 2019 · 13 citations

wileyonlinelibrary.com/journal/acp 1032 Summary Despite the prevalence of the spacing effect in the psychological literature, the impact of lesson timing has not yet been fully explored in real classrooms. The current study examined whether spacing could improve long-term retention of both factual and critical thinking curriculum-based teaching materials for children. Students 9 to 12 years old were taught to judge the credibility of websites in either three consecutive days of lessons or one lesson per week. Thirty-five days after the final lesson, students were tested on factual knowledge and applied their knowledge to evaluating a new website. Students in the spaced condition remembered more facts from the lessons and were better able to explain their website ratings than students in the massed group.

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32. · 2014 · 5.3 cit/yr

The Effect of Retrieval Practice in Primary School Vocabulary Learning (link)
Nicole A. M. C. Goossens, Gino Camp, P. Verkoeijen, and H. Tabbers
Applied Cognitive Psychology · 65 citations

Summary The testing effect refers to the finding that retrieval practice leads to better long-term retention than additional study of course material. In the present study, we examined whether this finding generalizes to primary school vocabulary learning. We also manipulated the word learning context. Children were introduced to 20 words by listening to a story in which novel words were embedded (story condition) or by listening to isolated words (word pairs condition). The children practised the meaning of 10 words by retrieval practice and 10 words by restudy. After 1 week, they completed a cued recall test and a multiple choice test. Words learned by retrieval practice were recalled better than words learned by additional study, but there was no difference in recognition. Furthermore, the children in the word pairs condition outperformed the children in the story condition. These results show that retrieval practice may improve vocabulary learning in children. Copyright © 2013 John Wiley & Sons, Ltd.

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33. · 2025

A Meta-analytic Review of the Effectiveness of Spacing and Retrieval Practice for Mathematics Learning (link)
Ewan Murray, Aidan J. Horner, and Silke M. Göbel
Educational Psychology Review · Jul 29, 2025 · 0 citations

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34. · 2018 · 3.3 cit/yr

Testing Encourages Transfer Between Factual and Application Questions in an Online Learning Environment (link)
Ruthann C. Thomas, C. Weywadt, Janis L. Anderson, Brenda Martinez-Papponi, and M. McDaniel
Journal of Applied Research in Memory and Cognition · Jun 1, 2018 · 26 citations

Quizzing improves retention compared to additional study opportunities, a phenomenon known as test-enhanced learning. Two experiments investigated whether the type of question at quiz improves

retention for factual and applied course material on exams in an online college course. Students were given quizzes with either factual questions or questions designed to encourage application of a particular concept. As expected, quizzing with feedback improved exam performance compared to material that had not been quizzed. Further, the benefits of quizzing transferred to different question types. Performance on application exam questions improved if students were quizzed with factual questions. Likewise, performance on factual exam questions improved if students were quizzed with application questions. These results replicate the finding that quizzing benefits retention in an online learning environment and, more importantly, that the benefits of quizzing transfer to exam questions that differ in type from the quiz question.

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35. · 2010 · 3.6 cit/yr

The testing effect: The role of feedback and collaboration in a tertiary classroom setting (link)

Marija Vojdanoska, J. Cranney, and B. Newell

Applied Cognitive Psychology · Nov 1, 2010 · 56 citations

SUMMARY Successful retrieval on a test compared to just re-studying material improves long-term retention—a phenomenon called the 'testing effect'. This study investigated the role of feedback and collaborative testing on the retention of course material in a tertiary educational setting. Tested material was better retained relative to non-tested material (testing effect), and feedback facilitated correction of errors. Group testing produced higher performance on the initial, but not final test performance, compared to individual testing. This set of findings suggests that to encourage long-term retention, educators should utilise individual formative testing with feedback; theoretical implications are also discussed. Copyright # 2009 John Wiley & Sons, Ltd. The core purpose of education and training is the transfer of knowledge to students, such that this knowledge is retained in the long-term. Research has suggested that testing is one way to increase long-term retention, relative to re-studying material or not being tested (Glover, 1989; Spitzer, 1939). This phenomenon is called the 'testing effect'. One prominent theoretical explanation singles out the key role played by retrieval effort in accounting for the testing effect. Internal memorial processes, like retrieval, are proposed to be the direct effect of the testing procedure on memory, in contrast to indirect effects such as motivation for subsequent study (see Roediger & Karpicke, 2006a, for a review). Most of the research on the testing effect has been conducted in the laboratory. Formative testing with feedback, as well as group activities, is becoming more common in educational settings; however the effectiveness of these strategies, particularly in combination, has received little evaluative attention. The current study examines these issues in a tertiary educational context.

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36. · 2020 · 0.4 cit/yr

Improving retention by placing retrieval practice at the end of class: a naturalistic study (link)

Roberta Ekuni and S. Pompéia

Revista Latinoamericana De Psicologia · Jul 15, 2020 · 2 citations

Attempting to recall previously encountered information by being tested or quizzed (retrieval practice: RP) enhances memory. In real classrooms, however, it is unclear when testing should take place

(placement) in order to elicit better learning. We tested students using authentic undergraduate-course materials with two placements, followed by collective feedback: (a) at the end of the class in which content was taught; or (b) at the beginning of the next class. Re-teaching (RT) the same content through lecturer led-reviews at the same placements was used as a control condition. RP and RT plus feedback took 15 min of 100 min-long classes and were applied during 12 classes after which retention was assessed by exams. Participants were 114 students enrolled in a biweekly taught course. Testing (RP) once at the end of the same class in which content was taught boosted academic scores by around 10% compared to the other manipulations. Mejorando la retención al realizar la práctica de recuperación al final de la clase: un estudio naturalístico Resumen El intento de recordar la información presentada previamente mediante pruebas o cuestionarios (práctica de recuperación, RP) mejora la memoria. Sin embargo, en las clases reales no está claro en qué momento debe realizarse las pruebas para obtener un mejor aprendizaje. Probamos a los estudiantes utilizando materiales auténticos de cursos de licenciatura en dos momentos, seguidos de una retroalimentación colectiva: (a) al final de la clase en la que se enseñó el contenido; o (b) al principio de la siguiente clase. La reenseñanza (RT) del mismo contenido a través de revisiones dirigidas por el profesor en el mismo momento se utilizó como condición de control. La RP y la RT más la retroalimentación tomaron 15 minutos de clases de 100 minutos de duración y se aplicaron durante 12 clases después de las cuales la retención fue evaluada por exámenes. Los participantes fueron 114 estudiantes inscritos en un curso impartido cada dos semanas. Las pruebas (RP) realizadas una vez al final de la misma clase en la que el contenido se enseñó, aumentó los resultados académicos en alrededor de un 10% en comparación con las otras manipulaciones.

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37. · 2018 · 0.5 cit/yr

Optimizing the Use of Interpolated Tests: The Influence of Interpolated Test Lag (link)

É. Lavigne and Evan F. Risko

Scholarship of Teaching and Learning in Psychology · Dec 1, 2018 · 4 citations

The use of recorded lectures is increasing rapidly due to growth in online learning. One technique that can be used to improve learning from lectures is interpolated testing—the presentation of tests throughout a lecture. In the present investigation, we examine a critical question with respect to the implementation of interpolated testing. Where should the tests be located relative to the tested material? Specifically, we examine the influence of the lag between the presentation of the material in the lecture and the interpolated test. Across 2 experiments, we compare an immediate test condition (i.e., a test immediately after the relevant information is presented) and a delayed test condition (i.e., a test presented about 3 min after the relevant information is presented). When no feedback was provided, immediate interpolated testing was superior to delayed interpolated testing. There was no difference when feedback was provided. Implications of the present results for implementing interpolated testing in educational contexts are discussed.

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38. · 2017 · 3.4 cit/yr

Timing of Quizzes During Learning: Effects on Motivation and Retention (link)

A. Healy, Matt Jones, L. A. Lalchandani, and Lindsay Anderson Tack

Journal of Experimental Psychology: Applied · Mar 9, 2017 · 31 citations

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39. · 1995 · 1.2 cit/yr

Distributed Versus Massed Practice in High School Physics (link)

Michael Grote

School Science and Mathematics · Feb 1, 1995 · 38 citations

> An analysis of the effects of distributed practice in physics was undertaken. The subjects were 41 students, nearly equal numbers of males and females, in two suburban high school physics classes. All students were exposed to both massed and distributed practice on two different physics topics. The interaction of practice type with time and previous physics achievement were evaluated using a repeated measures MANOVA. A significant difference in achievement at the 0.01 level was found between the group which used distributed practice and the group which used massed practice in favor of distributed practice; the effect was stable with time, and the treatment was of benefit to both high and low achievers. The results suggest that using distributed practice in high school physics classrooms can lead to higher student achievement in physics.

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40. · 2015 · 0.2 cit/yr

On the Robustness of the Quizzing Effect under Real Teaching Conditions (link)

Tilmann Betsch, Nancy Quittenbaum, and Manfred Lüders

Zeitschrift Fur Padagogische Psychologie · May 21, 2015 · 2 citations

> Lab experiments and field studies showed that studying improves short-term memory, whereas active retrieval improves long-term memory – a phenomenon known as the quizzing (or testing) effect. In a quasi-experimental field study with four elementary school classes ($18 < n < 22$) and a pretest – posttest (5 min after the intervention) – posttest (6 weeks later) design, we tested the robustness of the quizzing effect under real conditions involving verbal teacher-student interactions in geometry lessons on symmetry in elementary schoolers. Results showed that re-studying compared to active retrieval (quizzing) enhanced learning more when measured directly after the lessons. This pattern revered when knowledge was measured six weeks later, demonstrating that the quizzing effect was robust. Moreover, long-term memory generally increased after six weeks. Limitations of the quasi-experimental approach are discussed.

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41. · 2013

The Lag Effect in Secondary School Classrooms 1 (link)

Carolina E. Küpper-Tetzel, E. Erdfelder, and O. Dickhäuser

0 citations

> Educators often face serious time constraints that impede multiple repetition lessons on the same material. Thus, it would be useful to know when to schedule a single repetition unit to maximize

memory performance. Laboratory studies revealed that the length of the retention interval (i.e., the time between the last learning session and the final memory test) dictates the optimal lag between two learning sessions. The present study tests the generalizability of this finding to vocabulary learning in secondary school. Sixth-graders were retaught EnglishGerman vocabulary after lags of 0, 1, or 10 days and tested 7 or 35 days later. In line with our predictions, we found that the optimal lag depends on the retention interval: Given a 7-day retention interval, students performed best when relearning occurred after 1 day. When vocabulary was tested after 35 days, however, students benefited from lags of both 1 and 10 days. Model-based analyses show that enhanced encoding processes and stronger resistance to forgetting – but not better retrieval processes – underlie the benefits of optimal lag. Our findings have practical implications for classroom instruction and suggest that review units should be planned carefully by taking the time of the final test into consideration.

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42. · 2020 · 2.6 cit/yr

Implementing Distributed Practice in Statistics Courses: Benefits for Retention and Transfer (link)

M. Ebersbach and Katharina Barzagar Nazari

Journal of Applied Research in Memory and Cognition · Nov 18, 2020 · 14 citations

The present study investigated the effect of distributed versus crammed practice before a course deadline on the retention and transfer of knowledge, and whether learner characteristics moderate the effect. In Experiment 1, only 41% (N = 38) of the initially enrolled students worked the voluntary but recommended practice tasks. Moreover, markedly fewer students did so in the distributed condition (12%) than the crammed practice condition (29%). In Experiment 2, working the practice tasks was mandatory and more students completed them (N = 105, i.e., 81%). Students who distributed practice clearly outperformed students who crammed practice on tests of knowledge retention and transfer five weeks after the practice deadline. No moderating effects of learner characteristics emerged. The study shows that distributed practice following knowledge acquisition is a powerful learning tool for fostering long-term retention and transfer with adults in authentic educational contexts.

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43. · 2019

How the Amount and Spacing of Retrieval Practice Affect the Short- and Long-Term Retention of Mathematics Knowledge (link)

K. Lyle, Campbell R. Bego, Robin F. Hopkins, Jeffrey L. Hieb, and Patricia A. S. Ralston

Educational Psychology Review · Jun 6, 2019 · 0 citations

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44. · 2022 · 3.8 cit/yr

Spaced Retrieval Practice Imposes Desirable Difficulty in Calculus Learning (link)

K. Lyle, Campbell R. Bego, Patricia A. S. Ralston, and J. Immekus

Educational Psychology Review · Apr 29, 2022 · 15 citations

After being taught how to perform a new mathematical operation, students are often given several practice problems in a single set, such as a homework assignment or quiz (i.e., massed practice). An

alternative approach is to distribute problems across multiple homeworks or quizzes, increasing the temporal interval between practice (i.e., spaced practice). Spaced practice has been shown to increase the long-term retention of various types of mathematics knowledge. Less clear is whether spacing decreases performance during practice, with some studies indicating that it does and others indicating it does not. To increase clarity, we tested whether spacing produces long-term retention gains, but short-term practice costs, in a calculus course. On practice quizzes, students worked problems on various learning objectives in either massed fashion (3 problems on a single quiz) or spaced fashion (3 problems across 3 quizzes). Spacing increased retention of learning objectives on an end-of-semester test but reduced performance on the practice quizzes. The reduction in practice performance was nuanced: Spacing reduced performance only on the first two quiz questions, leaving performance on the third question unaffected. We interpret these findings as evidence that spacing led to more protracted, but ultimately more robust, learning. We, therefore, conclude that spacing imposes a desirable form of difficulty in calculus learning.

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45. · 2023 · 4.6 cit/yr

Systematic review of distributed practice and retrieval practice in health professions education (link)

Emma Trumble, J. Lodge, A. Mandrusiak, and R. Forbes

Advances in Health Sciences Education · Aug 24, 2023 · 12 citations

To determine the effect of distributed practice (spacing out of study over time) and retrieval practice (recalling information from memory) on academic grades in health professions education and to summarise a range of interventional variables that may affect study outcomes. A systematic search of seven databases in November 2022 which were screened according to predefined inclusion criteria. The Medical Education Research Study Quality Instrument (MERSQI) and Newcastle-Ottawa Scale-Education (NOS-E) were used to critically appraise eligible articles. A summary of interventional variables includes article content type, strategy type, assessment type and delay and statistical significance. Of 1818 records retrieved, 56 were eligible for inclusion and included a total of 63 experiments. Of these studies, 43 demonstrated significant benefits of distributed practice and/or retrieval practice over control and comparison groups. Included studies averaged 12.23 out of 18 on the MERSQI and averaged 4.55 out of 6 on the NOS-E. Study designs were heterogeneous with a variety of interventions, comparison groups and assessment types. Distributed practice and retrieval practice are effective at improving academic grades in health professions education. Future study quality can be improved by validating the assessment instruments, to demonstrate the reliability of outcome measures. Increasing the number of institutions included in future studies may improve the diversity of represented study participants and may enhance study quality. Future studies should consider measuring and reporting time on task which may clarify the effectiveness of distributed practice and retrieval practice. The stakes of the assessments, which may affect student motivation and therefore outcomes, should also be considered.

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46. · 2010 · 16 cit/yr

Spacing and Testing Effects: A Deeply Critical, Lengthy, and At Times Discursive Review of the Literature (link

Peter F Delaney, P. Verkoeijen, and Arie S. Spirgel

Psychology of Learning and Motivation · 262 citations

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47. · 2020 · 1.6 cit/yr

Should You Use Frequent Quizzing in Your College Course? Giving up 20 Minutes of Lecture Time May Pay Off (link)

A. Thomas, Amy M. Smith, Kanika Kamal, and Leamarie T. Gordon

Journal of applied research in memory and cognition · Mar 1, 2020 · 10 citations

> This study examined whether frequent testing would promote long-term retention of college-level course material. Students in a college course engaged in three different types of interval practice over the course of a 13-week semester: quizzes, quizzes with feedback, and study. We examined the impact of type of interval practice on performance on unit exams. Six exams were given that consisted of multiple choice (MC) questions presented during earlier practice, new highly related MC questions, and new highly related short answer (SA) questions. The variation in type of unit exam questions allowed for the examination of interval quiz-related transfer to related MC and related SA questions. Further, half of the unit exams were taken individually and half were taken collaboratively. This manipulation allowed us to examine post-collaborative facilitation. Results suggest that interval quizzing resulted in beneficial transfer effects to highly related MC and SA questions and post collaborative facilitation.

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48. · 2016 · 1.3 cit/yr

The Testing Effect and Far Transfer: The Role of Exposure to Key Information (link)

Gerdien G. van Eersel, P. Verkoeijen, M. Povilenaite, and R. Rikers

Frontiers in Psychology · Dec 26, 2016 · 12 citations

> Butler (2010: Experiment 3) showed that retrieval practice enhanced transfer to a new knowledge domain compared to rereading. The first experiment of the present study was a direct replication of Butler's third experiment. Participants studied text passages and then either reread them three times or went through three cycles of cued recall questions (i.e., retrieval practice) with feedback. As in Butler's (2010) experiment, an advantage of retrieval practice on the final far transfer test emerged after 1 week. Additionally, we observed an advantage of retrieval practice on the final test administered after 5 min. However, these advantages might have been due to participants in the retrieval practice condition receiving focused exposure to the key information (i.e., the feedback) that was needed to answer the final test questions. We therefore conducted a second experiment in which we included the retrieval practice condition and the reread condition from our first experiment, as well as a new reread-plus-statements condition. In the reread-plus-statements condition, participants received focused exposure to the key information after they had reread a text. As in Experiment 1, we found a large effect on far transfer when retrieval practice was compared to rereading. However, this effect was substantially reduced when retrieval practice was compared to the reread-plus-statements condition. Taken together, the results of the present experiments demonstrate that Butler's (2010) testing effect in far transfer is

robust. Moreover, focused exposure to key information appears to be a significant factor in this far transfer testing effect.

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49. · 2022 · 0.5 cit/yr

Judging the credibility of websites: an effectiveness trial of the spacing effect in the elementary classroom (link)

Vanessa Foot-Seymour and M. Wiseheart

Cognitive Research: Principles and Implications · Jan 17, 2022 · 2 citations

Spaced learning—the spacing effect—is a cognitive phenomenon whereby memory for to-be-learned material is better when a fixed amount of study time is spread across multiple learning sessions instead of crammed into a more condensed time period. The spacing effect has been shown to be effective across a wide range of ages and learning materials, but few studies have been conducted that look at whether spacing can be effective in real-world classrooms, using real curriculum content, with real teachers leading the intervention. In the current study, lesson plans for teaching website credibility were distributed to homeroom elementary teachers with specific instructions on how to manipulate the timing of the lessons for either a one-per-day or one-per-week delivery. One month after the final lesson, students were asked to apply their knowledge on a final test, where they evaluated two new websites. Results were mixed, suggesting that classroom noise might lessen or impede researchers' ability to find spacing effects in naturalistic settings.

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50. · 2019 · 1.8 cit/yr

Distributed Learning in the Classroom: Effects of Rereading Schedules Depend on Time of Test (link)

Carla E. Greving and Tobias Richter

Frontiers in Psychology · Jan 9, 2019 · 13 citations

Research with adults in laboratory settings has shown that distributed rereading is a beneficial learning strategy but its effects depend on time of test. When learning outcomes are measured immediately after rereading, distributed rereading yields no benefits or even detrimental effects on learning, but the beneficial effects emerge two days later. In a preregistered experiment, the effects of distributed rereading were investigated in a classroom setting with school students. Seventh-graders (N = 191) reread a text either immediately or after 1 week. Learning outcomes were measured after 4 min or 1 week. Participants in the distributed rereading condition reread the text more slowly, predicted their learning success to be lower, and reported a lower on-task focus. At the shorter retention interval, massed rereading outperformed distributed rereading in terms of learning outcomes. Contrary to students in the massed condition, students in the distributed condition showed no forgetting from the short to the long retention interval. As a result, they performed equally well as the students in the massed condition at the longer retention interval. Our results indicate that distributed rereading makes learning more demanding and difficult and leads to higher effort during rereading. Its effects on learning depend on time of test, but no beneficial effects were found, not even at the delayed test.

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