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Retrieval Practice & Bloom's Taxonomy:

Do Students Need Fact Knowledge Before Higher Order Learning?

Pooja K. Agarwal

Washington University in St. Louis

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Correspondence concerning this article should be addressed to Pooja K. Agarwal, who is now at the Berklee College of Music: pooja@poojaagarwal.com, poojaagarwal.com.

Abstract

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 to 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.

Keywords: retrieval practice; Bloom's taxonomy; higher order learning; transfer; testing effect

Educational Impact and Implications Statement

This study demonstrates that students' higher order learning increases most from higher order retrieval practice, or no-stakes quizzes with complex materials that engage students in bringing what they know to mind. While fact quizzes were beneficial for fact learning, they did not facilitate higher order learning, contrary to popular intuition based on Bloom's taxonomy.

Retrieval Practice & Bloom's Taxonomy:

Do Students Need Fact Knowledge Before Higher Order Learning?

The development of students' higher order learning is a critical component of education. From both an educational perspective and a scientific perspective, it is of practical interest to develop robust strategies that increase higher order learning. For decades, educators and scientists have engaged in an ongoing debate about instructional approaches: Should we build students' foundation of factual knowledge *before* engaging them in higher order learning, or can higher order learning be enhanced *directly* by engaging students in complex instructional techniques during the initial learning process?

Regarding the first approach, many argue that in order to foster higher order learning, we must focus on and reinforce students' basic knowledge. For instance, cognitive scientist Daniel Willingham wrote, "Factual knowledge must precede skill" (2009, p. 163). Diane Ravitch (2015), an education professor and historian, argued,

We have neglected to teach [teachers] that one cannot think critically without quite a lot of knowledge to think about. Thinking critically involves comparing and contrasting and synthesizing what one has learned. And a great deal of knowledge is necessary before one can begin to reflect on its meaning and look for alternative explanations.

This view is not new; there has been a long standing call to spend a substantial amount of instructional time on foundational fact learning spanning more than 100 years (Bartlett, 1958; Bruner, 1977; Hirsch, 1996; James, 1900; Münsterberg, 1909).

On the other hand, many educators hold that less instructional time should be spent on fact learning and more time should be allotted for classroom activities that promote critical thinking, analysis, and inquiry (Cuban, 1984; Dewey, 1916/1944; Kohn, 1999). For example, education professor Jal Mehta (2018) recently argued,

What if, in science, we taught students the scientific method... by having them write junior versions of scientific papers rather than reading from textbooks? ... [W]hy in school, do we think it has to be dry basics first, and the interesting stuff only later?

According to the National Research Council (1987, p. 8),

[T]he term “higher order” skills is probably itself fundamentally misleading, for it suggests that another set of skills, presumably called “lower order,” needs to come first. This assumption... justifies long years of drill on the “basics” before thinking and problem solving are demanded.

Higher Order Learning & Bloom's Taxonomy

What, exactly, is “higher order” learning? While there are few agreed-upon definitions, higher order learning is frequently classified using *The Taxonomy of Educational Objectives* by Bloom, Engelhart, Furst, Hill, and Krathwohl (1956). The original “Bloom's taxonomy” included six categories of cognitive processes, ranging from simple to complex: *knowledge*, *comprehension*, *application*, *analysis*, *synthesis*, and *evaluation*. Bloom et al. explained that the taxonomy was designed as a step process: to achieve a higher objective or category, one must first master cognitive processes at a lower category. In other words, before comprehension, application, or analysis can take place, a student must first acquire knowledge.

In 2001, Anderson and co-authors of the original taxonomy proposed a revised taxonomy (see Figure 1). The revised taxonomy highlights learning in verb tense: *remember*, *understand* (previously called comprehension), *apply*, *analyze*, *evaluate*, and *create* (previously called synthesis and reordered with evaluation). Within the revised taxonomy, higher order learning is considered to comprise the *apply*, *analyze*, *evaluate*, and *create* categories. On the other hand, “lower order” learning requiring recognition, memory, and comprehension fall under the *remember* and *understand* categories.

Bloom's taxonomy has had a large impact on teacher preparation programs, classroom pedagogy, small and large-scale assessment programs, and educational research. Due in part to its simplicity, Bloom's taxonomy has contributed to the collective notion that foundational knowledge (literally the foundation or base of the pyramid) precedes higher order learning (the categories located higher in the pyramid). For example, educator Doug Lemov (2017) explained,

Generally when teachers talk about “Bloom's taxonomy,” they talk with disdain about “lower level” questions. They believe, perhaps because of the pyramid image which puts knowledge at the bottom, that knowledge-based questions, especially via recall and retrieval practice, are the least productive thing they could be doing in class. No one wants to be the rube at the bottom of the pyramid.

Lemov's comment perfectly illustrates the existing struggle to identify whether knowledge at the base of Bloom's taxonomy is a prerequisite for higher order learning, or simply a nuisance in the way of higher order learning.

In addition to Bloom's taxonomy, how else might we define or classify higher order learning? More recently, a taxonomy by Barnett and Ceci (2002) is being used to classify students' transfer of knowledge across a number of content and context domains, including physical location, type of task, and format. For example, students' "near transfer" along the content or knowledge domain may involve learning how to calculate the Pythagorean theorem and applying it using a novel set of numbers. In contrast, "far transfer" along the physical domain could include a medical student learning something from a textbook and then applying it in clinical practice with patients (Pan & Agarwal, 2018; Pan & Rickard, in press).

In terms of higher order learning, we are likely most interested in far transfer, which could occur across content and/or context domains. In addition, Barnett and Ceci (2002) briefly offered a distinction between horizontal and vertical transfer – where horizontal transfer involves two tasks at the same level of complexity and vertical transfer involves learning knowledge that is required for a wide array of tasks that differ in complexity (p. 622, footnote 8). They do not elaborate on the horizontal versus vertical distinction further, unfortunately, but a third domain of "cognitive complexity" may be crucial in identifying the type of higher order learning we seek in educational settings.

Retrieval Practice & Transfer of Knowledge

Based on decades of scientific research, we have identified robust strategies for enhancing students' fact learning and transfer of knowledge, including retrieval practice, spaced practice, and interleaving (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; McDaniel, Roediger, & McDermott, 2007; Pashler et al., 2007; Rohrer & Pashler,

2010). One strategy in particular – retrieval practice – dramatically improves long-term learning (Agarwal, Roediger, McDaniel, & McDermott, 2017; Roediger & Karpicke, 2006b). In typical experiments, students study a set of material (e.g., word pairs, foreign language vocabulary words, prose passages); engage in retrieval practice (e.g., via free recall or multiple-choice quizzes); and immediately or after a delay (e.g., ranging from hours, to days, to weeks), students complete a final test. When students engage in retrieval activities that bring knowledge to mind, learning is strengthened by the challenge (for recent meta-analyses, see Adesope, Trevisan, & Sundararajan, 2017; Rowland, 2014).

Specifically, recent research in classroom settings has demonstrated that retrieval practice improves learning for diverse student populations (e.g., middle school students to medical school students), subject areas (e.g., introductory history to CPR skills), and time delays (e.g., from a few days to 9 months; Kromann, Jensen, & Ringsted, 2009; Lyle & Crawford, 2011; Roediger, Agarwal, McDaniel, & McDermott, 2011). In addition, benefits from retrieval practice have been demonstrated in diverse educational settings, including K-12 classrooms (Agarwal, Bain, & Chamberlain, 2012), undergraduate engineering courses (Butler, Marsh, Slavinsky, & Baraniuk, 2014), and medical neurology courses (Larsen, Butler, Lawson, & Roediger, 2013).

Retrieval practice also promotes students' learning of complex materials (Karpicke & Aue, 2015; Jensen, McDaniel, Woodard, & Kummer, 2014; Pyc, Agarwal, & Roediger, 2014; Rawson, 2015; c.f., van Gog & Sweller, 2015). In one study examining the impact of retrieval practice on the learning of complex materials, subjects studied bird exemplar picture-family name pairs (e.g., a picture of a bird from the thrasher

family) in either a repeated study condition or a repeated quiz condition (Jacoby, Wahlheim, & Coane, 2010). In the repeated study condition, subjects viewed pictures of birds paired with their family names four times. For the quiz condition, subjects studied picture-family name pairs once, followed by three attempts to classify pictures for the eight bird families. On a final test, recognition and classification performance for picture exemplars was greater following repeated quizzes than restudying. The materials in this study were more complex than typical laboratory materials (e.g., word pairs, textbook passages), while the cognitive processes comprised the lowest two categories of Bloom's taxonomy: remember and understand.

Moving to complex cognitive processes, recent research provides compelling evidence that retrieval practice is an effective strategy to promote students' transfer of learning (Butler, Black-Maier, Raley, & Marsh, 2017; Carpenter, 2012; Karpicke & Blunt, 2011; Pan & Rickard, in press; Rohrer, Taylor, & Sholar, 2010). Butler (2010) examined students' transfer of knowledge across the content domain described by Barnett and Ceci (2002), using passages drawn from Wikipedia and similar online sources. Subjects read multiple passages and some were followed by repeated studying, while others were followed by repeated quizzing. On final tests, repeated quizzes led to greater fact and inferential learning, compared to repeated studying. Importantly, when subjects were given final test questions from a different knowledge domain (e.g., an initial quiz question about the wing structure of bats, in contrast with a final test question about the wing structure of military aircraft), repeated quizzes led to greater transfer performance than repeated studying. In other words, retrieval practice improved students' transfer of content knowledge from bats to airplanes and it also improved students' inferential

processing, moving closer toward what we think of as higher order learning in terms of both content and complexity.

In a real-world demonstration of the benefits of retrieval practice on transfer, McDaniel, Thomas, Agarwal, McDermott, and Roediger (2013, Experiment 2) conducted an experiment in an 8th grade Science classroom in which retrieval practice included fact and application questions (compared to no quizzing) and the final tests also included fact and application questions. Of interest was which type of retrieval practice would enhance final test performance two weeks later, particularly on final application questions. Retrieval practice significantly increased final test performance regardless of format, and the application quiz condition was most beneficial for application test performance. In other words, when it comes to promoting complex learning, such as students' application of knowledge, engaging in complex retrieval practice was more beneficial than starting with basic facts and definitions. This finding supports the notion that higher order learning can be enhanced directly by higher order retrieval practice, one of the first such demonstrations in an authentic classroom setting. The study by McDaniel et al. (2013) did not examine transfer across content or context domains; however, the materials in the study extended students' cognitive complexity from the remember category to the apply category – the next step higher in Bloom's taxonomy (see Figure 1).

Critically, how far “up the pyramid” can we move student learning, based on Bloom's taxonomy? Should we first build students' foundation of knowledge or can we skip straight ahead to complex retrieval practice during initial learning? The primary purpose of this study was to examine the intuition that “factual knowledge must precede

skill" (Willingham, 2009). By using complex passages, quizzes, and tests, I aimed to shed light on the relationship between fact learning and higher order learning – a critical distinction with practical and theoretical implications for research and instruction.

Theoretical Rationale

Three theoretical frameworks were utilized to explore the relationship between fact knowledge and complex higher order learning: the desirable difficulties framework, the transfer appropriate processing framework, and what I refer to as the "foundation of factual knowledge framework." Importantly, these theories are not mutually exclusive; rather, the three frameworks suggest both similar and different results depending on the experimental condition in the present study (see Table 1). By teasing apart these theoretical similarities and differences in the current study, optimal strategies to promote higher order learning can be developed and implemented in authentic educational settings.

Desirable Difficulties Framework. According to the desirable difficulties framework, mental processes that are challenging and effortful typically increase retention and application of knowledge (Bjork, 1994). Exposure to "desirable difficulties," particularly via retrieval activities, produces a struggle to bring information to mind that improves learning and delays forgetting. In addition to retrieval practice, a number of other strategies enhance learning to a greater extent than their less effortful comparisons, such as spaced practice instead of massed practice (Rohrer & Taylor, 2006) and interleaved practice instead of blocked practice (Kornell & Bjork, 2008; Taylor & Rohrer, 2010; see Dunlosky, et al., 2013 for a review).

Furthermore, difficult retrieval practice may benefit delayed test performance to a greater extent than easier retrieval practice (Bjork, 1994; Gardiner, Craik, & Bleasdale, 1973; Pyc & Rawson, 2009). For example, Kang, McDermott, and Roediger (2007) found that retrieval practice with short answer quizzes enhanced final test performance to a greater extent than retrieval practice with multiple-choice quizzes. Kang et al. concluded that short answer quizzes may engage deeper recollective processing and greater retrieval effort compared to multiple-choice quizzes, thereby enhancing performance on both final short answer and multiple-choice tests. These findings support the notion that retrieval practice with challenging questions (short answer or application) can benefit performance on less and more demanding criterial tests (both multiple-choice and short answer, or definition and application; c.f., McDermott, Agarwal, D'Antonio, Roediger, & McDaniel, 2014).

Regarding the present study, the desirable difficulties framework suggests that delayed test performance will be greater following retrieval practice compared to restudying or no quizzes, consistent with previous research (e.g., Agarwal, Karpicke, Kang, Roediger, & McDermott, 2008; Callender & McDaniel, 2009; Carrier & Pashler, 1992). Initial higher order quizzes may serve as a desirable difficulty, enhancing performance on both fact and higher order tests (Table 1). Meanwhile, mixed quizzes with both fact and higher order questions (in Experiments 2 and 3) may pose an additional challenge because the difficulty of questions varies within quizzes, leading to even greater benefits on final test performance than higher order quizzes.

Transfer Appropriate Processing. According to the transfer appropriate processing framework, final performance is greatest when encoding processes engaged

during learning match retrieval processes engaged during testing (McDaniel, Friedman, & Bourne, 1978; Morris, Bransford, & Franks, 1977). This framework is often cited as another explanation for why retrieval practice enhances long-term retention – by engaging in retrieval practice, students match their initial processing to the type of processing required at test (Roediger & Karpicke, 2006a).

In the classroom study described earlier, McDaniel et al. (2013) demonstrated that challenging application quizzes promoted learning for both basic definition and complex application tests. They also found results consistent with the transfer appropriate processing framework: Across two experiments, test performance was greatest when quiz questions matched the final test format, compared to no quizzes or a quiz-test mismatch. For example, student performance was greater on the application test following application quizzes instead of definition quizzes. Final test performance was greater following quizzes (compared to no quizzes), regardless of quiz-test question match.

Regarding the present study, the transfer appropriate processing framework suggests that delayed test performance will be optimal when initial quiz and final test formats match (Table 1). Specifically, retrieval practice with fact questions should benefit delayed fact performance, and retrieval practice with higher order questions should benefit delayed higher order performance (compared to no quizzes or restudying). Further, a match between quiz and test questions may promote performance to a greater extent than a mismatch (fact quiz-higher order test or higher order quiz-fact test).

Foundation of Factual Knowledge Framework. In accordance with the original Bloom's taxonomy, the "foundation of factual knowledge" framework suggests that we must focus on and reinforce basic factual knowledge before we can foster students' higher order learning (Brown, Roediger, & McDaniel, 2014). For instance, Willingham (2009) argued that when students practice facts until they are memorized, students can more easily apply their deeper knowledge to higher order learning. Retrieval practice of facts and procedures (e.g., applying the distributive property in algebra) may make recall automatic, thereby requiring less effort and capacity from working memory. Subsequently, this process may enable students to use additional working memory capacity in more complex learning situations (Agarwal, Finley, Rose, & Roediger, 2017). Consistent with these arguments, cognitive load theory posits that if cognitive demands are reduced or diminished, subsequent learning may increase (Plaas, Moreno, & Brünken, 2010; Sweller, 2010; van Gog & Sweller, 2015). As such, facilitation of fact learning via retrieval practice may reduce cognitive demands and enhance final higher order test performance, consistent with the foundation of factual knowledge framework. Mental effort ratings (Paas, 1992) were collected in the present study to elucidate this possibility.

Note that Willingham (2009) also distinguished between rote knowledge and integrated or connected knowledge, the latter of which may be required for higher order learning (see also Ausubel, 1961/1965; Ausubel, Novak, & Hanesian, 1978). For instance, knowing the basic fact that George Washington was the first president of the United States may not lead to a deeper understanding of United States civics or government. Willingham argued that, instead, the learning of connected knowledge

(e.g., presidents are leaders who make important decisions) can facilitate deep knowledge (e.g., if George Washington was the first president, he must have made many important decisions) in order to construct a rich understanding of a topic. In other words, simply learning isolated facts without connecting them to a deeper understanding of a topic may not benefit students' higher order learning.

To directly examine the foundation of factual knowledge framework, experiments included fact-based retrieval practice and delayed higher order tests. All fact questions in the present study were developed to encompass key concepts or ideas from passages (i.e., integrated knowledge, such as the goal of welfare programs), rather than details such as names, dates, vocabulary words, definitions, etc. (such as the year in which the Temporary Assistance for Needy Families program was initiated). In keeping with Willingham (2009) and the foundation of factual knowledge framework, if an understanding of integrated concepts is required for higher order learning, then delayed higher order test performance should benefit from integrated fact quizzes (Table 1). Note that this prediction contradicts the transfer appropriate processing framework, which suggests that the match between higher order quizzes and a delayed higher order test will result in greater test performance than the mismatch between fact quizzes and a delayed higher order test.

Introduction to Experiments

The relationship between fact learning and higher order learning is often speculated, but empirically unknown. To maximize learning while also experimentally manipulating cognitive complexity, I used a retrieval practice paradigm with educational materials that engaged students in lower order (e.g., remembering and understanding)

and higher order (e.g., analyzing, evaluating, and creating) cognitive processes (Figure 1). I also conducted a conceptual replication in an authentic K-12 classroom in which retrieval practice was embedded in students' and teachers' daily activities, fluctuating schedules, and standard lessons (Experiment 3). Across three experiments, if initial fact learning increases delayed higher order learning, findings will shed light on a long-standing theoretical and practical debate – how best to achieve the “holy grail” of the highest levels in Bloom's taxonomy.

Experiment 1

In Experiment 1, college students participated in four retrieval practice conditions: a study once condition, a study twice condition, study once followed by a fact quiz, and study once followed by a higher order quiz. After two days, students completed fact and higher order tests for each condition.

Method

Participants. Forty-eight college students (M age = 20.58 years, 29 females) were recruited from the Department of Psychology human subjects pool. Subjects received either credit towards completion of a research participation requirement or cash payment (\$25). Analyses were conducted only after data from 48 subjects were collected, a sample size determined at the outset of the study using a power analysis with an assumed effect size of $d = 0.5$.

Design. A 4 x 2 within-subject design was used, such that four retrieval practice conditions (study once, study twice, fact quiz, higher order quiz) were crossed with two delayed test types (fact test, higher order test). Eight passages, two per retrieval practice condition, were presented in the same order for all subjects, but the order in

which the conditions occurred was blocked by retrieval practice condition and counterbalanced using a Latin Square (see Appendix A). Retrieval practice conditions appeared once in every ordinal position and were crossed with the two types of final tests, creating eight counterbalancing orders. Six subjects were randomly assigned to each of the eight orders. After a two-day delay (i.e., 48 hours later), subjects completed one test type (a fact test or a higher order test) per passage, with tests presented in the same order in which passages were encountered during Session 1.

Materials. Eight passages were adapted from eight books included in the “Taking Sides” McGraw-Hill Contemporary Learning Series (<http://www.mhcls.com>; Daniel, 2006; Easton, 2006; Madaras & SoRelle, 1993; Moseley, 2007; Noll, 2001; Paul, 2002; Rourke, 1987). Each passage was approximately 1,000 words in length ($M = 1,006$ words, range = 990 to 1016 words), with half of each passage presenting one viewpoint of a controversial topic, and the remaining half of each passage presenting the opposite viewpoint (all passages are available upon request). For example, a passage entitled, “Does welfare do more harm than good?” was adapted from *Taking sides: Clashing views on controversial social issues* (Finsterbusch & McKenna, 1984), for which 500 words were drawn from the book to describe a “yes” argument and approximately 500 words were used to describe a “no” argument.

For Session 1, eight four-alternative multiple-choice fact questions and eight four-alternative multiple-choice higher order questions were developed for each passage (see Appendix B). For each question type, approximately four questions pertained to the “yes” argument and approximately four questions pertained to the “no” argument. For Session 2, all question stems were rephrased and multiple-choice alternatives were

randomly re-ordered, but alternatives were not rephrased. Across Session 1 and Session 2, regardless of counterbalancing order, the correct multiple-choice alternative appeared in every position (1, 2, 3, or 4) an equal number of times.

For fact questions, broad ideas stated in the passages were tested in order to measure subjects' overall understanding of the content. For example, a fact question from the "Does welfare do more harm than good?" passage included:

Which is the primary reason the "yes" author is against welfare programs?

- 1) Welfare programs don't benefit recipients or taxpayers
- 2) Welfare programs create dependence for recipients
- 3) Welfare programs are too expensive for taxpayers
- 4) Welfare programs are not the government's responsibility

The correct answer for this fact question is alternative #1 and the answer was stated directly in the passage. Critically, all fact questions in the present study were designed to encompass key concepts or ideas from passages, rather than details such as names, dates, vocabulary words, definitions, etc. (e.g., the definition of welfare).

Higher order questions were developed in accordance with the *apply*, *analyze*, *evaluate*, and *create* categories of Anderson et al.'s (2001) revised Bloom's taxonomy (see Figure 1). For *apply* questions, subjects were asked about a new situation or problem that was related to a broad idea that was stated in the passage. For example, an *apply* question from the welfare passage included:

What type of society would the "yes" author expect if there were no welfare programs in the future?

- 1) A society in which all individuals are self-reliant and independent

- 2) A society in which there would be no role for the government
- 3) A society in which no one would be required to pay taxes
- 4) A society in which all individuals are treated equally

The correct answer for this *apply* question is alternative #1 and it could be inferred from the passage, but it was not stated explicitly.

For *analyze* questions, subjects were asked to differentiate the authors' arguments; they were presented with a statement and asked which author (the "yes" author, the "no" author, both authors, or neither author) would agree or disagree with the statement. For example, an *analyze* question included:

Which author would agree with the following statement? "It is honorable for the government to help society."

- 1) The "yes" author
- 2) The "no" author
- 3) Both authors
- 4) Neither author

The correct answer for this *analyze* question is alternative #3.

For *evaluate* questions, subjects were asked to check or critique an author's argument by selecting a statement (which was not presented in the passage) that most accurately summarized the author's argument. For example, an *evaluate* question included:

Which statement is an accurate evaluation or summary of the "yes" author's views?

- 1) Welfare programs can never work, because they are always too expensive
- 2) Welfare programs are harmful, because they make bad situations even worse
- 3) Welfare programs waste taxpayer money on people who don't really need help
- 4) Welfare programs could work, but they rarely meet the needs of the people

The correct answer for this *evaluate* question is alternative #4.

Lastly, for *create* questions, subjects were asked to plan or predict an outcome for a novel situation that was not stated in the passage; thus, the author's potential reaction must be generated based on information presented in the passage. For example, a *create* question included:

How do you predict the "yes" author would react if he or she became unemployed and needed welfare assistance?

- 1) The "yes" author might accept government assistance, but would seek help from local organizations first
- 2) The "yes" author would not accept government assistance, but would try to find a new job
- 3) The "yes" author might accept government assistance, but would try to find a new job first
- 4) The "yes" author would not accept government assistance, but would seek help from local organizations

The correct answer for this *create* question is alternative #2. All reading passages and questions developed are available upon request (see Appendix B for sample questions).

Procedure. Subjects were tested in small groups (up to five people) using E-Prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2007). At the beginning of Session 1, subjects were instructed that they would be reading passages and taking multiple-choice tests. Subjects were presented with a sample passage about the Nicaraguan Contras, drawn from the same book series as experimental materials, for 20 seconds. They were instructed to familiarize themselves with the computer program's scrolling feature (viewing the entire passage using the up and down keys on the keyboard) without worrying about reading the passage. Next, subjects were presented with a practice test of two 4-alternative multiple-choice questions (self-paced) that asked subjects whether they turned off their cell phone and whether they could return in two days; in other words, subjects did not receive sample test questions related to the sample passage. After responding to the two practice questions, subjects were asked to make a mental effort rating on a nine-point scale (adapted from Paas, 1992), which was followed by 10 seconds of feedback, in order to acclimate subjects to the experimental procedure.

After the instruction phase during Session 1, subjects completed two blocks: First, subjects read all eight passages, presented in the same order for all subjects. Second, subjects completed four within-subject conditions (two per passage), blocked by retrieval practice condition (see Appendix A). In other words during the second block, subjects did not re-encounter two of the passages (in the study once condition), they read two of the passages for a second time (in the study twice condition), they

completed quizzes with fact questions for two of the passages and they completed quizzes with higher order questions for the remaining two passages.

During six-minute study periods, each passage was presented in its entirety on the computer screen and subjects were able to scroll up and down in order to read the complete text at their own pace. Subjects were asked to study the passage during the time allotted and after six minutes, the computer moved on to the next passage (during the first reading block) or to the appropriate condition (during the second condition block following the restudy condition). Subjects' keyboard presses were recorded during study periods to ensure that all subjects scrolled appropriately through the passages from the top of the passage to the bottom.

During self-paced initial quiz periods, multiple-choice questions (blocked by passage) were presented one at a time, in a different random order for each subject. Subjects were asked to type a number (1, 2, 3, or 4) corresponding to the multiple-choice alternative (forced choice). As soon as subjects responded to each question, the computer moved on (i.e., subjects were not allowed to change their answer) and subjects were asked to estimate the mental effort required ("How much mental effort did you invest in this question") on a 9-point scale (adapted from Paas, 1992) by typing a number corresponding to the rating. After subjects rated their mental effort, the computer presented immediate feedback for 10 seconds by displaying the word "CORRECT" or "INCORRECT" corresponding to subjects' response, while also displaying the original question and the correct answer (without incorrect multiple-choice lures). After 10 seconds, the computer moved on to the next question. In other words, multiple-choice question responses were self-paced, whereas feedback was

experimenter-controlled and presented for 10 seconds per item. In summary, subjects completed a question, provided a mental effort rating, and then viewed feedback, followed by the next question. After each passage and quiz (regardless of condition), subjects received a 15 second break, during which the computer screen displayed, "Please clear your mind and wait for the computer to move on." Then, the computer moved on to the next passage or condition, according to subjects' counterbalancing order.

After two days, subjects returned for Session 2 and completed multiple-choice fact tests for four of the passages and multiple-choice higher order tests for the other four passages. Testing procedures outlined above for Session 1 were followed during Session 2, except subjects did not receive feedback during Session 2.

In sum, subjects participated in four within-subject retrieval practice conditions, crossed with two delayed test types. Dependent variables measured included accuracy on test questions, response times for test questions, mental effort ratings for test questions, and response times for mental effort ratings. The entire procedure lasted approximately two and a half hours across the two sessions. At the end of the experiment, subjects were debriefed and thanked for their time.

Results

All results in the current study were significant at an alpha level of .05. A Greenhouse-Geisser correction was applied to analyses of variance (ANOVAs) when the sphericity assumption was violated (Greenhouse & Geisser, 1959) and a Bonferroni correction for multiple comparisons was applied to p values from t -tests by multiplying the p value by the number of comparisons (Rice, 1989). Effect sizes reported include

partial eta-squared (η_p^2) for ANOVAs (Pearson, 1911; Pierce, Block, & Aguinis, 2004) and Cohen's d for t -tests (Cohen, 1988). Error bars in figures represent 95% confidence intervals, specifically calculated for within-subject designs according to methods described by Cousineau (2005) and Morey (2008). Data from response times and mental effort ratings did not contribute to the overall findings from the present study, as discussed in the General Discussion. Thus, these data are not reported and are available upon request.

Initial quiz performance. Initial performance on the fact quiz and the higher order quiz is displayed in Table 2. As predicted, initial performance was greater on the fact quiz (59%) compared to performance on the higher order quiz (47%), likely due to item difficulty, confirmed by a one-way ANOVA on initial performance, $F(1, 47) = 12.62$, $p = .001$, $\eta_p^2 = .21$.

Final test performance. Final test performance on rephrased questions for the four retrieval practice conditions is displayed in Table 2 and Figure 2. Reliability (Cronbach's alpha) was .501 for final fact test performance and .467 for final higher order performance. When collapsed over final test type, delayed test performance was lower for the study once (49%) and study twice (51%) conditions, and greater for the fact quiz (62%) and higher order quiz (62%) conditions. When collapsed over initial learning condition, overall performance on the final fact test was greater (60%) than performance on the final higher order test (53%), likely due to item difficulty. A 4 (retrieval practice condition: study once, study twice, fact quiz, higher order quiz) x 2 (delayed test type: fact, higher order) repeated measures ANOVA on delayed test performance indicated a main effect of retrieval practice condition, $F(3, 141) = 13.47$, p

$< .001$, $\eta_p^2 = .22$, a main effect of delayed test type, $F(1, 47) = 12.47$, $p = .001$, $\eta_p^2 = .21$, and a significant interaction between retrieval practice condition and test type, $F(3, 141) = 27.39$, $p < .001$, $\eta_p^2 = .37$.

Regarding delayed performance on the fact test, post-hoc t -tests confirmed a significant effect of retrieval practice, such that final fact test performance for the fact quiz condition (78%) was significantly greater than final fact test performance for the study once (54%) and study twice (54%) conditions, $t(47) = 5.96$, $p < .001$, $d = 1.23$ and $t(47) = 6.63$, $p < .001$, $d = 1.24$, respectively. However, final fact test performance was similar for the higher order quiz condition (53%) compared to the study once and study twice conditions, $ts < 1$, indicating that retrieval practice with higher order questions did not benefit final fact test performance. In other words, an initial fact quiz improved final fact test performance (78%) to a much greater degree than an initial higher order quiz (53%), $t(47) = 6.93$, $p < .001$, $d = 1.29$. There was no effect of restudying when comparing final fact test performance for the study once and study twice conditions, $t < 1$.

Regarding delayed performance on the higher order test, post-hoc t -tests also confirmed a significant effect of retrieval practice, such that final higher order test performance for the higher order quiz condition (72%) was significantly greater than final higher order test performance for the study once (44%) and study twice (49%) conditions, $t(47) = 8.17$, $p < .001$, $d = 1.39$ and $t(47) = 5.31$, $p < .001$, $d = 1.12$, respectively. However, final higher order test performance was similar for the fact quiz condition (46%) compared to the study once and study twice conditions, $ts < 1$, indicating that retrieval practice with fact questions did not benefit final higher order test

performance. In other words, an initial higher order quiz improved final higher order test performance (72%) to a much greater degree than an initial fact quiz (46%), $t(47) = 6.73$, $p < .001$, $d = 1.21$. Again, there was no effect of restudying on final higher order test performance when comparing the study once and study twice conditions, $t(47) = 1.40$, $p > .05$.

In sum, initial retrieval practice enhanced final test performance, but only when the initial quiz type (fact or higher order) matched the final test type (fact or higher order, respectively). For these congruent conditions, performance was marginally greater for the fact quiz-fact test condition (78%) than for the higher order quiz-higher order test condition (72%), $t(47) = 1.94$, $p = .059$, $d = 0.32$, though this difference may be due to relative difficulty between fact versus higher order test questions.

Discussion

In Experiment 1, retrieval practice with higher order questions greatly improved delayed higher order test performance by 23-28% (compared to studying once or twice, Figure 2). Consistent with prior research, retrieval practice with fact questions also improved delayed fact performance by 24%. When the type of initial quizzes matched the type of final test, even when final test questions were rephrased, retrieval practice yielded comparable benefits on performance for both fact and higher order learning. Thus, results from Experiment 1 are consistent with predictions based on the transfer appropriate processing framework (Table 1).

Critically, retrieval practice with fact questions did not enhance delayed higher order test performance, contrary to the foundation of factual knowledge framework. In addition, retrieval practice with higher order questions did not enhanced delayed fact

test performance, contrary to the desirable difficulty framework. There were no benefits from restudying on delayed test performance, even when the first and second study periods were spaced over time, replicating previous findings (Agarwal et al., 2008; Callender & McDaniel, 2009; Carrier & Pashler, 1992; Karpicke & Roediger, 2007; Roediger & Karpicke, 2006b; Wheeler, Ewers, & Buonanno, 2003).

In sum, there were no benefits of initial fact quizzes on delayed higher order test performance, no benefits of initial higher order quizzes on delayed fact test performance, and no benefit of restudying on delayed test performance, regardless of test type. Of the three theoretical frameworks, results from Experiment 1 most closely align with the transfer appropriate processing framework.

Experiment 2

Experiment 2 was designed to examine whether a mix of both fact and higher order question types used during retrieval practice would be more beneficial for enhancing delayed test performance than using one type of question during initial retrieval practice. Considering the results from Experiment 1 where fact quizzes did not enhance delayed higher order test performance and higher order quizzes did not enhance delayed fact test performance, retrieval practice with both types of questions during initial learning may benefit delayed test performance, regardless of test type.

When receiving a fact quiz and a higher order quiz in close succession during the first session (i.e., in a mixed condition), students may be more likely to activate elaborative information (Carpenter, 2009), create more robust mediators or connections between concepts (Pyc & Rawson, 2010), and subsequently transfer knowledge from initial learning to a delayed higher order test. In addition, providing students with

prompts or hints to transfer their knowledge to novel situations enhances their subsequent transfer performance (Gick and Holyoak, 1980), thus a mixed quiz condition may prompt students to transfer their knowledge during initial learning and also on delayed tests (see also Butler et al., 2017; Pan & Rickard, in press). From an instructional standpoint, recent depictions of Bloom's taxonomy in the shape of a wheel or web eliminate the typical hierarchical structure in favor of an integrated approach (see Knapp, 2016, for examples). Thus, mixed complexity during initial learning may serve as an effective alternative to the prevalent "factual knowledge first" standpoint.

In Experiment 2, subjects participated in four retrieval practice conditions, each after studying a passage once: they completed one higher order quiz, two higher order quizzes, two fact quizzes, and two mixed quizzes. After two days, subjects completed fact and higher order tests for each condition. In Experiment 1, no-quiz and restudy conditions did not improve final test performance. Thus, these conditions were not included in Experiment 2. Instead, the comparisons of interest in Experiment 2 were the optimal combination of quizzes for improving delayed fact and higher order learning – namely, two fact quizzes, two higher order quizzes, or a mix of quizzes.

Given the results from Experiment 1, it was expected that the higher order quiz (once or 1X) and higher order quiz (twice or 2X) conditions would benefit delayed higher order test performance, and that the fact quiz (twice or 2X) condition would benefit delayed fact test performance. Regarding one quiz versus two quizzes, it was predicted that two higher order quizzes would provide an additional benefit to delayed higher order test performance compared to one higher order quiz. On the other hand, this additional benefit may be due to re-exposure to the same item twice; i.e., question

stems were only rephrased between the initial and final sessions, not between the first and second initial quizzes.

Regarding the mixed quiz condition (2X, with one fact and one higher order quiz), it may be the case that including both question types provides students with “the best of both worlds” – the mixed quiz condition could enhance delayed performance on both types of tests compared to the non-mixed retrieval practice conditions (Table 1). In line with the transfer appropriate processing framework, engaging in both types of processing during initial learning may have the greatest overlap in processing required for the two final test types, enhancing delayed performance. At the same time, one quiz of each format (in the mixed quiz condition) may not prove as potent as two quizzes of the same format; therefore, it was unclear whether the mixed quiz (2X) condition would provide a smaller or larger benefit to delayed test performance compared to the fact (2X) and higher order (2X) quiz conditions.

Method

Participants. Forty-eight college students (M age = 20.04 years, 31 females) were recruited from the Department of Psychology human subjects pool. Subjects received either credit towards completion of a research participation requirement or cash payment (\$25). Subjects who participated in Experiment 2 did not participate in Experiment 1. Analyses were conducted only after data from 48 subjects were collected, a sample size determined at the outset of the study using a power analysis with an assumed effect size of $d = 0.5$.

Design. A 4 x 2 within-subject design was used, such that four retrieval practice conditions [higher order quiz (1X), higher order quizzes (2X), fact quizzes (2X), mixed

quizzes (2X)] were crossed with two delayed test types (fact test, higher order test). Eight passages, two per retrieval practice condition, were presented in the same order for all subjects. The order in which the conditions occurred was blocked by retrieval practice condition and counterbalanced using a Latin Square (see Appendix A). Retrieval practice conditions appeared once in every ordinal position and were crossed with the two types of final tests, creating eight counterbalancing orders. Six subjects were randomly assigned to each of the eight orders. Specifically for the mixed quiz (2X) condition, subjects completed a fact quiz followed by a higher order quiz, or they completed a higher order quiz followed by a fact quiz. Order of quizzes in the mixed quiz condition was counterbalanced equally across subjects (see Appendix A).

After a two-day delay (i.e., 48 hours later), subjects completed one test type (a fact test or a higher order test) per passage. Tests were presented in the same order in which passages were encountered during Session 1.

Materials. The same materials from Experiment 1 were used in Experiment 2 (see Appendix B for sample questions).

Procedure. The same procedures used in Experiment 1 were used in Experiment 2, except that subjects completed three blocks during Session 1: First, subjects read all eight passages, presented in the same order for all subjects. Second, subjects completed the first quiz block with eight quizzes (one quiz per passage, presented in the same order as passages during the reading block). Third, subjects completed a second quiz block with six quizzes [one quiz per passage, except for passages in the higher order quiz (1X) condition, again presented in the same order]. After two days, subjects returned for Session 2 and completed multiple-choice fact tests

for four of the passages and multiple-choice higher order tests for the other four passages.

In sum, subjects participated in four within-subject retrieval practice conditions, crossed with two delayed test types. Dependent variables measured included accuracy on test questions, response times for test questions, mental effort ratings for test questions, and response times for mental effort ratings. The entire procedure lasted approximately two and a half hours across the two sessions. At the end of the experiment, subjects were debriefed and thanked for their time.

Results

Data from response times and mental effort ratings did not contribute to the overall findings from the present study, as discussed in the General Discussion. Thus, these data are not reported and are available upon request.

Initial quiz performance. Initial performance during the first and second quiz blocks is displayed in Table 3. There was no effect of counterbalancing order on initial quiz performance for the mixed quiz (2X) condition (fact-higher order or higher order-fact), $F < 1$, therefore means were collapsed over initial order for subsequent analyses (see Table 3 for the complete set of means). For the first quiz block, initial performance was greatest for the fact quiz (2X) condition (57%), followed by initial performance for the mixed quiz (2X, 52%, collapsed over quiz order), higher order quiz (2X, 49%), and higher order quiz (1X, 47%) conditions, respectively. For the second quiz block, initial performance was again greatest for the fact quiz (2X) condition (91%), followed by the higher order quiz (2X, 83%) and mixed quiz (2X, 53%, collapsed over quiz order) conditions.

A 3 [retrieval practice condition: higher order quiz (2X), fact quiz (2X), mixed quiz (2X)] x 2 (quiz block: first, second) repeated measures ANOVA on initial performance revealed a significant main effect of retrieval practice condition, $F(2, 94) = 64.27, p < .001, \eta_p^2 = .58$, a significant main effect of quiz block, $F(1, 47) = 356.69, p < .001, \eta_p^2 = .88$, and a significant interaction between retrieval practice condition and quiz block, $F(2, 94) = 42.77, p < .001, \eta_p^2 = .48$. As displayed in Table 3, the higher order quiz (2X) and fact quiz (2X) conditions resulted in a similar increase in performance from the first quiz block to the second quiz block (34% for each condition).

Performance in the mixed quiz (2X) condition, on the other hand, remained relatively constant across quiz blocks (see Table 3). Note that performance for each quiz block includes subjects' performance on both types of quizzes (fact and higher order). This finding suggests a replication of Experiment 1, namely that retrieval practice on one quiz format did not benefit performance on a second quiz of a different format, even in close succession during the first session – performance on the second quiz in the mixed condition was similar to performance on the first quiz of the same type in the fact quiz (2X) and higher order quiz (2X) conditions.

In general, the fact quiz (2X) performance resulted in substantially greater performance during both the first and second quiz blocks compared to the other initial learning conditions, likely due to differences in item difficulty between fact and higher order questions. Post-hoc comparisons confirmed that the fact quiz (2X) condition resulted in greater performance than the higher order quiz (1X) and higher order quiz (2X) conditions on the first quiz block, $t(47) = 4.00, p < .001, d = 0.71$ and $t(47) = 2.66, p = .011, d = 0.56$, respectively, but fact quiz (2X) performance was not significantly

greater than mixed quiz (2X) performance on the first quiz block, $t(47) = 1.91$, $p > .05$, likely because the mixed quiz condition includes subjects whose first quiz was also a fact quiz. On the second quiz block, the fact quiz (2X) condition resulted in greater performance than the higher order quiz (2X) and mixed quiz (2X) conditions, $t(47) = 4.29$, $p < .001$, $d = 0.77$ and $t(47) = 15.66$, $p < .001$, $d = 3.13$, respectively.

Final test performance. Final test performance for the four retrieval practice conditions is displayed in Table 3 and Figure 3. Reliability (Cronbach's alpha) was .462 for final fact test performance and .254 for final higher order performance. There was no effect of counterbalancing order on final test performance for the mixed quiz (2X) condition (fact-higher order or higher order-fact), $F < 1$, therefore means were collapsed over counterbalance order for subsequent analyses (see Table 3 for the complete set of means).

As seen on the far right side of Table 3, delayed test performance was greatest for the mixed quiz (2X) condition (75%), compared to the fact quiz (2X, 69%), higher order quiz (2X, 69%), and higher order quiz (1X, 65%) conditions, respectively. Overall performance for the two test types was similar: 69% correct on the final fact test and 70% correct on the final higher order test. A 4 [retrieval practice condition: higher order quiz (1X), higher order quizzes (2X), fact quizzes (2X), mixed quizzes (2X)] x 2 (delayed test type: fact, higher order) repeated measures ANOVA on delayed test performance revealed a main effect of retrieval practice condition, $F(3, 141) = 4.85$, $p = .003$, $\eta_p^2 = .09$, and a significant interaction between retrieval practice condition and delayed test type, $F(3, 141) = 86.23$, $p < .001$, $\eta_p^2 = .65$.

Regarding delayed performance on the fact test, post-hoc *t*-tests confirmed that the fact quiz (2X) condition (90%) and the mixed quiz (2X) condition (78%) resulted in greater delayed test performance compared to the higher order quiz (1X, 54%) and the higher order quiz (2X, 53%) conditions, $t_s > 6.10$, $p_s < .001$, $d_s > 1.21$. The difference in delayed fact test performance between the fact quiz (2X) and mixed quiz (2X) conditions was also significant, $t(47) = 3.72$, $p = .006$, $d = 0.77$.

Regarding delayed performance on the higher order test, post-hoc *t*-tests confirmed that the higher order quiz (2X, 85%), higher order quiz (1X, 77%), and mixed quiz (2X, 71%) conditions resulted in greater delayed test performance compared to the fact quiz (2X) condition (48%), $t_s > 5.80$, $p_s < .001$, $d_s > 1.24$. The difference between the higher order quiz (2X) and the mixed quiz (2X) conditions was also significant, $t(47) = 4.52$, $p < .001$, $d = 0.84$; however, neither of these two conditions differed significantly from the higher order quiz (1X) condition, $p_s > .05$.

Lastly, the difference in delayed performance between the congruent conditions, namely delayed fact test performance for the fact quiz (2X) condition (90%) and delayed higher order test performance for the higher order quiz (2X) condition (85%), was not significant, $t(47) = 2.01$, $p > .05$, and performance was close to ceiling levels. The difference between the mixed quiz (2X) condition on the delayed fact test (78%) versus the delayed higher order test (71%) was marginally significant, $t(47) = 2.08$, $p = .088$, $d = 0.39$.

Consistent with Experiment 1, the congruent conditions (fact quizzes-fact test, higher order quizzes-higher order test) resulted in the greatest delayed test performance compared to the mixed quiz (2X) condition, suggesting that two quizzes of

the same format are more potent for long-term learning than one quiz of each format. Interestingly, the fact quiz (2X) condition still did not benefit delayed higher order performance, even when compared to only one initial higher order quiz, providing further evidence that a boost in fact learning does not necessarily improve delayed higher order performance.

Discussion

In Experiment 2, retrieval practice with two higher order quizzes improved delayed higher order test performance by an additional 8% compared to only one higher order quiz (Figure 3). When the type of initial quizzes matched the type of final test, retrieval practice yielded benefits for both fact and higher order learning to a greater extent than one quiz of each format (in the mixed quiz condition). Replicating Experiment 1, retrieval practice with fact questions did not enhance delayed higher order test performance, inconsistent with the foundation of factual knowledge framework. In addition, retrieval practice with higher order questions did not enhance delayed fact test performance. The findings from Experiment 2 provide further evidence that retrieval practice is the most powerful when questions encountered during initial quizzes are similar to questions on a final test, consistent with the transfer appropriate processing framework.

Experiment 3

Experiment 3 was designed to investigate whether results from Experiments 1 and 2 would replicate in an applied setting with a different population (6th grade students) and a different content domain (world history). In previous research with middle school students, retrieval practice enhanced delayed test performance

compared to no quizzes, although information to be learned was mainly fact-based (Agarwal et al., 2012; McDaniel, Agarwal, Huelser, McDermott, & Roediger, 2011; McDaniel et al., 2013; McDermott et al., 2014; Roediger et al., 2011). Do younger students receive the same benefit from mixed quizzing as do college students? It may be the case that, particularly for younger students, the close succession of both question types within one quiz facilitates students' building of connections across the two types of processing, while also providing a prompt or hint to transfer knowledge from fact questions to the immediate higher order questions (Gick and Holyoak, 1980; Pan & Rickard, in press).

In Experiment 3, students completed mixed quizzes or higher order-only quizzes, and learning was measured on final fact and higher order tests. In accordance with prior research, retrieval practice (regardless of quiz condition) was expected to enhance both delayed fact and higher order test performance, compared to delayed test performance on non-quizzed items. Based on findings from Experiments 1 and 2, higher order quizzes were expected to enhance delayed higher order test performance, but not delayed fact test performance. Regarding mixed quizzes, the transfer appropriate processing framework suggests a partial improvement for both types of delayed tests, based on a partial overlap of similar question types (Table 1).

Method

Participants. One hundred forty-two 6th grade students ($M = 24$ students in each of six classroom sections; 71 males, 71 females) from a Midwestern suburban middle school participated in the current experiment. Assent from each student was obtained in accordance with guidelines from the Human Research Protection Office. Twelve

students declined to include their data in the study (although they participated in all classroom activities) and data from eight special education students were excluded from analyses because they received accommodations (e.g., additional study and quiz opportunities outside of class).

Design. A 3 x 2 within-subjects design was used, such that three retrieval practice conditions (higher order quizzes, mixed quizzes, non-quizzed) were crossed with two delayed test types (fact test, higher order test). Conditions were manipulated across two chapters of Social Studies material, with chapters presented in the same order for all students (as determined by the classroom teacher). Six classroom sections were split into two sets of three class sections each; in other words, sections 1, 3, and 6 comprised Set A, and sections 2, 5, and 7 comprised Set B. For the first chapter, Set A students completed three quizzes with higher order questions, whereas Set B students completed three quizzes with a mix of question types. For the second chapter, the retrieval practice conditions switched. At the end of each chapter unit (approximately 7-8 school days in length; 48 hours after the third quiz), students completed a final test comprised of both question types (fact and higher order), with all questions presented in a different random order for each of the six classroom sections. In order to maximize power using the largest number of items per condition as possible, while reducing classroom time required for the manipulation, a restudy condition was not included in this experiment (prior research demonstrated that retrieval practice enhanced delayed test performance compared to a restudy exposure control in the same school; Roediger et al., 2011; McDermott et al., 2014).

Materials. Two Social Studies textbook chapters (Russian Revolution and World War II; Banks et al., 1997), assigned by the classroom teacher, were used in this experiment. Each chapter was approximately 2,350 words in length (e.g., 2,335 words for the Russian Revolution chapter and 2,407 words for the World War II chapter).

Twelve four-alternative multiple-choice fact questions and twelve four-alternative multiple-choice higher order questions were developed for each textbook chapter (see Appendix B for sample questions). The classroom teacher approved all questions and multiple-choice alternatives. Across all initial quizzes and delayed tests, each classroom section received a different set of quizzed and non-quizzed items, and every item was quizzed or not quizzed at least once. In addition, for every initial quiz and final test, each classroom section received a different random order of questions and the multiple-choice alternatives were randomly re-ordered. The correct multiple-choice alternative appeared in every position (A, B, C, or D) an equal number of times across quizzes and tests.

Initial quizzes were comprised of either eight higher order questions or a mix of fact and higher order questions (four of each type). For mixed quizzes, question type (fact or higher order) was blocked and order was counterbalanced across classroom sections and quizzes, with questions presented in random order within question type block. Questions that were not on initial quizzes (a non-quizzed control condition) were covered in the textbook chapter and also during the teacher's lessons.

Final chapter tests comprised all multiple-choice fact and higher order questions (12 fact and 12 higher order questions per chapter). Final chapter test questions and alternatives were the same as those from initial quizzes (i.e., questions were not

rephrased) due to the teacher's concerns regarding floor effects and all 24 items were presented in random order (not blocked by question type) on final chapter tests. All reading passages and questions developed are available upon request.

For fact questions, broad concepts stated in the chapters were tested in order to measure students' overall understanding of the content. For example, a fact question from the "Russian Revolution" textbook chapter included:

Why was Nicholas II forced to give up his role as tsar?

- A) Because the Duma elected a new tsar
- B) Because Stalin took over the government
- C) Because his wife and children moved to Moscow
- D) Because of angry protestors, soldiers, and railroad workers

The correct answer for this fact question is alternative D and this answer was stated directly in the textbook chapter. In contrast to typical laboratory experiments, all fact questions in the present study were drawn from authentic classroom material and designed to encompass key concepts or ideas from the textbook chapters, rather than details such as names, dates, vocabulary words, definitions, etc. (e.g., the year in which the Russian Revolution began).

Higher order questions were developed based on categories from a revised Bloom's taxonomy (*apply*, *analyze*, and *evaluate*; Anderson et al., 2001; see Figure 1).

For example, an *analyze* question from the "Russian Revolution" chapter included:

Which person would agree with the following statement? "Revolutions are hard to prevent."

- A) Alexander II

- B) Lenin
- C) Nicholas II
- D) Stalin

The correct answer for this *analyze* question is alternative C. Higher order questions from the taxonomic *create* category were not included in this experiment, due to the teacher's concerns that 6th grade students may have difficulty extending textbook facts to completely novel situations (i.e., floor effects).

Procedure. Students completed initial quizzes individually via a clicker response system (Ward, 2007) in the classroom using a computer, projector, and projection screen at the front of the classroom. At the beginning of the study, students were instructed that they would be taking quizzes (via clickers, with which students were already familiar) and tests as part of a research study, and that their scores may or may not count for a grade. In actuality, students' scores were not factored into their individual grades; instead, the average score for each of the six classroom sections counted towards a pizza party held at the end of the school year. The classroom section with the highest score on each initial quiz or final test received five points towards the pizza party. The classroom section with the second highest score on each quiz or test received four points towards the pizza party. Additional classroom assignments and exams also factored into students' pizza party point totals, as determined by the classroom teacher.

In general, each chapter unit lasted approximately one week. For each unit, students read a chapter from their Social Studies textbook, listened to seven or eight

lessons, participated in quizzes (the experimental manipulation), and completed standard assignments developed by the teacher.

Before the first lesson, students completed a pre-quiz via clickers without having read the textbook chapter. Immediately after the pre-quiz (i.e., on the same day), students began reading the chapter and participated in the teacher's corresponding lesson. After 2-3 school days, during which students completed the chapter reading and the teacher covered all chapter content, students completed a post-quiz via clickers. Two days after the post-quiz, the classroom teacher reviewed all chapter material, which was followed by a review quiz via clickers.

During all clicker quizzes (pre-, post-, and review quizzes), multiple-choice questions were displayed on a projection screen at the front of the classroom one at a time, in a different random order for each classroom section. I read the question stem and four multiple-choice alternatives aloud. After I was finished reading the question and alternatives, I made the software's response option available and students were asked to press a letter (A, B, C, or D) on their clicker remote corresponding to the multiple-choice alternative (forced choice). Once all students in the classroom responded (after approximately one minute), I closed the response option and the clicker software displayed a green checkmark next to the correct alternative (i.e., immediate feedback was administered during quizzes). I read aloud the question stem and the correct answer, and then moved on to the next question. Each clicker quiz was comprised of eight questions, which took each class section approximately seven to nine minutes to complete. Mental effort ratings were not collected.

Two days after the review quiz, students completed a final test comprised of all 24 multiple-choice questions for the chapter. Final chapter tests were administered online (via Google Docs, <http://docs.google.com>), while students sat individually at PC computers. The chapter test was self-paced and students viewed each multiple-choice question one at a time. Once students selected a multiple-choice alternative, they moved on to the next question; however, the online chapter test also allowed students to return to earlier questions if they wanted to review or change their answers. Once students responded to all 24 test questions, students were no longer able to return to the test to change their answers. No feedback was provided during the final chapter test.

In sum, students participated in three within-subject retrieval practice conditions, crossed with two final test types. The dependent variable of interest was accuracy on final test questions. The entire procedure was followed for two textbook chapters over the course of two weeks. At the end of the study, students were debriefed and thanked for their time.

Results

Thirty-four students were absent during at least one initial quiz or the final chapter test and their data were excluded from the reported analyses to ensure the integrity of the experimental manipulation. Thus, data reported are from 88 students (M age = 11.58 years, 48 females); similar patterns of results were found when data from all students who assented to participate were included (i.e., $n = 122$ absent and present students, excluding special education students).

Note that middle school students were assigned to class sections before the current study began and this assignment was non-random. Thus, data from students are nested within class section, and again nested within set. Experiment 3 was carried out completely within-subjects, all materials and conditions were completely counterbalanced, and there was no significant difference in final test performance between the two sets ($p = .082$). Even so, nested individuals tend to be more alike than individuals selected at random (Raudenbush & Bryk, 2002). Because the number of levels within nests was low, the use of a multilevel model to determine the influence of non-random assignment on performance was not possible and means have not been adjusted to account for this nesting.

Initial Quiz Performance. Initial quiz performance for the first (pre-quiz), second (post-quiz), and third (review) quizzes is displayed in Table 4. In general, initial performance increased from the pre-quiz (38%) to the post-quiz (71%) and also to the review quiz (84%), due to textbook reading, classroom lessons, and immediate feedback received during the clicker quizzes. Across the initial quizzes, performance was slightly greater in the mixed quiz condition (66%) compared to performance in the higher order quiz condition (62%), likely due to the inclusion of fact questions in the mixed quiz condition.

A 2 (retrieval practice condition: higher order quizzes, mixed quizzes) x 3 (quiz type: pre, post, review) repeated measures ANOVA on initial quiz performance revealed a marginal main effect of retrieval practice condition, $F(1, 87) = 3.55, p = .063, \eta_p^2 = .039$, and a significant main effect of quiz type, $F(2, 174) = 442.05, p < .001, \eta_p^2 = .84$; however, the interaction was not significant, $F(2, 174) = 2.03, p > .05$. In other words,

students' initial quiz performance increased across the three quizzes, and did so similarly for the mixed quiz and the higher order quiz conditions.

Final Test Performance. Performance on the final tests, administered two days after the review quizzes, is displayed in Table 4 and Figure 4. Reliability (Cronbach's alpha) was .709 for final fact test performance and .686 for final higher order performance. A univariate ANOVA with set as a between-subjects factor (two sets of three classroom sections each; see Appendix A) revealed no significant difference on overall final test performance, $F(1, 87) = 3.12, p = .082$, therefore means were collapsed over set for subsequent analyses.

Delayed test performance (collapsed over test type) was greatest for the mixed quiz condition (86%), followed by the higher order quiz (70%) and non-quizzed (60%) conditions. In addition, delayed performance was similar for the final fact (73%) and final higher order (71%) tests. A 3 (retrieval practice condition: higher order quizzes, mixed quizzes, non-quizzed) x 2 (final test type: fact, higher order) repeated measures ANOVA on final test performance revealed a significant main effect of retrieval practice condition, $F(2, 174) = 128.98, p < .001, \eta_p^2 = .60$, a marginal main effect of final test type, $F(1, 87) = 3.19, p = .078, \eta_p^2 = .04$, and a significant interaction between retrieval practice condition and final test type, $F(2, 174) = 28.30, p < .001, \eta_p^2 = .25$.

For the final fact test, the mixed quiz condition resulted in far greater performance (91%) than the higher order quiz and non-quizzed conditions (64% each), $t(47) = 12.24, p < .001, d = 1.44$ and $t(47) = 13.63, p < .001, d = 1.55$, respectively. For the final higher order test, the mixed quiz condition again resulted in the greatest performance (82%) compared to the higher order (75%) and non-quizzed (56%)

conditions, $t(87) = 2.27$, $p = .078$ ($p = .026$ without Bonferroni correction), $d = 0.34$ and $t(87) = 12.24$, $p < .001$, $d = 1.37$, respectively. Consistent with Experiments 1 and 2, higher order retrieval practice led to significantly greater higher order test performance compared to the non-quizzed condition, $t(87) = 7.87$, $p < .001$, $d = 0.99$.

Overall, mixed retrieval practice produced the greatest level of performance on both fact and higher order final tests, while providing a marginal benefit above and beyond the benefit from higher order retrieval practice on delayed higher order test performance.

Discussion

Retrieval practice dramatically increased learning for middle school students compared to no quizzes, contributing to a growing body of applied research (McDaniel et al., 2011; McDaniel et al., 2013; McDermott et al., 2014; Roediger et al., 2011). Remarkably, mixed quizzes increased final fact test performance from the letter grade equivalent of a D to an A- (a difference of 27%, Figure 4). Mixed quizzes also produced a slight improvement over and above higher order quizzes on delayed higher order test performance (7%), although this difference was marginally significant. Replicating Experiments 1 and 2, findings were consistent with the transfer appropriate processing framework (Table 1): benefits from higher order quizzes were limited to the higher order test, and benefits from the mixed quizzes extended to both types of final tests.

General Discussion

Contrary to popular intuition, building a foundation of factual knowledge via retrieval practice did not enhance students' higher order learning. Instead, students' final fact test and higher order test performance was greatest following retrieval practice

that matched in cognitive complexity based on Bloom's taxonomy: fact quizzes enhanced final fact test performance and higher order quizzes enhanced final higher order test performance. Retrieval practice increased learning by 20-30% under laboratory conditions with college students and also in an authentic K-12 classroom.

Fact Quizzes Do Not Enhance Higher Order Learning

Why didn't fact quizzes improve higher order learning in the present study, as many cognitive scientists and educators contend? First, students may have been unaware that information on fact quizzes was related to final higher order tests, thus they did not transfer their knowledge without explicit instructions to do so. Chan, McDermott, and Roediger (2006, Experiment 3) found a benefit of retrieval practice on novel items when subjects were instructed to adopt a "broad retrieval strategy" during study, whereas subjects who were told to adopt a "narrow retrieval strategy" did not demonstrate a benefit of retrieval practice on related novel items. Butler (2010, Experiment 3) also found a benefit of retrieval practice on far transfer to novel items when subjects were explicitly told that the final test was related to information learned during the initial session (see also Chan, 2009). Furthermore, a classic study by Gick and Holyoak (1980) demonstrated that students' conceptual knowledge remains "inert" when not explicitly told to use previously learned information on novel items (see also Bransford, Sherwood, Vye, & Rieser, 1986; Pan & Rickard, in press). Thus, students in the current study may have transferred their factual knowledge to the higher order test questions had they been given explicit instructions, prompts, or hints.

Second, quiz and final test questions were multiple-choice, a retrieval practice format that improves learning in laboratory and classroom settings (Bjork, Little, &

Storm, 2014; McDermott et al., 2014). Some educators argue that higher order learning cannot be facilitated or measured using multiple-choice quizzes or tests. Instead, educators often advocate for paper assignments, essay tests, open-book tests, and ongoing portfolio evaluations to determine higher order learning (Ausubel et al., 1978; Hart, 1994; Kohn, 1999; Martinez, 1999). It is possible that by using multiple-choice items, an element of genuine higher order learning may have been lost in the present study. Alternatively, multiple-choice quizzes may have provided an *added* benefit from short answer quizzes because well-constructed multiple-choice alternatives can facilitate retrieval of information pertaining to correct and incorrect alternatives, as well as enhance transfer to novel information (Gierl, Bulut, Guo, & Zhang, 2017; Little & Bjork, 2015; Little, Bjork, Bjork, & Angello, 2012; Marsh & Cantor, 2014).

In the present study, multiple-choice alternatives were developed to require students to make fine-grained distinctions between similar concepts. For instance, in Experiments 1 and 2, college students were asked to evaluate an author's views on welfare and whether the government's primary role is to advance morality, security, equality, or liberty (see Appendix B). Each of these multiple-choice alternatives related to the reading passage, the target question, and current policy on welfare programs. As such, the multiple-choice alternatives may have *increased*, rather than decreased, potential transfer from fact to higher order questions. Further examination of higher order learning with a variety of question formats – including multiple-choice – may shed light on whether students' transfer of fact knowledge to higher order learning is dependent upon the type of questions used during retrieval practice.

It is important to note that all multiple-choice alternatives remained identical from initial retrieval practice to final tests for all three experiments. In addition, Experiments 1 and 2 included slightly rephrased final test questions, whereas Experiment 3 included final test questions that were identical to initial quiz questions. Recent research has found that rephrased quiz or test questions do not facilitate transfer to a greater extent than identical questions (Butler, 2010; Pan & Rickard, in press); thus, while rephrased questions would be ideal for examining the flexibility of learning, it is uncertain whether materials in the current study diminished or eliminated transfer of fact knowledge. Further, if memorization of quiz and test items were a concern, then one would expect ceiling performance greater than 90% on final tests, which was not found in the present experiments.

Third, cognitive load theory suggests that fact quizzes should facilitate higher order learning by reducing cognitive demands required during the final test (Plaas et al., 2010; Sweller, 2010; van Gog & Sweller, 2015). It was expected that mental effort ratings on higher order tests would be lower when preceded by fact quizzes compared to higher order quizzes (rated on a 9-point scale, adapted from Paas, 1992; data available upon request). Unfortunately, mental effort ratings did not shed light on this puzzle. Across experiments and conditions, mental effort ratings during higher order tests were lower when students first completed higher order quizzes. In other words, students' mental effort ratings did not reveal sensitivity to a foundation of factual knowledge on higher order learning.

The key finding that fact quizzes did not enhance higher order learning directly contradicts the long-held belief that "factual knowledge must precede skill" (Willingham,

2009). Instead, a match between initial quiz and final test questions produced the greatest learning in the current study, consistent with the transfer appropriate processing framework (Morris et al., 1977; see Table 1, rows 1 and 2). In addition, discrepant conditions in the present study (fact quiz-higher order test and higher order quiz-fact test; see Table 1, rows 3 and 4) did not promote learning, contrary to recent findings (Hinze & Wiley, 2011; Jensen et al., 2014; McDermott et al., 2014). Whether a foundation of factual knowledge promotes higher order learning – and under what conditions – remains to be seen. Exploration of prompts to transfer and question format may yield fact-based retrieval strategies that push student learning higher on Bloom's taxonomy and to greater levels of complexity.

Mixed Quizzes Enhance Higher Order Learning

Mixed quizzes, comprised of both fact and higher order questions, increased higher order test performance more than fact quizzes (in Experiment 2) and slightly more than higher order quizzes (in Experiment 3). The robust benefits of mixed quizzes on higher order learning is consistent with predictions from the three theoretical frameworks of interest: the desirable difficulty framework suggests that mixed quizzes pose a challenge for students by switching between question complexity during retrieval (see also Butler et al., 2017); the transfer appropriate processing framework suggests a benefit of mixed quizzes due to an overlap in processing with the final test; and the foundation of factual knowledge framework predicts a benefit from mixed quizzes when students are given the opportunity to engage in fact questions during initial learning (see Table 1, rows 5 and 6).

Compared to higher order quizzes, why were mixed quizzes more potent for higher order learning in Experiment 3 (middle school students) than in Experiment 2 (college students)? Of course, students of different ages may benefit differentially from mixed retrieval practice. Varied complexity may be advantageous by providing a scaffold between lower order and higher order questions, particularly for students who have limited experience with complex materials (i.e., 6th grade students in Experiment 3). Meanwhile, scaffolding from varied complexity may be unnecessary for students who already have experience extracting factual information from complex materials (i.e., college students in Experiment 2); thus, older students may reap more benefits from higher order retrieval practice. While pure speculation, the current study is the first to implement a retrieval practice paradigm under similar conditions for two distinct student populations. More research is necessary to ascertain whether factual knowledge improves higher order learning, but also to ascertain whether it differs *for different age groups*. Support for the foundation of factual knowledge framework is frequently articulated from a K-12 perspective, an indication that the relationship between fact learning and higher order learning might be unique for younger students.

Another major difference between Experiment 2 and Experiment 3 was the procedure followed for mixed quizzes. In Experiment 2, mixed quizzes were counterbalanced across numerous within-subject conditions (e.g., students completed a fact quiz on the welfare passage, next completed quizzes on other passages, and then completed a higher order quiz on the welfare passage; see Appendix A). In contrast, mixed quizzes in Experiment 3 were comprised of fact and higher order questions concurrently. Furthermore, within-subject conditions were administered one after

another during a single session in Experiment 2, whereas middle school students in Experiment 3 spent one week with one type of retrieval practice (higher order or mixed) and then spent another week with the other type of retrieval practice.

These procedural differences may have influenced students' motivation to pay attention and learn the material, resulting in different benefits from mixed quizzing in the two experiments. Prior research indicates that students prefer learning activities that vary in terms of item difficulty, particularly in mathematics (Skinner, Fletcher, Wildmon, & Belfiore, 1996; Wildmon, Skinner, & McDade, 1998). Recent research also indicates that students adjust their learning strategies based on expectancy for different types of tests (Agarwal, D'Antonio, Roediger, McDermott, & McDaniel, 2014; Agarwal & Roediger, 2011; Jensen et al., 2014). Broadly, it would have been challenging for college students to modulate their motivation specifically for the mixed condition due to the extensive counterbalancing of passages and quizzes. It is possible that middle school students exerted more motivational effort during the week in which they had mixed quizzes compared to the week of higher order quizzes, even though students were provided with an incentive (a pizza party) based on quiz and test performance during both weeks.

It is also unlikely that students in Experiments 2 and 3 would have had greater motivation in the mixed quiz condition due to the novelty of quiz items. In order to recognize which conditions were mixed or not mixed, college students would have needed to keep track of multiple-choice items across seven intervening quizzes on unrelated passages, and middle school students would have needed to ascertain the distinction between a change in chapter material versus a change in the complexity of

quiz questions. Considering the amount of attention required to do this in either experiment, the likelihood that the mixed quiz condition increased student motivation due to item novelty is doubtful. (I thank an anonymous reviewer for bringing this possibility to my attention.)

When it comes to instruction, what type of retrieval practice will help students achieve the highest levels of Bloom's taxonomy? Surprisingly, fact-based retrieval practice only increased fact learning, whereas higher order and mixed retrieval practice increased higher order learning. If we want to reach the top of Bloom's taxonomy, building a foundation of knowledge via fact-based retrieval practice may be less potent than engaging in higher order retrieval practice at the outset, a key finding for future research and classroom application.

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Table 1

Theoretical Predictions and Obtained Results of Initial Retrieval Practice Condition on Final Test Performance, Compared to a No Quiz Condition

Retrieval Practice	Final Test	Desirable Difficulties	Transfer Appropriate Processing	Foundation of Factual Knowledge	Obtained Results
Fact Quiz	Fact Test	++	++	++	E1: ++ E2: ++ E3: N/A
Higher Order Quiz	Higher Order Test	++	++	0	E1: ++ E2: ++ E3: ++
Fact Quiz	Higher Order Test	+	0	++	E1: 0 E2: 0 E3: N/A
Higher Order Quiz	Fact Test	++	0	0	E1: 0 E2: 0 E3: N/A
Mixed Quiz	Fact Test	++	+	+	E1: N/A E2: ++ E3: ++
Mixed Quiz	Higher Order Test	++	+	+	E1: N/A E2: ++ E3: ++

Note. Facilitation: ++, partial facilitation: +, no prediction or effect: 0, not applicable: N/A

Table 2

Initial Quiz and Delayed Test Performance (Proportion Correct) as a Function of Retrieval Practice Condition From Experiment 1

	Initial Quiz	Final Fact Test	Final Higher Order Test	Delayed Average
Study Once		.54 (.21)	.44 (.18)	.49
Study Twice		.54 (.21)	.49 (.19)	.51
Fact Quiz	.59 (.17)	.78 (.19)	.46 (.22)	.62
Higher Order Quiz	.47 (.15)	.53 (.21)	.72 (.21)	.62
Average	.53	.60	.53	

Note. Standard deviations are displayed in parentheses.

Table 3

Initial Quiz and Delayed Test Performance (Proportion Correct) as a Function of Retrieval Practice Condition From Experiment 2

	First Quiz	Second Quiz	Final Fact Test	Final Higher Order Test	Delayed Average
Higher Order Quiz (1X)	.47 (.11)		.54 (.23)	.77 (.17)	.65
Higher Order Quizzes (2X)	.49 (.14)	.83 (.12)	.53 (.22)	.85 (.13)	.69
Fact Quizzes (2X)	.57 (.17)	.91 (.08)	.90 (.13)	.48 (.19)	.69
Mixed Quizzes (2X)	.52 (.19)	.53 (.15)	.78 (.18)	.71 (.18)	.75
Mixed: Fact-Higher	.58 (.22)	.47 (.11)	.81 (.17)	.71 (.18)	.76
Mixed: Higher-Fact	.45 (.13)	.60 (.15)	.76 (.18)	.71 (.19)	.73
Average	.53	.76	.69	.70	

Note. Standard deviations are displayed in parentheses.

Table 4

Initial Quiz and Delayed Test Performance (Proportion Correct) as a Function of Retrieval Practice Condition From Experiment 3

	Pre-Quiz	Post-Quiz	Review Quiz	Final Fact Test	Final Higher Order Test	Delayed Average
Non-Quizzed				.64 (.18)	.56 (.18)	.60
Higher Order Quizzes	.38 (.16)	.68 (.21)	.82 (.17)	.64 (.20)	.75 (.21)	.70
Mixed Quizzes	.38 (.18)	.73 (.19)	.87 (.15)	.91 (.17)	.82 (.21)	.86
Average	.38	.71	.84	.73	.71	

Note. Standard deviations are displayed in parentheses.

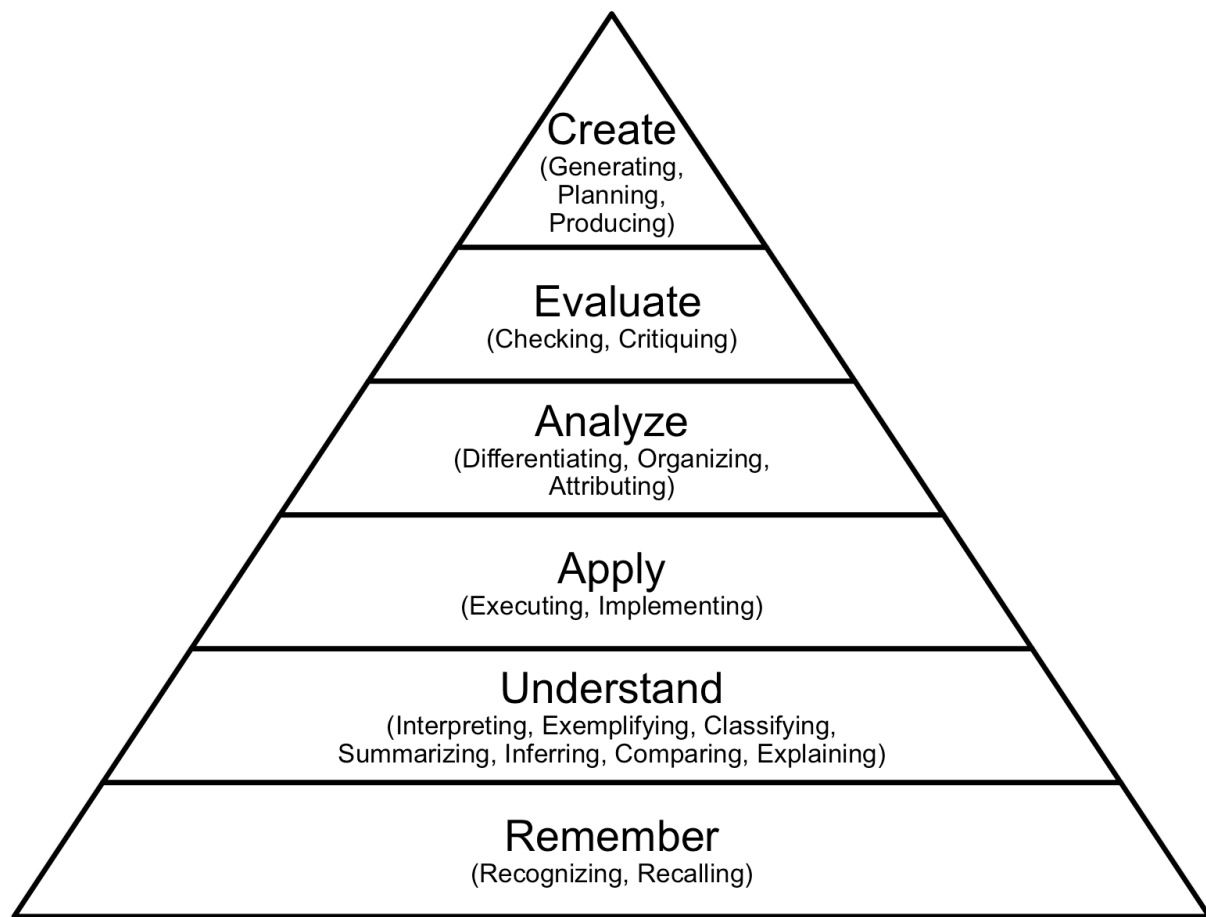


Figure 1. An illustration of the revised Bloom's Taxonomy, adapted from Anderson et al. (2001).

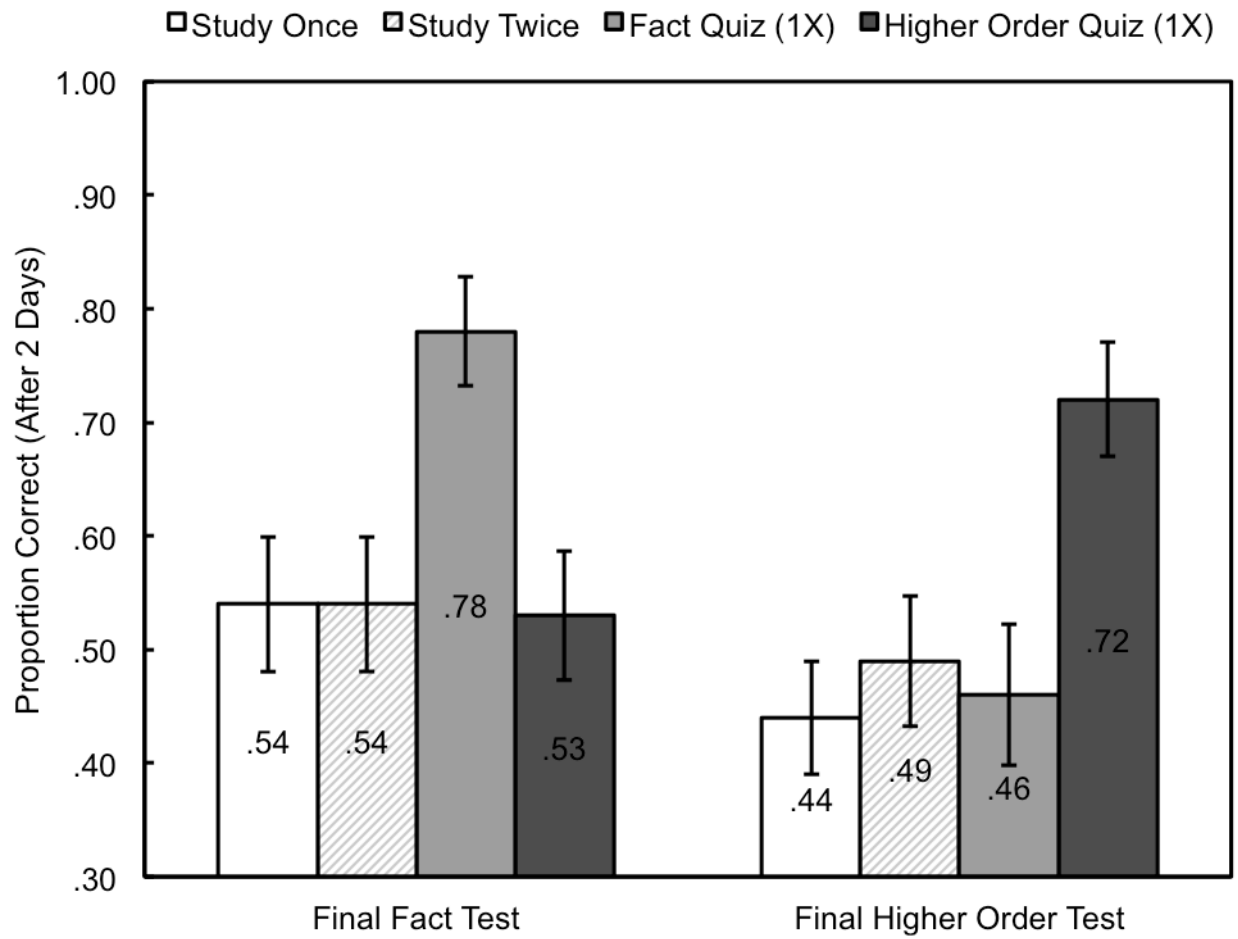


Figure 2. Delayed test performance (proportion correct after two days) as a function of retrieval practice condition from Experiment 1. Errors bars represent 95% confidence intervals.

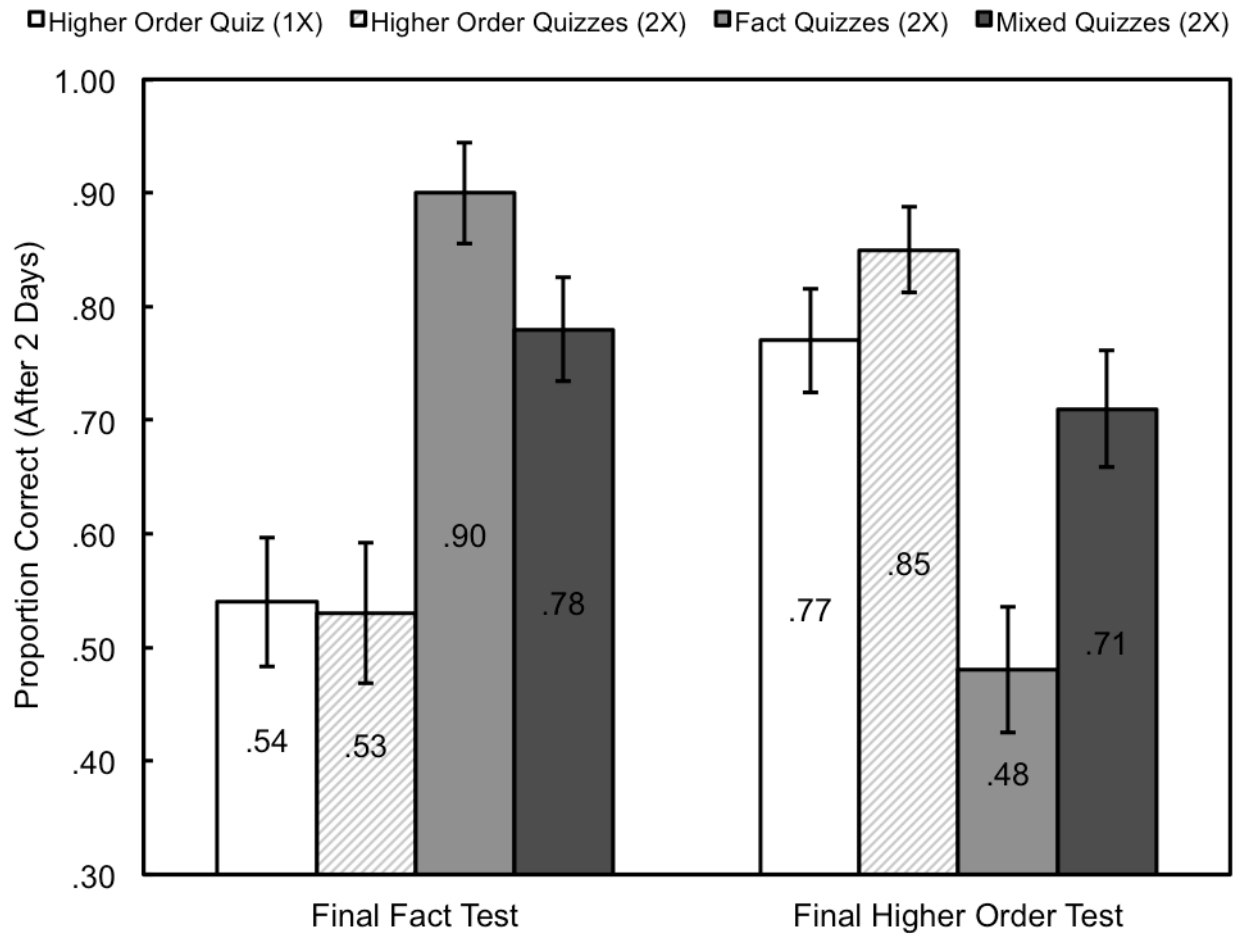


Figure 3. Delayed test performance (proportion correct after two days) as a function of retrieval practice condition from Experiment 2. Errors bars represent 95% confidence intervals.

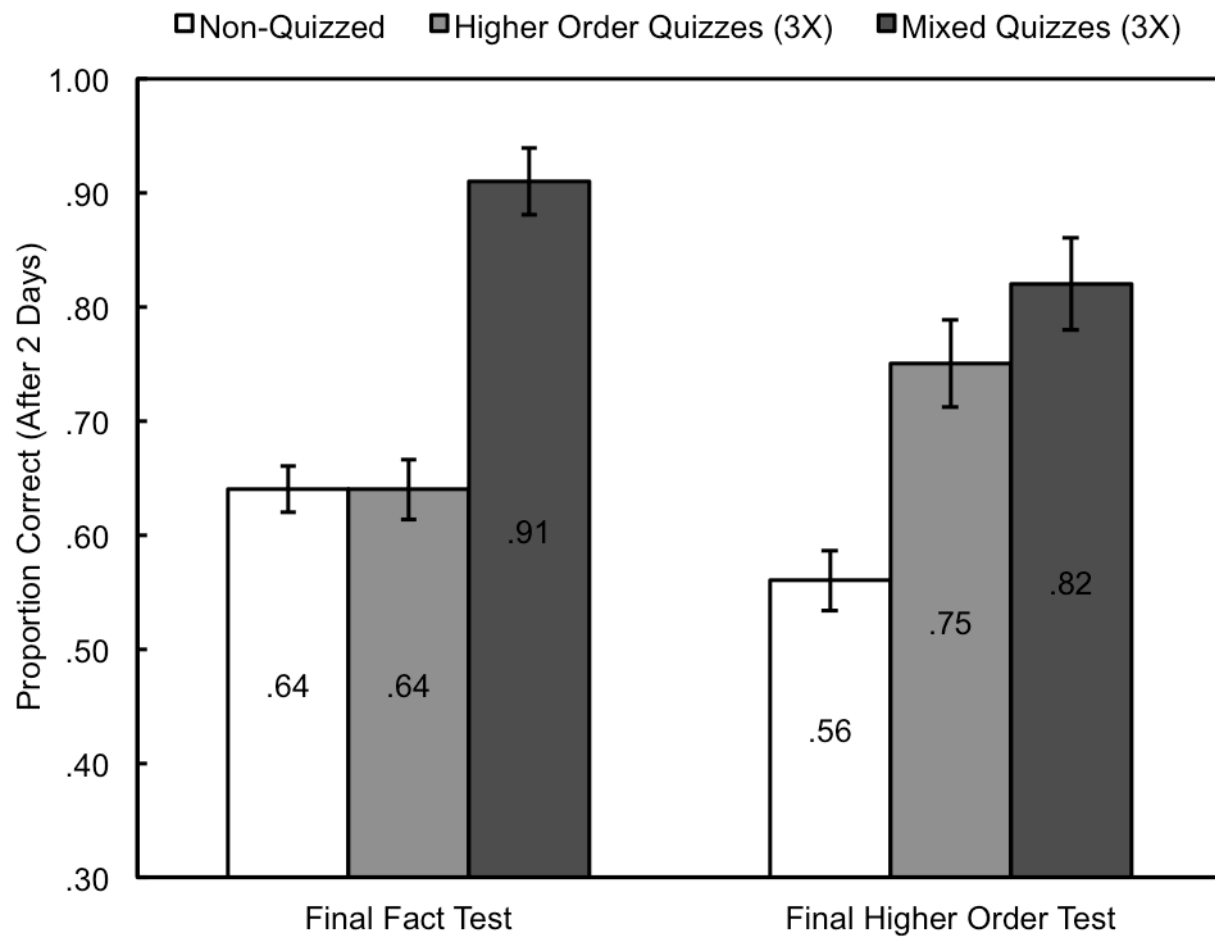


Figure 4. Delayed test performance (proportion correct after two days) as a function of retrieval practice condition from Experiment 3. Errors bars represent 95% confidence intervals.

Appendix A*Counterbalancing Orders***Experiment 1**

	Welfare	Vaccines	Multicul	Biotech	SexDiff	Lincoln	Superfund	WWII
1, 2	Study Twice	Study Twice	Fact	Fact	Study Once	Study Once	Higher Order	Higher Order
3, 4	Study Once	Study Once	Higher Order	Higher Order	Fact	Fact	Study Twice	Study Twice
5, 6	Higher Order	Higher Order	Study Once	Study Once	Study Twice	Study Twice	Fact	Fact
7, 8	Fact	Fact	Study Twice	Study Twice	Higher Order	Higher Order	Study Once	Study Once

Experiment 2

	Welfare	Vaccines	Multicul	Biotech	SexDiff	Lincoln	Superfund	WWII
1, 2	Fact 2X	Fact 2X	Mixed (H-F)	Mixed (H-F)	Higher 1X	Higher 1X	Higher 2X	Higher 2X
3, 4	Mixed (F-H)	Mixed (F-H)	Fact 2X	Fact 2X	Higher 2X	Higher 2X	Higher 1X	Higher 1X
5, 6	Higher 1X	Higher 1X	Higher 2X	Higher 2X	Mixed (H-F)	Mixed (H-F)	Fact 2X	Fact 2X
7, 8	Higher 2X	Higher 2X	Higher 1X	Higher 1X	Fact 2X	Fact 2X	Mixed (F-H)	Mixed (F-H)

Experiment 3

	Russian Revolution	World War II
Set A (three class sections)	Higher Order Only	Fact + Higher Order Mix
Set B (three class sections)	Fact + Higher Order Mix	Higher Order Only

Note. For Experiments 1 and 2, odd counterbalancing orders received final fact tests first, alternating with final higher order tests. Even orders received final higher order tests first, alternating with final fact tests.

Appendix B

Question Examples

Experiments 1 and 2 (College Students) and Vaccines

	Fact Question	Higher Order Question
Retrieval Practice (Session 1)	<p>What is one benefit of welfare programs that the “no” author supports?</p> <p>A. <u>They eradicate discrimination</u></p> <p>B. They help support local communities</p> <p>C. They are affordable and feasible</p> <p>D. They help everyone, not just recipients</p>	<p>Which statement is an accurate evaluation or summary of the “no” author’s views?</p> <p>A. The government’s primary role is advancing morality</p> <p>B. The government’s primary role is advancing security</p> <p>C. <u>The government’s primary role is advancing equality</u></p> <p>D. The government’s primary role is advancing liberty</p>
Final Test (Session 2)	<p>The “no” author supports welfare programs because</p> <p>A. They are affordable and feasible</p> <p>B. They help everyone, not just recipients</p> <p>C. <u>They eradicate discrimination</u></p> <p>D. They help support local communities</p>	<p>The “no” author would agree with which statement?</p> <p>A. The government’s primary role is advancing liberty</p> <p>B. <u>The government’s primary role is advancing equality</u></p> <p>C. The government’s primary role is advancing morality</p> <p>D. The government’s primary role is advancing security</p>

Retrieval
Practice
(Session 1)

Which is the primary reason the "yes" author is against welfare programs?

- A. Welfare programs don't benefit recipients or taxpayers
- B. Welfare programs create dependence for recipients
- C. Welfare programs are too expensive for taxpayers
- D. Welfare programs are not the government's responsibility

Final Test
(Session 2)

The "yes" author is against welfare programs, largely because

- A. Welfare programs are too expensive for taxpayers
- B. Welfare programs don't benefit recipients or taxpayers
- C. Welfare programs are not the government's responsibility
- D. Welfare programs create dependence for recipients

Which statement is an accurate evaluation or summary of the "yes" author's views?

- A. Welfare programs can never work, because they are always too expensive
- B. Welfare programs are harmful, because they make bad situations even worse
- C. Welfare programs could work, but they rarely meet the needs of the people
- D. Welfare programs waste taxpayer money on people who don't really need help

The "yes" author would agree with which statement?

- A. Welfare programs could work, but they rarely meet the needs of the people
- B. Welfare programs waste taxpayer money on people who don't really need help
- C. Welfare programs can never work, because they are always too expensive
- D. Welfare programs are harmful, because they make bad situations even worse

Retrieval
Practice
(Session 1)

The "no" author argues that vaccines may always carry some amount of risk, but that this risk

- A. Is a possibility with any medical procedure
- B. Is too small to be of concern to the community
- C. Should be of concern to scientists, not parents
- D. Is less than the likelihood of a disease epidemic

Which author would agree with the following statement? "The ends justify the means."

- A. The "yes" author
- B. The "no" author
- C. Both authors
- D. Neither author

Final Test
(Session 2)

The "no" author argues that vaccine risk

- A. Should be of concern to scientists, not parents
- B. Is a possibility with any medical procedure
- C. Is less than the likelihood of a disease epidemic
- D. Is too small to be of concern to the community

Which author would agree with the following statement? "The achieved outcome is more important than the process along the way."

- A. The "no" author
- B. Neither author
- C. Both authors
- D. The "yes" author

Retrieval
Practice
(Session 1)

Which is the primary reason the "no" author believes that all children should receive vaccinations?

- A. Our obligation is to protect children, not parents
- B. Our obligation is to prevent disease, not side effects
- C. Our obligation is to eliminate disease whenever possible
- D. Our obligation is to the population, not individuals

Which opinion regarding a public smoking ban do you predict the "no" author would most likely hold?

- A. The ban would benefit smokers, non-smokers, employees, and potential tourists
- B. The ban would increase tourism and revenue for restaurants, bars, and casinos
- C. The ban would force smokers to stop smoking, thereby improving their health
- D. The ban would give families the opportunity to enjoy a smoke-free environment

Final Test
(Session 2)

The "no" author believes that all children should receive vaccinations, largely because

- A. Our obligation is to the population, not individuals
- B. Our obligation is to prevent disease, not side effects
- C. Our obligation is to protect children, not parents
- D. Our obligation is to eliminate disease whenever possible

Regarding a public smoking ban, the "no" author would argue that

- A. The ban would give families the opportunity to enjoy a smoke-free environment
 - B. The ban would force smokers to stop smoking, thereby improving their health
 - C. The ban would benefit smokers, non-smokers, employees, and potential tourists
 - D. The ban would increase tourism and revenue for restaurants, bars, and casinos
-

Experiment 3 (Middle School Students)
Russian Revolution and World War II

	Fact Question	Higher Order Question
Retrieval Practice and Final Test	<p>Why were Nicholas II and the Duma in constant conflict?</p> <p>A. <u>Because the Duma wanted to help the poor</u></p> <p>B. Because Nicholas II wanted to help the poor</p> <p>C. Because the Duma wanted to support communism</p> <p>D. Because Nicholas II wanted control of all of Russia's power</p>	<p>Based on what you know about Nicholas II, how would he treat poor people?</p> <p>A. He would share some power with the poor</p> <p>B. He would help the poor</p> <p>C. He would take money away from the poor</p> <p>D. <u>He would ignore the poor</u></p>
Retrieval Practice and Final Test	<p>Under Stalin, how would you describe everyday life for the Russian people?</p> <p>A. <u>Stalin controlled all aspects of people's lives</u></p> <p>B. People were free to do whatever they wanted</p> <p>C. Stalin forced all people to go to church</p> <p>D. People were allowed to choose their careers</p>	<p>Which person would agree with the following statement? "People are the most productive when they are told what to do by one person, instead of listening to many people or doing what they want."</p> <p>A. Nicholas II</p> <p>B. Lenin</p> <p>C. <u>Stalin</u></p> <p>D. Alexander II</p>

Retrieval
Practice
and Final
Test

What did Franklin Roosevelt do during World War II?

- A. He dropped an atomic bomb on Japan
- B. He killed Adolf Hitler
- C. He joined the Axis war effort
- D. He declared war on Japan

Based on what you know about Franklin Roosevelt, what would he do if Spain attacked the U.S.?

- A. He would surrender to Spain
- B. He would negotiate with Spain
- C. He would attack Spain in return
- D. He would drop an atomic bomb on Spain

Retrieval
Practice
and Final
Test

Why did Hitler join forces with Japan?

- A. So they could work together to expand their empires
- B. So they could both take over the United States
- C. So Germany could build an army base in Japan
- D. So Japan wouldn't join the Allied Forces

Which statement is an accurate summary of Hitler's views?

- A. By invading the Soviet Union, Germany can increase food production
- B. By invading the Soviet Union, Germany can create a master race
- C. By invading the Soviet Union, Germany can expand its empire
- D. By invading the Soviet Union, Germany can strengthen its military

Note. Multiple-choice alternatives remained identical across initial quizzes and final tests for all experiments. The correct answers for each question are underlined. All materials are available upon request.