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The Effects of Prequestions on Classroom Learning

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Studies have shown that *prequestions*—asking students questions before they learn something—benefit memory retention. Prequestions would seem to be a useful technique for enhancing students' learning in their courses, but classroom investigations of prequestions have been sparse. In the current study, students from an introductory psychology course were randomly assigned to receive prequestions over each upcoming lesson (prequestion group) or to not receive prequestions (control group). At the end of class, students in the prequestion group remembered the material better than students in the control group, but this benefit was specific to the information that was asked about in the prequestions. When memory for other, nonprequestioned portions of the lesson were tested at the end of class, the prequestion group performed similarly to the control group. On a follow-up quiz 1 week later, both groups showed a memory advantage for material that was tested at the end of class 1 week prior, compared with information from the same lesson that was never tested. However, this benefit was comparable between the prequestion group and the control group, suggesting that students benefit from retrieval practice, but prequestions add little, if any, enhancement to this effect.

Keywords: prequestions, retrieval, testing, learning, classroom

A long history of research on cognition has revealed a variety of instructional techniques that enhance student learning. High on the list of simple yet powerful techniques is to ask students questions about what they are learning. An abundance of research on *retrieval practice* shows that, relative to reviewing or restudying the material, answering questions about the material after studying it produces significant learning gains (for recent reviews, see Carpenter, 2012; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Kornell & Vaughn, 2016; Rowland, 2014).

Retrieval enhances memory for a wide variety of materials, from fairly simple verbal information such as vocabulary (Finn & Roediger, 2011; Pyc & Rawson, 2010), to more complex reading passages (Butler, 2010; Roediger & Karpicke, 2006), to visuospatial information of the type found in maps and diagrams (Carpenter & Kelly, 2012; Carpenter & Pashler, 2007; Rohrer, Taylor, & Sholar, 2010). Moreover, classroom-based studies have demonstrated significant benefits of retrieval on a variety of curricular materials, such as elementary school students' learning of science concepts (Jaeger, Eisenkraemer, & Stein, 2015; Karpicke, Blunt, Smith, & Karpicke, 2014), middle school students' learning of history (Carpenter, Pashler, & Cepeda, 2009) science (McDaniel, Agarwal, Huelser, McDermott, & Roediger, 2011), and social studies (Roediger, Agarwal, McDaniel, & McDermott, 2011), as well as college students' learning of psychology (McDaniel, Anderson, Derbish, & Morrisette, 2007; McDaniel, Wildman, & Anderson, 2012), chemistry (Pyburn, Pazicni, Benassi, & Tappin, 2014), and biology (Carpenter et al., 2016).

A timely question for educational research is how to optimize the benefits of retrieval. Toward this goal, some research has explored the effects of asking students questions at different times during learning. Typical studies on retrieval practice provide students with questions *after* they are presented with something to learn. However, it can also be beneficial to ask students questions *before* they learn something. Though somewhat counterintuitive, asking students questions about the material prior to a lesson or reading assignment—even if students get those questions wrong and do not receive corrective feedback at the time—produces significant enhancements in later memory for that material. Most studies on this "prequestion effect" have explored these effects on memory for reading material, showing that students who answer prequestions before reading a passage score higher on a later test over that passage, compared with students who read the passage without answering prequestions first (e.g., Bull & Dizney, 1973; Little & Bjork, 2016; Pressley, Tanenbaum, McDaniel, & Wood, 1990; Richland, Kornell, & Kao, 2009; Rickards, 1976; Rickards, Anderson, & McCormick, 1976).

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Prequestions may enhance learning because they provide students with a preview that helps them organize the material (e.g., Hannafin & Hughes, 1986; Mayer, 1984), because they arouse curiosity about the to-be-learned material (e.g., Berlyne, 1954, 1962; Bull & Dizney, 1973), or because they provide students with a clear sense that they do not already know the material, which may reduce overconfidence and improve learning in an indirect way by increasing the effort expended during encoding (e.g., Bjork, Dunlosky, & Kornell, 2013). Through a potential variety of non-mutually exclusive submechanisms, therefore, the primary means by which prequestions are believed to enhance memory is through enhanced attentional processing at the time of encoding.

Prequestions would seem to be a valuable educational tool that can engage students' attention to what they are learning. In particular, asking students a question at the beginning of a class lesson might help them know what to look for in that day's lesson, and subsequently enhance their capacity to focus on and retain the information that was taught that day. As it stands, however, the effects of prequestions on lecture-based learning are not well-understood, as these effects have typically been explored using reading passages as stimuli. However, results from the limited research on video-recorded lectures suggests that prequestions might have broad benefits on memory. In one recent study (Carpenter & Toftness, 2017), students viewed a brief 2-min video presentation on the history of Easter Island, and then took a test over the information from the video. One group (the prequestion group) answered prequestions about the video prior to viewing it (e.g., "How many families originally settled on the island of Rapa Nui?"), and the other group (the control group) viewed the video and completed the same final test at the end, without answering any prequestions first. On the final test following the video, the prequestion group outperformed the control group. Furthermore, the prequestion group scored higher than the control group on the details from the video that were asked about in the prequestions (i.e., prequestioned information), as well as other details from the video that were not asked about in the prequestions (i.e., nonprequestioned information). For example, if students were asked a prequestion about how many families originally settled on the island of Rapa Nui, they later remembered this information better, along with other information from the video that was not prequestioned (e.g., "What was the purpose of building to Moai?"), relative to students who did not answer any prequestions. It appears, therefore, that prequestions may increase the overall amount of information retained from a lecture or presentation, including both information that was specific to the prequestions and information that was not.

Research has not yet systematically explored the effects of prequestions in classroom environments, however. There are important theoretical reasons to expect that the benefits of prequestions may be attenuated in realistic lecture settings. In particular, if prequestions serve to enhance attentional processing, then the benefits of prequestions may be most likely to occur over fairly short time intervals, such as the 2-min videos used by Carpenter and Toftness (2017). When the duration of a learning episode is longer (e.g., a classroom lecture), the enhanced attentional processing driven by prequestions may not last the duration of the learning episode, rendering the general benefits of prequestions less apparent. Though difficulty sustaining attention over the course of a lecture may lead to difficulties remembering general information from the lecture (i.e., nonprequestioned information), the specific information that was prequestioned at the beginning of class may be relatively more familiar to students and easier to recognize when it occurs. As such, the benefits of prequestions in a classroom environment may be specific rather than general, applying primarily to prequestioned information rather than nonprequestioned information.

In the only known classroom study to explore the effects of prequestions, McDaniel et al. (2011) presented middle-school science students with a number of prequestions in class prior to starting a lesson over that topic. At the end of the lesson, students were shown those same questions again, along with never-before-seen questions from the same topic—that is, prequestioned information and nonprequestioned information, respectively. Though memory for prequestioned information was only slightly (and not significantly) better than memory for nonprequestioned information in one experiment (78% vs. 76%, respectively), it was significantly better in a second experiment (84% vs. 79%, respectively). Relative to laboratory experiments, therefore, prequestions may not have strong and consistent effects in the classroom.

However, it is worth noting that the students in McDaniel et al.'s (2011) study always received prequestions. Due to the constraints inherent in collecting data in a real classroom, along with the fact that prequestions were a part of the normal routine for this particular course, the study did not include a control group for whom prequestions were intentionally withheld. Thus, it is unknown how memory for prequestioned and nonprequestioned information would fare in comparison to a group of students in the same class who learned the same material but did not receive prequestions first. The lack of difference in memory for prequestioned versus nonprequestioned information in one experiment (78% vs. 76%) could mean that prequestions did not enhance memory for the information. Or, it could mean that prequestions enhanced memory for *both* prequestioned and nonprequestioned information, but this effect was not detectable without a control group.

Thus, there is a need for more classroom-based research on the effects of prequestions. Important questions to address include (a) whether students who answer prequestions, relative to students who do not answer prequestions, learn course material better, and (b) whether these benefits apply only to information that was prequestioned, or more broadly to information that was both prequestioned and nonprequestioned.

In the current study, we explored the effects of prequestions in an introductory psychology course by comparing lecture-based learning of students who received prequestions versus students who did not. Students within the same class were randomly assigned to answer prequestions about the upcoming topic (the prequestion group) or to not answer prequestions (the control group). At the end of class, all students answered questions pertaining to the topic that had just been taught. For the prequestion group, half of the questions at the end of class were prequestions that students had seen before, and half of the questions were new, never-before-seen questions from the same lesson. Previous research on prequestions in laboratory settings has shown that students in the prequestion group outperform those in the control group (Carpenter & Toftness, 2017; Pressley et al., 1990; Richland et al., 2009). For reasons outlined earlier, however, whether this benefit is general or specific in a classroom setting is not altogether obvious.

An additional question explored in the current study was whether prequestions can boost the benefits of retrieval practice. When students answer a question at the beginning *and* end of class, is later memory for this information stronger compared with information that was tested only at the end of class? Consistent with a large number of studies on retrieval practice (e.g., Carpenter, 2012; Dunlosky et al., 2013; Kornell & Vaughn, 2016; Rowland, 2014), we expected that information tested at the end of class would be better remembered than information not tested at all. Whether previewing the question ahead of time enhances this effect is unknown, however. In McDaniel et al.'s (2011) study, a follow-up review that occurred just prior to the exam indicated that information tested at the beginning *and* end of a lesson was remembered best, followed by information tested only at the end, followed by information from that lesson that had not been tested at all. However, lack of a control group again precludes any definitive conclusions about whether the effects of retrieval practice are stronger in a group of students who first received prequestions versus a group that did not. Thus, in the current study we compared delayed retention on a follow-up quiz for information that had been tested at the end of class versus information from the same lesson that had not been tested—that is, the basic retrieval practice effect—and compared the size of this effect for the prequestion group versus the control group.

Method

Students and Course

The study was conducted in an introductory psychology laboratory course over two semesters. The course was taught by four graduate student instructors and organized into small sections of approximately 20 students each. Each instructor taught two sections of the course during one semester, and one section of the course the following semester. Total enrollment across the 12 sections was 230 students.

Each section met once per week for 100 min and covered material pertaining to topics such as research design, sensation and perception, memory, and personality. The course content (including all PowerPoint slides, homework assignments, and projects) was prepared in advance by the faculty course coordinator and was identical across all sections. Students' grades in the course were based on a series of homework assignments, in-class activities, and projects. There were no exams. Information relevant to each day's lesson was provided by the instructors via handouts or in-class exercises, and these were not made available to students ahead of time. As such, the course was structured in a way that outside exposure to the content before class was minimized, and with no exams in the course there was no clear incentive for students to be studying the information on a general basis. The study protocol was reviewed by Iowa State University's Institutional Review Board and determined to be exempt.

Materials and Design

The objectives of the study were to measure the effects of prequestions on immediate retention of course content, and to determine whether prequestions enhance the effects of retrieval practice. Within each class section, students were randomly assigned to either receive prequestions at the beginning of class (the prequestion group), or to not receive prequestions (the control group). To explore immediate retention, the prequestion group answered a question at the beginning of class pertaining to a concept that they would learn about in that day's class. The same question was repeated at the end of class, along with another never-before-seen question from the same lesson. The control group did not answer any questions at the beginning of class, but instead answered two questions at the end of class. This aspect of the design is similar to previous studies exploring prequestions in laboratory-based research (Carpenter & Toftness, 2017). A comparison of performance on the end-of-class questions between the prequestion group and control group allowed us to measure the effects of prequestions on immediate retention of prequestioned and nonprequestioned information.

To explore the potential effects of prequestions on retrieval practice, a review quiz was given at the beginning of the next class period (one week later) containing the same two questions that students answered at the end of class one week prior, in addition to one never-before-seen question from the same lesson. For students in the prequestion group, one of the three questions had been seen twice during class one week prior (once at the beginning of class, and once at the end), and one question had been seen only once (at the end of class). For students in the control group, two of the questions had been seen at the end of class. A comparison of performance between questions asked at the end of class one week prior versus questions not asked at all allowed us to measure the effects of retrieval practice on delayed retention of course concepts. A comparison of performance between questions asked at the beginning *and* end of class one week prior (i.e., prequestions) versus only at the end, allowed us to explore whether the effects of retrieval practice are enhanced by giving students a chance to preview the questions at the beginning of class.

This design required three questions to be constructed from each day's lesson. The questions required a short open-ended response, and were designed to cover independent concepts such that knowing the answer to one question would not give away the answer to another. All of the questions pertained to material that was fairly directly presented in the instructors' PowerPoint presentations, oftentimes representing a term or definition (e.g., "What is procedural memory?") that was introduced and discussed that day. The concepts addressed in the questions were discussed in class but were never directly utilized for any of the homework assignments, nor did they appear in any reading assignments outside of class, reducing the chances that students would reencounter the information outside of class or that it would affect their grades on course-related assessments.

For students in the prequestion group, one of the three questions was designated as the prequestion, to be asked at the beginning and end of class. Another question was designated as the new question, asked only at the end of class. The last question was designated as the quiz-only question, which was asked only on the review quiz one week later. For students in the control group, two of the three questions were designated as new questions, to be asked at the end of class, and the third question was designated as the quiz-only question. Thus, all students received two questions at the end of each class. The only difference was that the prequestion group saw one of these questions at the beginning of class and the control group did not. For all students, the same two questions from the

end of class appeared, along with the quiz-only question, on the review quiz one week later.

This design entailed answering questions at the beginning and end of every class period. These activities were introduced to students as "Orientation Activities" and "Consolidation Activities," respectively, that were designed to help them learn the course material. Figure 1 provides a schematic of the design for the first two weeks of the semester. For the first class meeting, the orientation activity required students to answer some questions about their interests in psychology, and for students in the prequestion group, to answer the prequestion pertaining to that day's lesson. The consolidation activity at the end of class required all students (both prequestion and control groups) to answer two questions pertaining to that day's lesson.

For each subsequent class meeting, the orientation activities involved answering the three questions from the previous week's class. After answering these three questions, students in the prequestion group were informed that they would be given a question pertaining to the upcoming lesson for that day, and then answered the prequestion pertaining to that lesson. This process was repeated across all subsequent class periods—the three questions from the previous week's lesson appearing at the beginning of class, followed by the prequestion over the upcoming lesson (for the prequestion group but not for the control group), followed by the instructor's lesson, followed by two questions at the end of class over the lesson that was just taught (see Figure 1). Students received participation credit for completing the orientation and consolidation activities, regardless of the correctness of their answers.

For students in the prequestion group, six counterbalancing conditions were created so that each of the three questions from each lesson appeared equally often as the prequestion, the new question, and the quiz-only question. For students in the control group, three counterbalancing conditions were created so that each of the questions appeared equally often as new questions and quiz-only questions. Within each class section, each student was randomly assigned to one of the nine counterbalancing conditions. This way, any potential effects of the questions themselves were balanced across sections and instructors.[1]

Procedure

Students completed the orientation and consolidation activities individually on laptop computers that were provided. To complete the activities, students logged into the online course management system and were provided with a link that displayed the questions according to the specific counterbalancing condition to which they were assigned. Instructions on the screen informed students that these activities were designed to help them learn the course content, and that they should try their best to answer the questions even if they were uncertain about the answers. The instructions also asked students to complete the activities individually, without help from books, notes, or classmates. The course instructors monitored the class during the activities to ensure that these instructions were followed.

Consistent with previous research on prequestions (e.g., Carpenter & Toftness, 2017; Little & Bjork, 2016; Richland et al., 2009), students in the prequestion group did not receive feedback after answering the prequestion. After submitting their answers to the prequestion, students were informed via instructions on the screen that the answer to the question would be provided during the lesson that day. On the consolidation activity at the end of class, students were informed via on-screen instructions that they would be asked some questions over the lesson that was just taught. After answering each of the two questions, one at a time, students were shown a screen with both of the questions and answers displayed together. They were permitted to view this screen as long as they liked, although students typically completed the consolidation activity in under five minutes. On the review quiz the following week, on-screen instructions informed students that they would be asked some questions about the previous week's lesson. Students answered each of the three questions, one at a time, without receiving feedback. Students in the prequestion group were then given the prequestion over the upcoming lesson, accompanied by the instructions that this question pertained to a concept to be covered in that day's class. Thus, questions on the orientation activities never received feedback, whereas questions on the consolidation activities always did.

Access to the orientation and consolidation activities was only permitted during class time. The online link to the orientation activity was made available at the start of class, and the instructors prompted students to complete the activity before they began teaching the lesson for that day. After students completed the orientation activity (which typically took under 10 min), the online link was no longer available, and the instructors proceeded with the lesson. The link to the consolidation activity was made available toward the end of class. As soon as the lesson was complete, the instructors prompted the students to complete the consolidation activity. After class ended, the link to the consolidation activity was no longer available. Though the instructors' PowerPoint slides were shared on the online course management system after each class, the questions used in the orientation and consolidation activities were not made available to students outside of class.

Our primary interest was the effect of prequestions on lecture-based learning. Therefore, we chose seven "target" class meetings that consisted of lecture presentations. The other class meetings consisted primarily of hands-on activities without direct presentation of information from the instructors. These hands-on activities included, for example, completing peer reviews of one another's research papers, performing literature searches, or completing in-class data collection activities for research projects. Focusing the analyses on the seven target classes allowed us to measure the effects of prequestions specifically on retention of lecture-based information, consistent with the goals of the study and with the methods used in previous research on prequestions (Carpenter & Toftness, 2017; McDaniel et al., 2011).

[1] More counterbalancing conditions in the prequestion group relative to the control group (six vs. three, respectively) resulted in a greater overall number of students in the former than in the latter, but ensured that the questions themselves were balanced across question types and the number of students in each counterbalancing condition was evenly distributed across the different class sections. For the outcome measures that were common to both groups (i.e., performance on new questions and quiz-only questions), mean performance on the same set of items learned was highly comparable between the prequestion group and the control group, suggesting that differences in sample size did not coincide with differences in performance outcomes.

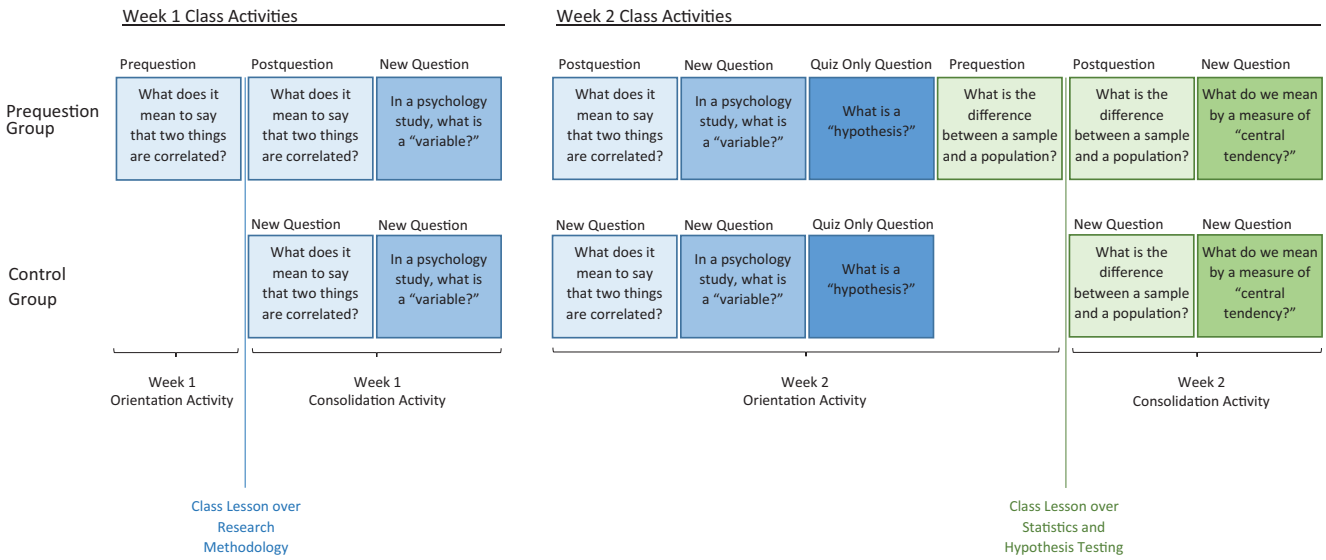

Figure 1. Class activities throughout the semester for the prequestion group and the control group. At the beginning of each class following Week 1, all students answered three questions from the previous week's class. The prequestion group, but not the control group, answered one additional question pertaining to a concept they were about to learn in the upcoming lesson. The instructors then commenced with class, and at the end of class all students answered two questions pertaining to the lesson that was just taught. This process repeated over the course of 12 weeks. See the online article for the color version of this figure.

To establish a consistent routine, students completed the orientation and consolidation activities at the beginning and end of every class. This routine was implemented over the first 12 weeks of the course, after which students worked on independent research projects for the remaining three weeks of the semester. Only data from the seven target class meetings were scored and analyzed.

Results

Scoring

Data were analyzed for students who completed the course and completed the orientation and consolidation activities associated with at least one of the seven target classes. Of the original 230 students enrolled, five students dropped the course, and two students did not complete enough activities to provide an analysis of the data from at least one orientation and consolidation activity. The following analyses are based on the remaining 223 students in the prequestion group ($n = 150$) and the control group ($n = 73$).

Students' responses to each question were scored as fully correct (2 points), partially correct (1 point), or incorrect (0 points). A scoring rubric was developed and applied in blind fashion by two independent raters to all of the responses from 58 students chosen at random (26% of the entire sample). In the prequestion group, the interrater correlations were positive for performance on the prequestions at the beginning of class ($r = .83$) and at the end of class ($r = .88$), and for the new questions at the end of class ($r = .75$). The correlations were positive as well for scores on the review quiz pertaining to prequestions ($r = .84$), new questions ($r = .70$), and quiz-only questions ($r = .70$). In the control group, correlations were positive for performance on the new questions at the end of class ($r = .84$), and for new questions and quiz-only questions on the review quiz ($rs = .87$ and .82, respectively). All correlations were significant, $ps < .001$, so the remaining responses were scored in blind fashion by a single rater who continued to apply the same scoring rubric.

Performance was calculated based on the number of points earned on each of the question types (prequestions, new questions, and quiz-only questions), out of the total number of points possible per question type. For students who completed the orientation and consolidation activities pertaining to all seven target classes, 14 points were possible for each question type (i.e., 2 points per question). For students who did not complete the activities for all seven classes, scores were calculated based on the activities that they did complete, under the constraint that all questions were completed for a given topic. For example, if a student completed the lecture-based questions for Week 1, but missed the review quiz the following week containing questions from Week 1, no questions from Week 1 were included in any of the analyses for that student. If a student completed the orientation activity but missed the Consolidation Activity for a given topic, then no questions from that topic were included in any of the analyses for that student. As such, only topics with a complete "question set" (i.e., receiving answers on all of the lecture-based questions and review quiz questions pertaining to that topic) were included.[2] This way, an individual student's scores on the immediate retention test (at the end of class) and the delayed retention test (one week later) were always based on the same material.

[2] All of the analyses were repeated after including only the students who completed the activities for all seven target classes ($n = 79$ students in the prequestion group, and $n = 45$ in the control group), and the same pattern of effects emerged.

The completion rate for the activities was fairly high. On average, students completed all of the orientation and consolidation activities for 6.18 topics (out of the total 7), and this completion rate did not differ between the prequestion group ($M = 6.15$, $SD = 1.22$) and the control group ($M = 6.26$, $SD = 1.25$), $t(221) = .65$, $p = .52$.

The Effects of Prequestions on Immediate Retention

Figure 2 shows the proportion of points earned on the lecture-based questions for both the prequestion group ($n = 150$) and the control group ($n = 73$). For students in the prequestion group, performance on the prequestion at the beginning of class and at the end of class are denoted by the labels "Prequestion" and "Postquestion," respectively. For the prequestion group, performance improved significantly from the prequestion to the postquestion, $t(149) = 17.58$, $p < .001$, $d = 1.44$, indicating that students' knowledge of the content significantly improved during class. Even though the correct answer was not provided at the time of the prequestion, students were able to discover that answer during class and remember it when the same question was repeated at the end of class.

Figure 2 also shows that students remembered prequestioned information better than nonprequestioned information. For students in the prequestion group, performance at the end of class was higher on the postquestions compared with the new questions, $t(149) = 3.73$, $p < .001$, $d = .31$. This demonstrates that students who receive prequestions at the beginning of class perform better at answering those same questions later, compared with new, never-before-seen questions from the same lesson.

To examine whether the effects of prequestions are general or specific, we compared performance at the end of class in the prequestion group for both prequestioned and nonprequestioned information, versus performance in the control group. The prequestion group showed better performance than the control group for prequestioned information. That is, they performed better on postquestions than the control group did on new questions, $t(221) = 2.29$, $p = .02$, $d = .33$. However, for nonprequestioned information (i.e., new questions), there was no difference in performance between the prequestion group and the control group, $t(221) = .50$, $p = .62$, $d = .07$. It appears, therefore, that the benefits of prequestions applied only to information that was prequestioned, and did not spread to other information from the same lesson that was not prequestioned.

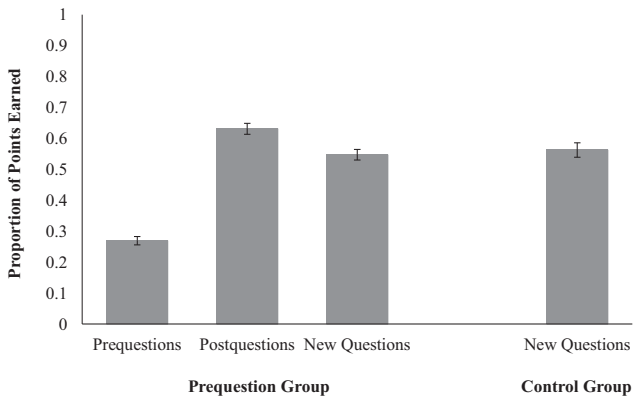

Figure 2. Proportion of points earned on the lecture-based questions for both the prequestion group and the control group. In the prequestion group, knowledge of the information in the prequestion significantly improved from the beginning of class to the end (prequestions vs. postquestions), and these students learned the prequestioned information better than the nonprequestioned information (postquestions vs. new questions). However, nonprequestioned information was not learned any better for students who received prequestions versus students who did not (new questions for the prequestion group vs. the control group). Error bars represent standard errors.

The Effects of Prequestions on Retrieval Practice

Figure 3 shows performance on the review quiz for both the prequestion group and the control group. For this phase of the study we were interested in two questions: (1) Does asking questions at the end of class enhance memory for course concepts, consistent with the benefits of retrieval practice? And (2) Do prequestions provided at the beginning of class boost this effect?

The first question can be answered by comparing performance on the new questions to the quiz-only questions. This difference was significant for both the prequestion group, $t(149) = 3.21$, $p = .002$, $d = .26$, and the control group, $t(72) = 2.91$, $p = .005$, $d = .34$. Thus, asking questions over a lesson at the end of class (and receiving feedback) significantly enhanced memory for that information one week later.

Is this effect enhanced by allowing students to preview the questions at the beginning of class? In the prequestion group, performance on the prequestions was significantly higher than performance on the quiz-only questions, $t(149) = 5.73$, $p < .001$, $d = .47$, and was also higher than performance on the quiz-only questions in the control group, $t(221) = 3.18$, $p = .002$, $d = .46$. However, in the prequestion group performance on the prequestions relative to the new questions was only marginally better, $t(149) = 1.89$, $p = .06$, $d = .15$, and was not significantly better than performance on the new questions in the control group, $t(221) = 1.02$, $p = .31$, $d = .15$. Thus, although asking questions at the end of class significantly boosted later memory for those concepts—that is, a retrieval practice effect—previewing the questions at the beginning of class appeared to add little, if any, enhancement to this effect.

Discussion

The current results shed important new light on the effects of prequestions in real classroom settings. These results add to previous classroom investigations of prequestions (i.e., McDaniel et al., 2011) and extend our understanding of these effects by including a control group that allows a direct comparison of student learning following prequestions versus no prequestions. In the current study, students who answered prequestions over material they were about to learn—compared with students who did not answer prequestions—retained the information better at the end of class. However, unlike previous research using short lecture videos (Carpenter & Toftness, 2017), in the current study this benefit was specific to information that was prequestioned and did not occur for information from the same lesson that was not prequestioned.

In this way, prequestions had similar effects to what has been observed in studies using reading materials (e.g., Bull & Dizney,

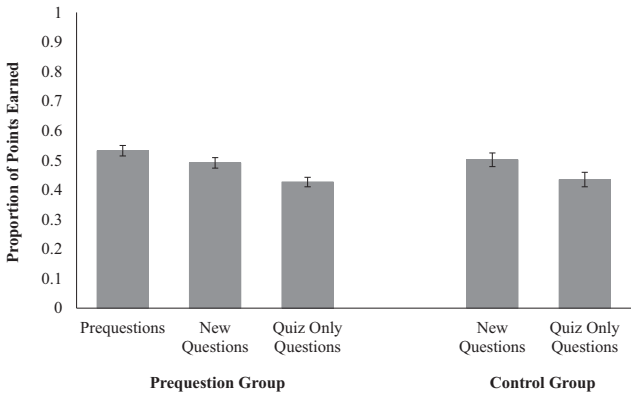

Figure 3. Proportion of points earned on the review quizzes for both the prequestion group and the control group. Both groups scored higher on information that was asked about at the end of class versus information that was not asked about (new questions vs. quiz-only questions), and this effect was comparable for the prequestion group and the control group. Error bars represent standard errors.

1973; Frase, 1968; Pressley et al., 1990; Richland et al., 2009; Rickards, 1976). Also consistent with results of these studies, students in the prequestion group retained prequestioned information better than nonprequestioned information. This benefit of prequestioned over nonprequestioned information is consistent with the classroom-based findings of McDaniel et al. (2011, Experiment 2b), and together with the results of the control group in the current study, add further evidence that the effects of prequestions in classroom-based learning appear to be specific rather than general.

Such a finding suggests that prequestions do not appear to enhance overall attentional processing of class lectures, unlike the general benefits that have been observed with short video presentations (Carpenter & Toftness, 2017). Why this is the case could likely be due to the duration of the material presented. Relative to a short 2-min video, a classroom lecture is much longer and could pose challenges for students' sustained attention. Even if a prequestion asked at the beginning of class arouses students' curiosity and interest, maintaining attention across a 100-min class period may be quite difficult. In contrast, noticing the relevant information from the prequestion when it appears in class may be easier because of the relatively greater familiarity associated with this information. Thus, when learning over educationally realistic durations of time, results of the current study suggest that the effects of prequestions may be specific rather than general.

The benefits of prequestions on classroom learning may be influenced by a number of additional factors that were not measured here. The dosage of the prequestions, for example, could coincide with the magnitude and specificity of these benefits. The current study provided only one prequestion per class lesson, which could have reduced the potency of prequestions, particularly on nonprequestioned information. Previous laboratory studies have often provided multiple prequestions prior to the learning episode (e.g., Little & Bjork, 2016; Peeck, 1970; Pressley et al., 1990; Richland et al., 2009), which could be one factor contributing to the larger effects of prequestions observed in these studies. Including prequestions over multiple concepts to be covered in a class lecture could increase their overall effectiveness on learning, and depending on how the concepts are distributed throughout the lecture, could increase their effects on nonprequestioned information as well. Based on laboratory research showing benefits of prequestions on memory for related but nonidentical information (Little & Bjork, 2016), designing prequestions to tap multiple related concepts from a lecture may also increase their general effectiveness for classroom learning.

Do prequestions boost the effects of retrieval practice? On the review quiz one week after covering a given topic, we found that information was best retained if it had been asked about at the beginning and end of class, followed by information asked only at the end of class, followed by information from the same lesson that was not asked about previously at all. Such results are consistent with those of McDaniel et al. (2011), who found that on a review just prior to an exam, information was best retained if asked about at the beginning and end of a lesson, followed by information asked about just at the end of the lesson, followed by information that appeared only on the review. Including the control group, the current study was able to answer the question of whether these effects differed for students who received prequestions versus students who did not. We found that information asked about at the end of class was better retained one week later compared with information that was not asked about in class—that is, the common effect of retrieval practice (e.g., Carpenter, 2012; Dunlosky et al., 2013; Kornell & Vaughn, 2016; Rowland, 2014). However, this benefit was not stronger for the prequestion group (49% vs. 43%, $d = .26$) compared with the control group (50% vs. 44%, $d = .34$). In fact, over the 1-week retention interval it appears that more forgetting occurred for information that had been prequestioned compared with information that had not. In the prequestion group, the drop in performance from the end-of-class questions to the review quiz was actually greater for information that had been prequestioned (62% vs. 53%, a 14% drop in performance) compared with information that was tested at the end of class only (55% vs. 49%, an 11% drop in performance).

The benefits of retrieval practice add to a growing literature demonstrating these effects in classroom settings (e.g., Carpenter et al., 2009; Carpenter, Lund, et al., 2016; Jaeger et al., 2015; Karpicke et al., 2014; McDaniel et al., 2007, 2011, 2012; Pyburn et al., 2014; Roediger et al., 2011). However, no strong evidence occurred that these effects are enhanced by prequestions. Practical advice to instructors, therefore, may be to save time by withholding questions at the beginning of class and reserving them for a later time, such as at the end of class or at intermittent points during the lecture (e.g., see Szpunar, Jing, & Schacter, 2014, for beneficial effects of interpolated testing).

In the current study, the effects of prequestions per se were specific to immediate retention of material at the end of class. These results therefore cannot speak to the effectiveness of prequestions for enhancing delayed retention. Because prequestions were always combined with retrieval practice, the current study also leaves open the question of how delayed memory retention is affected by questions that are asked only at the beginning of a lesson versus only at the end. McDaniel et al. (2011) found that on a review just prior to the unit exam, information that had been prequestioned was not retained better than information that had not been previously tested at all, and information that had been tested only at the end of class lessons (i.e., postlesson questions) was

retained as well (Experiment 2a) or better (Experiment 2b) than information that had been tested only at the beginning of the lessons (i.e., prelesson questions). This suggests that prequestions do not appear to benefit delayed memory performance, and placing questions before a lesson, relative to afterward, may not be advantageous for delayed retention. Of particular importance, the placement and frequency of questions did not matter for unit exams, where prequestioned information again was not retained better than untested information, and information tested via prelesson and postlesson questions was not retained better than information tested via postlesson questions alone. Thus, prequestions did not enhance the benefits of retrieval when unit exams were the outcome measure—a finding similar to the current study where we used low-stakes review quizzes. This research suggests that prequestions may have limited effects in classroom settings, especially over delayed retention intervals and on ecologically valid outcome measures.

Further research on the effects of questions in the classroom is needed, as these results provide only a beginning to understanding the complex and multifaceted ways in which learning occurs in real classroom settings. In the current study, the content being learned was fairly controlled such that the information in the experimental questions was clearly presented in the instructors' lessons (i.e., often a term or definition directly referred to in the PowerPoint slides), and out-of-class exposure to the information was assumed to be minimized by virtue of the fact that the information relevant to our experimental questions was not directly needed for homework assignments and did not appear in any out-of-class readings or other course materials. Such conditions allowed us to measure these effects under fairly controlled conditions as far as classrooms are concerned.

Notwithstanding the importance of methodological rigor in classroom-based studies, these research questions deserve further attention under more ecologically valid classroom conditions as well. When students do have access to the information outside of class, or learn about it in required reading prior to class, what are the effects of prequestions? Do prequestions under these conditions enhance the effects of retrieval practice? Do these effects depend upon individual differences in student knowledge of the material, out-of-class preparation, academic achievement, and other factors? Are there "warm up" effects such that students learn more from prequestions if they are more accustomed to receiving them? Current research underway has begun to explore these questions in diverse undergraduate courses in the science and engineering disciplines, with particular emphasis on how individual differences might account for variance in the effectiveness of prequestions (e.g., Carpenter, Rahman, et al., 2016).

In summary, providing students with questions over their course content produces significant benefits on learning. Optimizing the benefits of these questions, however, will require further research that explores the effects of such factors as timing of the questions, different types of questions, methods of feedback, and complexity of the material being learned. Further investigations in real classrooms will reveal important information about the real-world effectiveness and durability of learning principles that hold great promise for enhancing educational outcomes, but have yet to be widely implemented in classroom settings.

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