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Prequestions Enhance Learning, but Only When They Are Remembered

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Answering prequestions benefits learning, but this benefit is mostly specific to material that was relevant to the prequestions (prequestioned material) and does not extend to other, nonprequestioned material. The current study examined whether this specific benefit is due to selective processing of prequestioned information during a learning experience. In 4 experiments, participants were assigned to a prequestion group or control group before viewing a 30-min video lecture. In Experiment 2, participants were instructed to take notes on information they thought was important during the video; in Experiment 3, the prequestion group was instructed to write down the answers to the prequestions; and in Experiment 4, the prequestion group was given the prequestions and instructed to answer them while viewing the video. On a later posttest in all experiments, the prequestion group outperformed the control group, but only for prequestioned material. Further, this benefit only occurred when the prequestion group successfully discovered the answers to the prequestions during the video by writing them down (Experiments 2 and 3) or circling them (Experiment 4). These results suggest that prequestion benefits depend on the degree to which participants can successfully notice and discover the answers to the prequestioned material during a video lecture.

Public Significance Statement
Asking students questions before they learn something is beneficial, but this benefit tends to be highly specific. Here we show that prequestions have significant but limited benefits on learning by focusing participants' attention on the prequestioned material that they can successfully remember and discover the answers to while viewing a video lecture.

Keywords: prequestions, testing, memory, education, learning

Testing students' knowledge of material they are learning is most intuitively viewed as a means of measuring their learning. However, answering test questions does more than just measure learning, in that retrieving information for a test actually enhances learning to a greater degree than restudying it (Carpenter, 2012; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Kornell & Vaughn, 2016; Roediger & Karpicke, 2018; Rowland, 2014). This *testing effect* is quite robust, indicating that in addition to its utility in assessment, testing can enhance learning.

In a similar way, although giving students questions *before* they learn something might be viewed primarily as a method of gauging what students already know prior to a lesson, there is evidence that these "prequestions" can also enhance learning. For example, Richland, Kornell, and Kao (2009) manipulated whether or not participants answered prequestions before studying a short prose passage about colorblindness. In the prequestion group, participants began the experiment by answering a set of prequestions (e.g., "What color is tomato juice to Mr. I?") before they studied the passage. Even though it was unlikely that participants would know the answers to the prequestions (because they had not yet learned the material), they were encouraged to provide their best guess for each prequestion. By contrast, the control group did not answer any prequestions and instead began the experiment by simply studying the prose passage. Following the opportunity to read the passage, participants in both groups completed a posttest for the passage. For the prequestion group, the posttest comprised the original set of test questions they answered as prequestions (i.e., prequestioned material), along with other previously unseen test questions about the passage (i.e., nonprequestioned material). Because participants in the control group did not answer any prequestions, all of the questions on the posttest assessed nonprequestioned material.

Richland et al. (2009) showed that, overall, the prequestion group performed better on the posttest compared with the control group; however, these learning benefits were item specific, such that the prequestion group outperformed the control group on the

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prequestioned material but showed neither a benefit nor detriment compared with the control group on the nonprequestioned material. Such a finding suggests that the benefits of answering prequestions are specific to those questions that have been encountered previously. The specific benefit for prequestioned material and not for nonprequestioned material has been replicated by other studies employing similar prose-passage materials (Bull & Dizney, 1973; Hausman & Rhodes, 2018; James & Storm, 2019; McCrudden, Schraw, & Kambe, 2005; Memory, 1983; Pressley, Tanenbaum, McDaniel, & Wood, 1990; Rickards, 1976; Rothkopf & Billington, 1979).

Recent studies have begun to explore whether answering prequestions might benefit learning from video lectures and presentations as well. Using short 2-min video segments, Carpenter and Toftness (2017) assigned participants to a prequestion group that answered prequestions before watching the video segments or to a control group that viewed the same video segments without answering prequestions. On an immediate posttest, the prequestion group scored higher than the control group on both the prequestioned and nonprequestioned material. These findings suggest that prequestions might be a useful tool to enhance broad learning of information from videos or lectures.

However, follow-up studies show that the benefits of answering prequestions are weaker when using longer lecture videos that are more educationally realistic. Toftness, Carpenter, Lauber, and Mickes (2018) investigated prequestion effects when participants were asked to watch longer videos (e.g., 20 min) that better approximate the length of actual classroom lectures. Across two experiments, the findings demonstrated specific benefits of prequestions, showing enhanced learning for prequestioned material but not for nonprequestioned material (see also James & Storm, 2019, Experiment 5). A recent classroom study, in which the lecture was delivered by an instructor in an actual course, demonstrated similar effects, showing that prequestions enhanced later memory only for prequestioned material (Carpenter, Rahman, & Perkins, 2018).

The apparent limitations of prequestions under ecologically valid lecture conditions raise some uncertainties about their utility to enhance learning in real educational settings. The reasons why prequestions have limited benefits under these conditions are currently unknown but important to ascertain. Explaining the effects of prequestions on lecture-based learning depends on a thorough understanding of the processing that students engage in while learning from prequestions. Specifically, in order to learn from prequestions, students need to execute a number of steps successfully, including (a) remembering the prequestions during the lecture, (b) noticing the information in the lecture that is relevant to those prequestions, and (c) discovering the answers to the prequestions during the lecture. This sequence of steps may be harder to complete for longer and more authentic lectures compared with the brief 2-min video segments in the study by Carpenter and Toftness (2017).

This idea has yet to be empirically tested, however. When using prequestions to learn from authentic lecture videos, how easily can each of these steps be carried out? Do students have difficulty remembering the prequestions in the first place? Do they remember the prequestions but fail to notice the answers during the lecture? Or do they remember the questions and discover the answers but forget them by the time the test comes? Because effective solutions depend on a precise understanding of the problem, pinpointing where the learning difficulties occur is a critical step in understanding the effectiveness of prequestions as a learning tool.

The purpose of the current study was to explore the effects of prequestions on learning from authentic lecture videos as a function of how well participants processed the prequestioned material. Across four experiments, participants viewed an authentic lecture video, either receiving prequestions beforehand (the prequestion group) or not (the control group), and then completed a posttest over the video. Experiment 1 was conducted to determine whether the typical prequestion effect occurred with these materials. Experiment 2 explored the degree to which participants noticed information that was relevant to those prequestions while viewing the video, by instructing all participants to take notes on the information they felt was important to learn while viewing the video. Experiment 3 further explored the degree to which the prequestion effect was driven by participants' memory for the prequestions and discovery of their answers during the video, by requiring the prequestion group to write down only information provided during the lecture that gave the answers to the prequestions they saw earlier. Finally, Experiment 4 provided participants with the prequestions during the video and explored the degree to which the prequestion effect was driven by successful discovery of the answers without the need to remember the prequestions themselves. Collectively, these experiments address the important unanswered questions of how well participants can remember, notice, and discover the answers to prequestions while learning from video lectures and the degree to which each of these processes contributes to the benefits of prequestions.

Experiment 1

In Experiment 1, participants viewed a 31-min video-recorded lecture on information theory and then completed a 30-item multiple-choice test over the video (from Toftness et al., 2018). The video had not been used in any previous research on prequestions but was well suited for the current research questions because of its authentic material and duration. Participants were randomly assigned to either a prequestion group (receiving 15 prequestions prior to the video) or a control group (receiving no prequestions) and then completed the 30-item posttest after viewing the video. If prequestions produce specific—but not general—benefits on learning from authentic lecture videos, then final test performance should reveal an advantage for the prequestion group over the control group, but only for the 15 items that were previously prequestioned.

Method

Participants. In total, 122 introductory psychology students (60% female, 40% male) at Iowa State University participated in exchange for partial fulfillment of course requirements, as approved by the university's institutional review board.

Materials. The video lecture contained slides displaying the material on information theory, along with an inset of the instructor in the lower-right corner of the screen (for more details on the video and source, see Toftness et al., 2018, p. 4). The video format was, thus, similar to a classroom instructor delivering a lecture

while presenting lecture slides. Thirty fact-based multiple-choice questions over the content in the video lecture were included (e.g., "How many bits of information does a megabyte contain?"). Each question could be answered directly from the video material, and the information needed to answer it was clearly and directly presented by the instructor such that learning the answer to any question did not require participants to form any inferences. All test questions were presented with four answer options (e.g., "A. 8 million"; "B. 1 million"; "C. 8,000"; "D. 1,000"), of which only one was correct. The test questions, answers, and raw data for all experiments can be found at https://osf.io/7qjn2.

Design and procedure. Participants were randomly assigned to either the prequestion group (n = 60) or the control group (n = 62). Each participant assigned to the prequestion group began the experiment by answering 15 of the test questions at random before watching the video lecture, then later answered the whole set of 30 test questions during the posttest. By contrast, participants assigned to the control group did not answer any prequestions and only answered the 30 test questions during the posttest.

Participants completed all experimental tasks on individual computers and viewed the video while wearing headphones. At the beginning of the experiment, participants in both groups were told that they would be watching a video lecture and that their memory for the video would be assessed at the end of the experiment. Before watching the video, participants assigned to the prequestion group were given 15 of the questions, chosen at random for each individual. Participants were instructed to provide their best guess regardless of whether or not they knew the answers. The prequestions were presented one at a time, in a different randomized order for each participant. Consistent with the typical design of studies exploring prequestions, participants were not provided feedback of the correct answer after each prequestion but could glean the answers to the prequestions while they watched the lecture video. After answering all 15 prequestions, participants in the prequestion group began viewing the video. Participants in the control group began the experiment by simply viewing the video. The video was presented for the duration of the 31 min because the pause, rewind, and fast-forward features were not available.

At the end of the video, all participants completed a 5-min distractor task in which they answered a series of 28 unrelated trivia questions. Following the trivia task, participants completed the 30-item posttest for the video lecture. During the posttest, each question contained the four multiple-choice options, in addition to the fifth option, "I do not know," which participants could select instead of guessing. The order of the posttest questions was randomized for each participant, and feedback was not provided.

After finishing the posttest, all participants were asked to respond to a single-item multiple-choice question determining whether they had any prior knowledge of the video material. Participants chose one of the following options: "1. No, I did not have detailed prior knowledge of this information"; "2. I have heard of it before but did not know the details until today"; "3. I may have learned this information before, but I did not remember the details"; and "4. I learned this information before, and I remembered the details before coming to today's experiment." After answering this question, participants were thanked and debriefed. Altogether, the experiment lasted approximately 50 min.

Results

Data from 20 participants were excluded due to computer malfunctions and from 1 participant for a posttest score more than 2.5 standard deviations (*SD*) below the group mean. No participants reported having detailed prior knowledge of the material. The final sample included 47 participants in the prequestion group and 54 participants in the control group. The raw and summary data for all four experiments can be found at https://osf.io/7qjn2.

Pretest performance. Performance on the prequestions was 31% (SD = 13%), indicating low prior knowledge of the lecture material.

Posttest performance. Table 1 shows posttest performance for the prequestion group and the control group. For participants in the prequestion group, posttest performance was computed separately for the prequestioned and nonprequestioned material. Prequestioned material reflects scores on the 15 posttest questions that were originally presented as prequestions, and nonprequestioned material reflects scores on the 15 posttest questions that were not presented as prequestions. For the control group, performance reflects scores on all 30 posttest questions, all of which represent nonprequestioned material.

Participants in the prequestion group performed significantly better than the control group but only on the prequestioned material, $t(99) = 2.59$, $p = .011$, $d = 0.50$. For nonprequestioned material, there was no difference in posttest scores between the prequestion group and the control group, $t(99) = 0.81$, $p = .420$, $d = 0.19$. Thus, answering prequestions before watching the video only benefitted later memory for the specific material that was prequestioned.

Discussion

Experiment 1 showed that with authentic lecture materials, prequestions produced specific benefits on prequestioned material but not general benefits on nonprequestioned material. This finding is a conceptual replication of Toftness et al. (2018) and is consistent with other studies using authentic lecture videos in the laboratory (James & Storm, 2019) and actual lectures in the classroom (Carpenter et al., 2018). Having demonstrated the expected prequestion effect with the current materials, Experiment 2

Table 1
Overall Posttest Performance for Prequestioned and Nonprequestioned Material in the Prequestion Group and the Control Group for Experiments 1–4

		Posttest performance	
Experiment	Condition	Prequestioned material	Nonprequestioned material
1	Prequestion	.64 (.18)	.53 (.18)
	Control	—	.56 (.14)
2	Prequestion	.68 (.15)	.61 (.16)
	Control	—	.60 (.18)
3	Prequestion	.74 (.18)	.60 (.18)
	Control	—	.54 (.20)
4	Prequestion	.85 (.13)	.48 (.15)
	Control	—	.52 (.17)

Note. Standard deviations are given in parentheses.

was designed to explore whether answering prequestions might differentially influence which pieces of information participants noticed while watching a video lecture and how the noticing of this information might influence what they ultimately learned from the video.

Experiment 2

Experiment 2 used the same video materials and basic design from Experiment 1. This time, however, participants in both the prequestion group and control group were provided with a sheet of paper and pen while they watched the video and were instructed to take notes on the information they felt would be important to learn. This note-taking opportunity was incorporated to determine what kind of information participants noticed and considered important while viewing the video. Previous studies on prequestions (including Experiment 1) have shown that participants in the prequestion group perform better than the control group on posttest questions relevant to prequestioned information. However, it has not been determined whether this effect is driven by the tendency of the prequestion group to notice the prequestioned information more often than the control group. Thus, in Experiment 2, we explored whether participants in the prequestion group more often took note of prequestioned material than participants in the control group and to what degree posttest performance was dependent on the information that participants took note of while viewing the video

Method

Participants. In total, 105 new introductory psychology students (64% female; 36% male) from Iowa State University participated in exchange for partial fulfillment of course requirements.

Materials and design. As in Experiment 1, participants were randomly assigned to either the prequestion group or the control group. In the prequestion group, participants answered prequestions prior to viewing the video, as in Experiment 1. This time, however, participants in both groups were provided with a sheet of paper before viewing the video, and they were asked to write down information they thought might be important to learn for a subsequent memory test.

The same videos from Experiment 1 were used. Of the 30 test questions used in Experiment 1, six were removed in order to better facilitate the process and coding of participants' note-taking. More specifically, three of the questions were removed because the answers to these questions were presented in piecemeal across various different times throughout the video (e.g., "Which of these is NOT a unit of information measurement?"; the four answer options—"A. Boolean"; "B. Shannon"; "C. Binary unit"; "D. Bit"—were mentioned at multiple different times in the video). Discovering these answers would require noticing and writing down multiple pieces of information that could potentially complicate the coding of participants' written protocols. The remaining 27 questions could be answered from information that was clearly presented at just one point in time during the video.

We also ensured that the information in the video providing the answers to the different test questions occurred with enough time in between so that writing down the answer to one question would not interfere with noticing a critical detail for the answer to another test question. To accomplish this, the 27 remaining questions (after eliminating the 3 questions described previously) were ordered chronologically according to the time during which the information needed to answer each question appeared in the video. Two questions were removed because their answers occurred in close proximity to other chronologically adjacent questions, resulting in 25 questions. In order to achieve equal numbers of questions to serve as prequestioned and nonprequestioned material for the prequestion group, one additional question was eliminated at random, resulting in 24 total questions. For the prequestion group, each of the 24 chronologically ordered questions was then assigned to one of two counterbalancing conditions on an alternating basis. Thus, the final set of 24 questions contained two counterbalanced conditions with 12 prequestions each that pertained to content that was adequately spaced throughout the video. Within each counterbalancing condition, it was verified that the answers to each of the 12 questions occurred approximately 2–3 min apart in the video.

As in Experiment 1, participants were randomly assigned to either the prequestion group ($n = 53$) or the control group ($n = 52$). Within the prequestion group, participants were randomly assigned to one of the two counterbalancing conditions receiving one set of the 12 prequestions ($n = 26$) or the other set of 12 prequestions ($n = 27$). The control group received no prequestions prior to viewing the video.

Procedure. All participants were informed at the start of the experiment that they would be watching a video lecture on the computer followed by a test over the video at the end of the experiment. Participants assigned to the prequestion group were then presented with the 12 prequestions, one at a time and in a different randomized order for each participant. After participants in the prequestion group finished answering the 12 prequestions (and after participants in the control group finished reading the instructions), all participants were directed to a face-down sheet of paper on their desks. Printed on the sheet of paper were the following instructions: "While watching the video lecture, we would like you to take notes on this sheet of paper using the pen that is provided. Please pay careful attention to the lecture and take notes over the information that you feel is important to learn for an upcoming test." After reading these instructions, participants in both groups began to watch the video lecture and take notes.

Once the video lecture ended, participants' note sheets were collected by the experimenter, and participants were directed to the same 28-item trivia distractor task from Experiment 1. After the trivia task, all participants completed the same 24-question posttest and answered the single question determining whether they had prior knowledge of the video material and were then debriefed and dismissed. The entire experiment lasted approximately 50 min for both groups.

Results

Data were excluded from one participant due to a computer malfunction, from one participant who fell asleep and did not complete the experiment, from two participants who did not comply with the instructions to take notes during the video, from one participant for reporting detailed prior knowledge, and from two participants for having posttest scores more than 2.5 *SD* below the group mean. The final sample included 49 participants in the prequestion group and 49 participants in the control group.

Prequestion performance. As in Experiment 1, accuracy on the prequestions was low (mean [*M*] = 35%, *SD* = 13%), indicating little prior knowledge.

Posttest performance. Table 1 displays posttest performance for the prequestion group and the control group. Overall, participants in the prequestion group performed significantly better on the prequestioned material than did the control group, $t(96) = 2.32$, $p = .022$, $d = 0.48$. However, this benefit did not extend to the nonprequestioned material, $t(96) = 0.44$, $p = .663$, $d = 0.06$. As in Experiment 1, this indicated that answering prequestions enhanced learning, but these benefits were specific to prequestioned material.

Note-taking performance. We next examined the degree to which this benefit of prequestions may have been driven by more frequent noticing of prequestioned information in the prequestion group compared with the control group. To identify the information contained in participants' notes, we created a coding scheme in which 1 point was awarded when participants included the answer to any of the 24 test questions in their notes. Because our primary objective was to determine whether participants could successfully note information relevant to the prequestions that would later appear as prequestioned information on the posttest, participants were awarded credit only when the answer to a question was written down in a clear, explicit, and complete fashion. Credit was not given in cases where only the question itself, or some incomplete portion of the question, was written down without the answer accompanying it. Close inspection of participants' notes revealed that the answers to the test questions were either clearly present in the notes or they were not, resulting in the application of an all-or-none coding method. We also noted that participants wrote down information implicating both a test question and its answer 81% of the time, indicating a close correspondence between noticing of the questions themselves and noticing of the answers to those questions.

When coding participants' note sheets, it was often obvious which notes corresponded to specific test questions because participants frequently referenced enough key words and phrases that the test question could be clearly identified. For example, for the test question, "According to the lecture, cancerous tumors sometimes form when _____ occurs" (answer: transcriptional mutagenesis), one participant simply wrote, "cancer—transcriptional mutagenesis"; another participant wrote, "cancer = error in genetics (transcriptional mutagenesis)"; and another participant wrote, "cancer → noise transcriptional mutagenesis." In each of these cases, participants' notes drew reference to the key concept from the question, cancer, and its answer, transcriptional mutagenesis. To score the contents of the participants' note sheets, two independent coders coded all instances in which participants wrote down the answer to one of the 24 test questions. Interrater agreement from the coding was high ($r = .97$, $p < .001$), and discrepancies in coding were resolved through discussion.

Did the pattern of information included in the notes differ for the prequestion group and control group? Participants in the prequestion group successfully wrote down the answers to 62% of the 12 prequestions they had received (*SD* = 23%) and 33% of the 12 questions that did not appear as prequestions (*SD* = 20%). By contrast, the control group wrote down the answers to 33% of the 24 total questions (*SD* = 15%). Although the prequestion group wrote down more notes relevant to the prequestioned material than the control group, $t(96) = 7.33$, $p < .001$, $d = 1.49$, the prequestion group did not significantly differ in the percentage of nonprequestioned material that they wrote down compared with the control group. In fact, the amount of nonprequestioned material noted by the prequestion group and control group was virtually identical, $t(96) = 0.01$, $p = .995$, $d = 0.00$. In examining information in participants' notes that was not relevant to any of the 24 test questions, participants in the prequestion group wrote down significantly fewer notes that were not relevant to any of the 24 test questions (*M* = 44%, *SD* = 11%) than did participants in the control group (*M* = 62%, *SD* = 12%), $t(96) = 7.75$, $p < .001$, $d = 1.56$. Thus, it appears that participants who were given prequestions were likely to use those prequestions to guide their note-taking because information that was not prequestioned was not noted any more frequently, and information irrelevant to any of the questions was noted significantly *less* frequently, compared with participants who never received prequestions.

Conditionalized posttest performance. We next explored posttest performance as a function of whether participants successfully noted the answers to those questions while viewing the video. Figure 1 presents the overall posttest performance across the conditions (as in Table 1), along with conditionalized posttest performance on the test questions for which participants successfully wrote down the answers in their notes while viewing the video (solid horizontal lines) or did not successfully write down the answers in their notes while viewing the video (dashed horizontal lines).

When participants in the prequestion group successfully wrote down the answers to any of the 12 prequestions they received, posttest performance on these same items was significantly greater (*M* = 81%, *SD* = 15%) than posttest performance in the control group for answers that they also successfully wrote down (*M* = 73%, *SD* = 21%), $t(96) = 2.13$, $p = .035$, $d = 0.44$. However, on posttest questions representing nonprequestioned information for which participants in both groups successfully wrote down the correct answers, the prequestion group (*M* = 78%, *SD* = 23%) did not significantly outperform the control group (*M* = 73%, *SD* = 21%), $t(94) = 1.23$, $p = .223$, $d = 0.23$.[1]

Thus, even though both groups were able to include in their notes information that was relevant to the posttest questions they would later receive, posttest performance for the information included in participants' notes was significantly better for the prequestion group than for the control group, and only when participants in the prequestion group were given these questions in advance as prequestions. In contrast, when participants did not include the answers to any of the test questions in their notes (i.e., the dashed lines in Figure 1), posttest performance was no different between the prequestion group and the control group, and this was true for both prequestioned material, $t(92) = 1.40$, $p = .166$, $d =$

[1] This analysis excludes data from two prequestion group participants who did not write down an answer to any of the 12 nonprequestioned items while viewing the video.

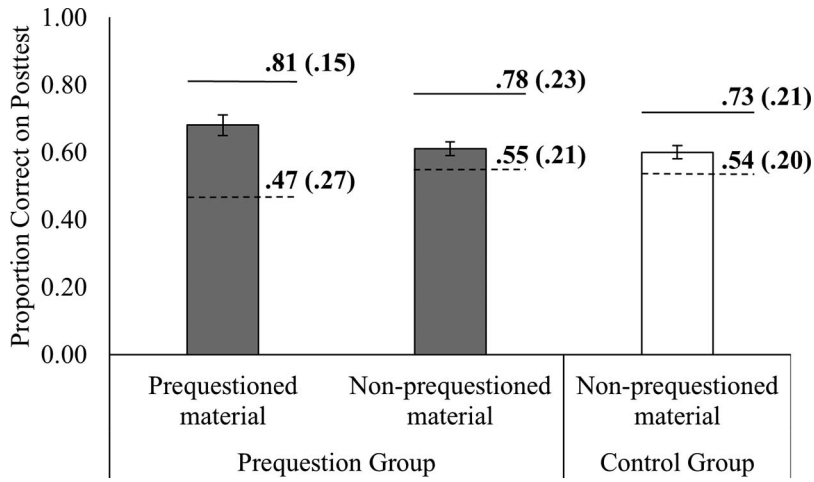

Figure 1. Posttest performance for the prequestion group and control group in Experiment 2. Bars indicate the overall mean proportion correct for both prequestioned and nonprequestioned material. Solid horizontal lines indicate the mean proportion correct on posttest questions when participants included the correct answer to a test question in their notes while viewing the video, and dashed horizontal lines indicate the mean proportion correct on posttest questions when participants did not include the correct answer to a test question in their notes while viewing the video. Error bars represent standard errors for the overall mean proportions. Standard deviations are given in parentheses for the conditionalized proportions.

0.29,[2] and for nonprequestioned material, $t(96) = 0.30$, $p = .768$, $d = 0.05$.

Discussion

Experiment 2 replicated the same basic outcomes from Experiment 1, in that prequestions prior to a video lecture benefitted the learning of prequestioned, but not nonprequestioned, material. Experiment 2 further shows that this finding held under conditions in which both the prequestion group and control group took notes on the video content while learning. Examination of participants' notes revealed that the prequestions appeared to serve as a guide for determining what information to include because participants in the prequestion group successfully noted 62% of the information they had received as prequestions but only one third of the information (no different from the control group) that had not been presented as prequestions. Although the information included in the notes across both groups was remembered more than 70% of the time (see Figure 1), the best memory retention occurred for the prequestioned information that was noted by the prequestion group. This suggests that prequestions play a role in learning from video lectures, over and above simply noting the information that one believes will be important to learn. Further, the lack of difference in posttest performance between the two groups with respect to information that was not successfully noted indicates that prequestions were only beneficial if participants successfully noticed their answers during a learning opportunity.

This conclusion is preliminary, however. The participants in Experiment 2 were given the general instructions to take notes on material that they thought would be important to learn, but they were never instructed to specifically learn the answers to the prequestions while viewing the video. Although these results provided informative outcomes about what kind of information participants noticed after receiving (or not receiving) prequestions, they did not tell us how successful participants would be in learning the answers to those prequestions when they were deliberately trying to do so, as well as the downstream effects of this on memory for both prequestioned and nonprequestioned material. Experiment 3 was designed to explore these questions.

Experiment 3

Experiment 3 used the same materials from Experiment 2. This time, however, only participants in the prequestion group were provided with a sheet of paper while viewing the video, and they were specifically instructed to write down only information that pertained to the earlier prequestions they had seen. This served as a measure of participants' memory for the prequestions and their ability to notice information relevant to those questions during the video. To determine the degree to which the prequestion effect is driven by successful noticing of the prequestioned material, we examined posttest performance for the prequestioned material that participants wrote down during the lecture versus the prequestioned material that they did not write down and how memory for this material on the posttest compared with memory for the material in the control group.

Method

Participants. In total, 93 new introductory psychology students (57% female, 43% male) at Iowa State University participated in exchange for partial fulfillment of course requirements.

Materials, design, and procedure. The same materials from Experiment 2 were used in Experiment 3. Participants were ran-

[2] This analysis excludes data from four prequestion group participants who successfully wrote down the answers to all 12 prequestioned items while viewing the video.

domly assigned to either the prequestion group (n = 47) or the control group (n = 46). Of the participants assigned to the prequestion group, participants were further assigned to answer either one set of 12 prequestions (n = 23) or the other set of 12 prequestions (n = 24).

As in Experiments 1 and 2, participants completed the experiment on individual computers and began with basic instructions that they would be watching a video lecture for which they would answer test questions at the end of the experiment. Participants in the prequestion group then completed the 12 prequestions on the computer (untimed and in randomized order for each individual), consistent with the counterbalancing group to which they had been assigned. After completing the prequestions, only the participants in the prequestion group were instructed via the computer to locate a face-down sheet of paper on their desks. Printed on the sheet (and not the computer) was the following instruction:

> Whenever the video presents some information that you believe is the answer to a question that you just saw in the previous section, please write that information down on this piece of paper. Try to write down information only if it provides the answer to one of the questions that you saw previously.

Participants in the prequestion group then proceeded to view the video, keeping the sheet of paper with them throughout the duration of the video. After finishing the video, the note sheets were collected from all participants in the prequestion group. After the sheets were collected, participants in the prequestion group completed the same trivia distractor task, then answered the 24-question posttest in randomized order (with 12 questions assessing prequestioned material and 12 assessing nonprequestioned material), and finally answered the question about whether they had any prior knowledge of the materials.

The control group, as in Experiment 1, received the same basic instructions at the beginning of the experiment before viewing the video, after which they completed the trivia distractor task, the 24-question posttest in randomized order, and the single item assessing prior knowledge. After finishing the experiment, all participants were thanked and debriefed. Altogether, the procedure for both groups lasted approximately 50 min.

Results

Data were excluded from one participant for not following instructions (i.e., the participant did not use the sheet of paper to write down any information during the video), from two participants for reporting detailed prior knowledge of the lecture material, and from one participant for having a posttest score more than 2.5 *SD* below the group mean. The final sample included 45 participants in the prequestion group and 44 participants in the control group.

Prequestion performance. As in Experiments 1 and 2, accuracy on the prequestions was quite low (M = 30%, SD = 11%), reflecting little prior knowledge of the video material.

Posttest performance. Table 1 shows posttest performance for the prequestion group and the control group. For prequestioned material, participants in the prequestion group performed significantly better compared with the control group, $t(87) = 5.12$, $p < .001$, $d = 1.05$. However, this benefit did not extend to the nonprequestioned material, $t(87) = 1.61$, $p = .111$, $d = 0.32$. These data suggest that answering prequestions enhances learning, but as in the previous experiments, the learning benefits were specific to prequestioned material.

Noticing of prequestioned information. To examine how often participants noticed the answers to the prequestions while they watched the video, we examined the written protocols of participants in the prequestion group. For specific test questions to count as being included in the written protocols, we again established that participants' written protocols contained a clear and explicit answer to a test question (as opposed to only the question or a portion of the question without the answer). Similar to Experiment 2, this meant that participants' written protocols were coded in an all-or-none fashion: Either the answer to a test question was present or it was not. Further inspection revealed that whenever participants wrote down information that was the answer to a prequestion, they also wrote enough information about the question itself that the question they were referring to could usually be clearly identified. For example, for the prequestion, "Who proposed the equation $I = \log_2 N$ in 1928?" (answer: Ralph Hartley), one participant wrote, "Ralph Harley, 1928 $\rightarrow I = \log_2 N$"; another participant wrote, "$I = \log_2 N$—Hartley"; and another participant wrote, "Made the formula $I = \log_2 N$ Ralph Hartley." Information about the relevant question accompanied the answer included in participants' written protocols 74% of the time, indicating that successful noticing of the correct answers to prequestions appeared to coincide with good memory for the questions themselves.

Two independent raters coded all of the participants' written protocols to determine the number of prequestions for which participants successfully wrote down the answers. Interrater agreement was high, $r = .98$, $p < .001$, and discrepancies in coding were resolved through discussion. While watching the video lecture, participants successfully wrote down the answers to 69% of the prequestions (SD = 20%). On average, they also inadvertently wrote down the answers to 13% (SD = 12%) of the questions that were not presented as prequestions but that were included on the posttest as nonprequestioned material. Participants rarely wrote down pieces of information that were not relevant to any of the test questions (only 7% of the written statements reflected information that appeared to be irrelevant to any of the test questions).

Conditionalized posttest performance. We next explored posttest performance for participants in the prequestion group as a function of whether or not they wrote down the answers to the prequestions while viewing the video. Figure 2 presents the overall posttest performance across the conditions (as in Table 1), along with conditionalized posttest performance for which participants in the prequestion group successfully wrote down the answers to the prequestions while viewing the video (solid horizontal line) or did not successfully write down the answers while viewing the video (dashed horizontal line). Regarding prequestioned material for which participants *did* write down the answers, posttest performance was significantly higher (M = 84%, SD = 14%) than overall performance in the control group (M = 54%, SD = 20%), $t(87) = 8.34$, $p < .001$, $d = 1.74$, and also significantly higher than the prequestion group's own performance on the nonprequestioned material (M = 60%, SD = 18%), $t(44) = 8.14$, $p < .001$, $d = 1.49$. Thus, prequestioned material that was successfully noticed during the video was remembered significantly better than the material that was not prequestioned.

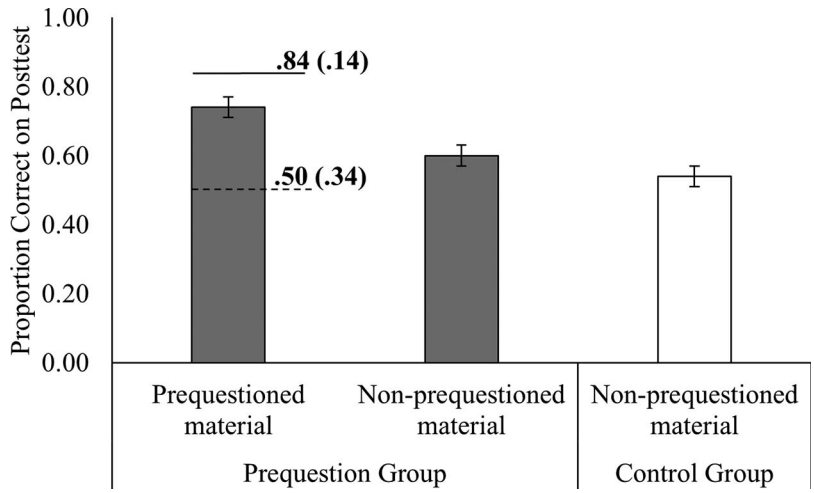

Figure 2. Posttest performance for the prequestion group and control group in Experiment 3. Bars indicate the overall mean proportion correct for both prequestioned and nonprequestioned material. The solid horizontal line indicates the mean proportion correct on posttest questions when participants included the correct answer to a prequestion in their notes while viewing the video, and the dashed horizontal line indicates the mean proportion correct on posttest questions when participants did not include the correct answer to a prequestion in their notes while viewing the video. Error bars represent standard errors for the overall mean proportions. Standard deviations are given in parentheses for the conditionalized proportions.

What about prequestioned material that was *not* successfully noticed? When participants in the prequestion group received a prequestion but failed to write down its answer during the video, there was no significant posttest advantage for the prequestion group (M = 50%, SD = 34%) over the control group, $t(86) = 0.56$, $p = .579$, $d = 0.14$.[3] Even though the information was prequestioned, the prequestioning appears to have been ineffective for prequestions that participants did not successfully remember and notice during the video.

Discussion

Experiment 3 demonstrated the same pattern of results from Experiments 1 and 2, in that answering prequestions before a video lecture benefitted later memory for prequestioned material but not for nonprequestioned material. Experiment 3 shed further light on this effect by demonstrating that the prequestion benefit was entirely dependent on participants' ability to remember the prequestions and notice their answers during the lecture. When participants could successfully do this, the performance advantage of the prequestion group over the control group was substantially increased ($d = 1.74$ compared with $d = 1.05$ in the overall average performance). When they could not, however, their final test performance was no better than the control group, even for material that was prequestioned.

Consistent with the reasoning outlined earlier, therefore, it appears that the benefits of prequestions were influenced by limitations on participants' ability to remember and/or notice the prequestioned material. The participants in Experiment 3 noticed the answers to the prequestions only 69% of the time, suggesting that there were restrictions on either the ability to remember the prequestions or the ability to discover the answers to them. These results suggest, in particular, that over 30% of the prequestioned material was already lost by the time participants viewed the lecture.

The results of Experiment 3 do not pinpoint exactly where the information was lost, however. When participants failed to write down the answers to the prequestions, what was the reason for this? Did they fail to remember the prequestions themselves? Or did they remember the prequestions but have difficulty noticing the relevant information from the lecture that provided the answers to them? Experiment 4 was designed to address these questions.

Experiment 4

Experiment 4 used the same materials as Experiment 3. This time, however, participants in the prequestion group were provided with a sheet of paper containing the 12 prequestions, to which they could refer while viewing the lecture video. Unlike in Experiment 3, where participants had to remember *and* notice the information relevant to the prequestions, in Experiment 4, participants did not have to remember the prequestions but only had to discover their answers while viewing the lecture. Experiment 4 thus explored the rate at which participants noticed the answers to prequestions when memory itself for the prequestions was controlled and how this influenced the prequestion effect.

Method

Participants. In total, 100 (62% female, 38% male) new introductory psychology students were recruited from Iowa State University to participate in exchange for partial fulfillment of course requirements.

[3] This analysis excludes data from one participant who successfully wrote down the answers to all 12 prequestions while viewing the video.

Materials, design, and procedure. The same materials from Experiment 3 were used in Experiment 4. Participants were randomly assigned to either the prequestion group (n = 53) or the control group (n = 47), and participants assigned to the prequestion group were further randomly assigned to receive one set of the 12 prequestions (n = 26) or the other set of 12 prequestions (n = 27).

All participants first received the same basic instructions as in the previous experiments, informing them that they would be viewing a lecture video and tested on it afterward. The control group received no prequestions and was thus identical to Experiment 3. Participants in the prequestion group answered the 12 prequestions one at a time on the computer, followed by instructions to locate and turn over a face-down sheet of paper on their desks. The sheet of paper contained the same 12 prequestions that they had just finished answering. The 12 prequestions were printed on one side of a single sheet of paper, in random order, each with the question stem and the four multiple-choice alternatives. Participants were instructed to circle the answer to each question as they learned it during the video lecture. As in Experiment 3, the question sheets were collected after the video finished playing, at which time all participants completed the trivia distractor task and the 24-item posttest, followed by the question assessing participants' prior knowledge. At the end of the experiment, all participants were thanked and debriefed, with the procedure lasting approximately 50 min.

Results

Data were excluded from five participants for computer malfunctions, from three participants for audio problems with the headphones, from two participants for reporting detailed prior knowledge of the lecture material, from one participant for failing to circle any answers on the question sheet, and from three participants whose posttest scores were more than 2.5 *SD* from the group mean. The final sample included 43 participants in the prequestion group and 43 participants in the control group.

Prequestion performance. As in the previous experiments, accuracy on the prequestions was quite low (M = 31%, SD = 14%), reflecting little prior knowledge of the material.

Posttest performance. Table 1 shows posttest performance for the prequestion group and the control group. The prequestion group performed significantly better than the control group on prequestioned material, $t(84) = 10.27$, $p < .001$, $d = 2.18$, but not on nonprequestioned material, $t(84) = 1.23$, $p = .224$, $d = 0.25$. Consistent with each of the earlier experiments, this provided further evidence that answering prequestions before watching the video lecture only enhanced learning for prequestioned material and not for nonprequestioned material.

Noticing of prequestioned information. During the video lecture, participants in the prequestion group correctly answered 91% of the test questions on the sheets of paper (SD = 10%). Compared with only 62% of the correct answers written down in Experiment 2 and 69% of correct answers written down in Experiment 3, providing the questions themselves during the video in Experiment 4 appeared to greatly facilitate participants' successful discovery of their answers.

Conditionalized posttest performance. We next explored posttest performance for participants in the prequestion group as a function of whether or not they successfully answered the prequestions while viewing the video. Regarding prequestioned material that participants *did* answer correctly, posttest performance was 91% (SD = 9%), which was significantly higher than performance in the control group (M = 52%, SD = 17%), $t(84) = 13.36$, $p < .001$, $d = 2.87$, and significantly higher than the prequestion group's own performance on the nonprequestioned material (M = 48%, SD = 15%), $t(42) = 18.46$, $p < .001$, $d = 3.48$.

For prequestioned material that participants did *not* answer correctly during the video, posttest performance was only 27% (SD = 44%), which was no different from chance performance (p = .819). Although this very low performance should be interpreted with caution because it is based on only 9% of the items (one item per participant, on average), it is consistent with the results of Experiments 2 and 3 in showing that prequestions were only beneficial when participants successfully discovered the correct answers to the prequestions during the video lecture.

Discussion

Experiment 4, like the previous three experiments, demonstrated that prequestions benefitted memory for prequestioned material but not for nonprequestioned material. As in Experiments 2 and 3, this effect was limited to prequestioned material that participants could successfully notice during the lecture. Compared with Experiment 2, where participants correctly wrote down the answers to 62% of the prequestions, and Experiment 3, where they correctly noticed the answers to 69% of the prequestions, in Experiment 4, providing the list of prequestions during the lecture resulted in participants noticing the correct answers at a much higher rate—91% of the time. This translated into a sizable benefit of prequestions on later memory for prequestioned material—an effect size of $d = 2.87$ compared with $d = 0.50$ in Experiment 1 and $d = 0.37$ to $d = 1.00$ elsewhere in the literature (Carpenter et al., 2018; Toftness et al., 2018). Thus, a key factor underlying learning from prequestions during authentic lectures seems to be the ability to notice the information in the lecture that is relevant to those questions.

General Discussion

In the current study, answering prequestions before viewing a video lecture significantly enhanced learning of the information from that lecture. This finding is consistent with a number of prequestion studies using text materials (Bull & Dizney, 1973; Hausman & Rhodes, 2018; Little & Bjork, 2016; McCrudden et al., 2005; Pressley et al., 1990; Richland et al., 2009; Rickards, 1976; Rothkopf & Billington, 1979) and with more recent studies showing these effects with video lectures (Carpenter & Toftness, 2017; Toftness et al., 2018). Across all four experiments, we provided more evidence that answering prequestions benefitted learning, but that these benefits were specific to the prequestioned material only; there were no general learning benefits to the nonprequestioned material. This pattern of results replicates previous work that has employed similar-style video lectures (James & Storm, 2019; Toftness et al., 2018) and has been conducted in real classrooms (Carpenter et al., 2018).

This is the first known study using video materials to examine the process by which prequestions exert their specific benefits.

When participants were provided with general instructions to take notes over the information they thought would be important to learn in Experiment 2, the participants in the prequestion group took more notes over the prequestioned material than the control group did over any of the test questions, and the prequestion group preferentially took notes over the prequestioned material more often than the nonprequestioned material. The prequestion group, in turn, showed better final test performance than the control group for material relevant to the test questions that they included in their notes, but only when this information pertained to the prequestions. Along similar lines, in Experiment 3, participants showed superior final test performance for the prequestioned material that they included in their written protocols compared with the prequestioned material that they did not include in their written protocols, which was not remembered any better than the nonprequestioned material in the control group.

Although participants were not specifically instructed to remember the prequestions themselves in either Experiment 2 or Experiment 3, in cases where they successfully wrote down the answers to the prequestions during the video, they often included enough information about the questions themselves to suggest that they successfully remembered the questions as well. Participants successfully wrote down information implicating both the test question and its answer in 81% of cases in Experiment 2 and in 74% of cases in Experiment 3. Together, these data suggest that memory for the prequestions themselves might be needed in order to successfully discover the answers to the prequestions. In contrast, when participants did not have to remember the prequestions themselves because the questions were provided on a handout (Experiment 4), participants' ability to discover the answers to the prequestions was nearly perfect. Thus, the specific benefit of prequestions appeared to rely on the degree to which the prequestions were remembered and their answers were discovered during the video lecture.

These results shed new light on previous research that has explored the effects of prequestions. In the general prequestion paradigm, participants answer prequestions prior to learning but are not given the answers to those prequestions at the time. All of the learning from prequestions, therefore, must occur through participants' ability to remember the prequestions themselves, as well as their ability to accurately notice and discover the answers to the prequestions during the learning episode. The current results suggest that there were limits on participants' abilities to remember the prequestions, and these limits coincided directly with the learning that occurred (or did not occur) from the prequestions. Given that these benefits only occurred for prequestions whose answers were successfully discovered, the benefits of prequestions in any given study depend greatly on how readily this can be done. Under conditions in which prequestions are less likely to be remembered, therefore, the benefits of prequestions may be reduced or even nonexistent.

It is important to note that the current findings pertain to prequestions that target specific isolated facts. It remains unclear whether or not more complex prequestions would produce similar effects. Recent research by St. Hilaire, Carpenter, and Jennings (2019) has shown benefits of integrative prequestions (i.e., open-ended prequestions that require the integration of different concepts) on learning from text passages. Compared with isolated factual prequestions, integrative prequestions require more cognitive effort to remember and answer, and for that reason, it is not clear whether integrative prequestions might also enhance learning from videos, particularly considering that video materials do not always allow viewers to control the pace of the video. Given the importance of learning more complex information in real educational situations, this is a worthwhile question for future research.

Theoretical insights from the literature on text learning help to contextualize the findings of the current study. In particular, McCrudden and Schraw (2007) introduced a goal-focusing model, whereby prereading questions act as cues that indicate the specific information that readers need to know from the passage. These cues encourage readers to develop specific goals while reading to focus their limited attentional resources on the material that is relevant to the prereading questions. Material that is relevant to readers' goals is more slowly and meaningfully encoded than material that is not germane to readers' goals (Lapan & Reynolds, 1994; Reynolds, Standiford, & Anderson, 1979; Reynolds, Trathen, Sawyer, & Shepard, 1993), and consequently, the information relevant to the prereading questions is, in turn, better remembered than information not relevant to the prereading questions.

The current findings are in line with this goal-focusing model, in that participants demonstrated better learning of information from video lectures when that information was relevant to the prequestions than when it was not relevant to the prequestions. This specific benefit of prequestions is likely due to the tendency of the prequestions to focus participants' attention and/or learning goals on the information in the video that is relevant to those questions. The current study sheds additional light on this effect by showing that the enhanced attentional or goal-focused resources were only beneficial when participants were able to successfully notice and discover the answers to those prequestions while viewing the video. Thus, under conditions when memory or attention to the prequestions fails, no benefits of prequestions are likely to occur. The current results thus contribute important new information to theoretical perspectives on the benefits of prequestions, showing in particular that the role these questions play in orienting attention or focusing learners' goals is only effective when those goals (i.e., noticing the relevant to-be-learned information) can be successfully realized.

Indeed, this may explain why the benefits of prequestions are weaker with longer and more complex lecture material compared with shorter lecture videos. Carpenter and Toftness (2017) observed a sizable benefit of prequestions ($d = 1.25$) under conditions in which students answered two prequestions over an upcoming brief (2-min) segment of a simple video. Toftness et al. (2018), on the other hand, observed much weaker effects of prequestions (ds < 0.77) when students answered 10 prequestions over a longer, more educationally realistic 20-min lecture video. In the current Experiment 1, when students answered 15 prequestions prior to viewing a 30-min lecture video, we observed a benefit of prequestions that was comparable in size ($d = 0.50$) to that reported by Toftness et al. In Experiments 2 and 3, we found that the prequestion benefit was entirely dependent on the prequestioned material that participants were able to remember and notice during the video, which pertained to approximately 62% and 69% of the prequestions, respectively. Assuming that prequestions are harder to remember when there are more of them and the lecture is longer (as in the current experiments and in Toftness et al.), the

weaker effects of prequestions in these studies likely reflect the inability to remember some of the prequestions.

Identifying the stages involved in learning from prequestions (i.e., remembering the question, noticing the information relevant to it, and discovering its answer) thus sheds important new light on how and when prequestions enhance learning. A similar type of stage-oriented approach has been useful in understanding other phenomena as well. For example, based on Barnett and Ceci's (2002) three-stage conceptualization of transfer—recognizing that prior knowledge is relevant, recalling that knowledge, and applying it to a new situation—studies that have explored the (often elusive) phenomenon of far transfer have evaluated the stage or stages that are critical for transfer to occur in a particular task (e.g., Butler, Black-Maier, Raley, & Marsh, 2017; Wissman, Zamary, & Rawson, 2018). Such stage-oriented approaches can thus provide a useful methodological framework for more detailed investigations of learning.

These data reveal practical insights into the circumstances under which prequestions would be most effective. In particular, prequestions may work best in situations that facilitate memory for, and noticing of, the prequestioned material. Such situations might include a shorter proximity between the presentation of the prequestions and coverage of the prequestioned content (i.e., so that there is a shorter, rather than longer, time lag between the prequestion and the lecture content that provides the answer), reminding students of the prequestions just prior to covering those points in a lecture, or possibly presenting the prequestions in an interpolated fashion (just prior to each relevant segment of a lecture) rather than all at the beginning as has usually been the case in studies on prequestions.

Although the current set of experiments focused on specific subject matter (i.e., information theory) using a specific set of test questions, these data combine with a growing number of studies to show just how pervasive the benefits of prequestions are to learning. Namely, the benefits of prequestions have been demonstrated in laboratory-based experiments using lecture videos on topics related to history (Carpenter & Toftness, 2017), signal detection theory (Toftness et al., 2018, Experiment 1), and autobiographical memory (Toftness et al., 2018, Experiment 2). These benefits have also been demonstrated in laboratory-based experiments using prose passages on topics such as mechanical systems (St. Hilaire et al., 2019), geography (Little & Bjork, 2016), biographies of famous individuals (e.g., Leonardo da Vinci and Joan of Arc; James & Storm, 2019), and scientific phenomena (e.g., the visual system; Richland et al., 2009) and space travel (McCrudden et al., 2005). Beyond the laboratory, prequestions have been shown to benefit classroom learning in university psychology courses (Carpenter et al., 2018) and in middle school science courses (McDaniel, Agarwal, Huelser, McDermott, & Roediger, 2011). Thus, the benefits of prequestions appear to extend broadly across a variety of learning material and contexts.

Future research would benefit from further explorations of prequestions in authentic educational environments and the effects of different types of prequestions. Potential indirect effects of prequestions in educational settings are also worth exploring. When learning from lectures, for example, students often struggle to organize information effectively and take high-quality notes (e.g., Jairam & Kiewra, 2009). The results of our Experiment 2 suggest that prequestions might serve as a means of identifying key concepts in advance of a lesson so that they are more likely to be included in students' notes. A question for future research, therefore, is whether prequestions might increase the quantity or quality of students' note-taking and, subsequently, the amount of information they learn from course lectures.

Given the consistent yet highly specific nature of prequestion effects, further research that can address its theoretical mechanisms and potential boundary conditions is also encouraged. Because the benefits of answering prequestions appear to be constrained by one's ability to remember the prequestions and notice and discover their answers during subsequent learning, future research should examine the conditions under which prequestions can be most effectively remembered and utilized during a learning opportunity to maximize their potential as educational tools.

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