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Feedback for learning from text: What kind and where in the text is most effective?

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ABSTRACT

Etextbooks have the affordance of providing immediate feedback for review questions on the content. However, it needs to be clarified what type and placement of feedback is most effective. College and high school students ($N = 390$) were randomly assigned to receive either correct-answer-only feedback or elaborative feedback either in the middle-and-end of the textbook excerpt or the end only. Elaborative feedback at the end of the text had more accurate posttest scores and more efficient learning (based on time reading per correct answer) than did other conditions. Metacomprehension accuracy, based on the difference between predicted performance and actual performance, did not reliably differ by condition. Neither the perceived difficulty of the text nor the review questions reliably differed based on feedback condition. This study has practical implications for the design of etextbooks provided the findings generalize across disciplines and entire etextbooks.

One advantage etextbooks have over paper textbooks is embedded review questions with immediate feedback. Indeed, two meta-analyses have indicated the benefits of feedback on learning from electronic texts [1,2]. The feedback from review questions may be more effective when only at the end of the text than segmented in the middle and end of the text, but there have been few direct comparisons of review question placement (see [3,4] for exceptions). Furthermore, it needs to be clarified what type of feedback is most helpful for readers [1]. Two feedback types are knowledge of correct response, in which the reader is informed of the accuracy of their response and what the correct answer was if they were inaccurate, and elaboration, in which the reader is provided with an explanation of why the correct answer is correct in addition to knowledge of the correct response. Furthermore, there is a call for more scientific and theoretically grounded studies of feedback [5]. The primary purpose of this study is to directly test and compare two placements of review questions with feedback (middle and end versus end only) and two types of feedback (correct response only versus elaboration) to see which best supports learning from the text. Instructors and publishers may apply these findings to designing review question feedback in etextbooks.

Etextbooks have become commonplace in secondary and college courses due to their cost and convenience [6,7]. Reading from screens may be cause for concern because multiple meta-analyses have shown that readers retain and comprehend expository text, such as science or history content, less well on screen than from paper [8–11]. In these meta-analyses, the screen conditions were static and lacked interactive features such as questions with immediate feedback. It should be noted that some studies have found that reading from paper and screens did not differ in terms of comprehension. For example, reading texts that do not require scrolling on a screen tends to be more similar to paper than reading texts that require scrolling [9,11]. In addition, college students reading from a tablet rather than a laptop may yield comprehension similar to paper [12,13].

However, laptops are the most common digital reading devices [14] and etextbooks often require scrolling to read. Therefore, it is necessary to find ways to optimize the interactive features of etextbooks to support student learning. One of these interactive features is questions with immediate feedback, which is difficult or impossible with paper texts. One proposed reason that readers remember and comprehend less from screens than paper is that readers are overconfident about how well they understand the text when reading from screens [15]. In other words, readers' awareness of how well they understand the text, known as metacomprehension, may be more inaccurate when reading from a screen compared to reading from paper. This lack of metacomprehension accuracy when reading from screens may lead to less engagement and comprehension [8,16]. Review questions with feedback are a potential means to improve metacomprehension accuracy. By answering questions and obtaining feedback about their comprehension

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prior to assessment, readers would be able to use the feedback to adjust their metacomprehension to be more accurate [17]. Indeed, both correct response and elaborative feedback during learning improved metacognitive accuracy in a geometry task [18]. However, it is uncertain whether these effects would carry over to reading. Improvements in metacomprehension accuracy could potentially prompt readers to reread or engage in reading strategies to better understand the text [19,20], which could potentially explain previously found benefits of feedback in reading comprehension [1]. Therefore, metacomprehension is examined in this study.

Readers' attitudes about feedback targeting text comprehension are an under-examined area in need of further inquiry [21]. One aspect of attitudes that may be particularly important is the perceived difficulty of both reading the text and answering the review questions. Perceived difficulty of feedback type is essential to consider because the elaborative feedback would be additional information to process, which could lead to more difficulty reading the text and answering the questions [22]. Having the questions in the middle and end of the text would segment the task into smaller units, which could yield lower perceived difficulty of both the text and the questions [23]. However, a meta-analysis indicated that end-of-text feedback is more effective, likely because the reader was interrupted by the questions placed in the middle of the text [1]. For these reasons, the difficulty of the text and the review questions are examined.

Examination of metacomprehension and perceived difficulty are important because they may shed light on why review questions with feedback benefit learning from etextbooks. Studying potential mechanisms behind the previously-noted benefits of feedback for learning is part of a more scientific, systematic approach to testing effective feedback [5]. If the mechanisms behind effective feedback for review questions are known, then it can be designed more optimally [5], thereby bolstering student learning from etextbooks). Moreover, knowledge of mechanisms is needed to properly theorize feedback research [24]. Knowing how and why feedback for review questions benefits learning can be used to inform theoretical frameworks to ground and organize future research in feedback development. Therefore, the secondary purpose of this study is to examine if there are differences in metacomprehension and perceived difficulty among feedback types that may explain any differences found in learning.

Theoretical background

Background knowledge

The benefits of feedback for reading may be understood through the *construction-integration model* of text comprehension [25]. In this model, readers mentally construct three different levels of representation of a text. The first is the surface structure, which is the text's literal words and phrasing. In the second level, readers connect the ideas expressed by the words and their phrasing. The situation model is the third level in which the ideas in the text are integrated with the readers' background knowledge [26]. Following this theory, correct-response feedback could assist in developing the textbase and situation model because it could correct inaccurate ideas from the text that would be connected with other ideas from the text and background knowledge. Furthermore, elaborative feedback may be particularly helpful in providing more information that serves as background knowledge in creating the situation model. Indeed, elaborative feedback served as a "knowledge equalizer" in a study of children playing literacy games [27]. The information provided in elaborative feedback allowed all children to have access to background knowledge [27]. Similarly, individuals who did not initially correctly solve math problems on a practice test benefited more from elaborative feedback than correct-response-only feedback on their posttest performance [28]. This is likely because they needed more background knowledge about how to solve the problem than individuals who initially solved the practice problems correctly, and the elaborative feedback provided scaffolding to compensate for the lack of background knowledge.

Cognitive resources

Constructing the three levels of representation of a text involves information processing resources [29,30]. A common feature of theories of cognition is the assumption that cognitive resources (such as those needed to process information in text) are limited (e.g., limited capacity hypothesis, [31]; capacity model, [32]; cognitive load theory, [33]). Subsequently, there is also a limit to the amount of information one's cognitive resources may process and store in memory at a given time. Placing feedback at the middle and the end of the text may possibly reduce the amount of information needed to process at a given time. The review questions in the middle of the text may serve as a manner of chunking the information into smaller quantities. Following these theories of cognition, it would be expected that questions with feedback in the middle of the text would benefit learning more than having the feedback only at the end of the text. If so, middle and end-of-text feedback would likely be perceived as less difficult compared to end-of-text-only feedback. Conversely, the review questions in the middle of the text may interrupt the reading process, which could increase perceived difficulty more so than end-of-text-only questions (see [34]).

Correct-response-only feedback may be better processed than elaborative feedback as the correct-response-only feedback has less information. However, this may depend on the background knowledge the reader has before reading, given that the elaborative feedback may provide necessary information to construct a situation model (see [27,28]). For example, elaborative feedback during practice with electric circuits was more helpful for learning how to calculate currents than correct-response-only feedback [35], likely because the information in the elaborative feedback was perceived as useful.

Metacomprehension

In general, readers tend to have poor metacomprehension accuracy in that there is a disconnect between their perceived understanding and their actual understanding of the text [17]. Readers may have the illusion of knowing in which they think they understand the text better than they actually do [36]. This leads to less strategy use and finishing their study of the text before they sufficiently understand it [37]. Logically, having feedback in the middle of the text may assist with metacomprehension accuracy more than at the end of the text. This is because readers would have their inaccurate perceptions of their understanding corrected earlier if feedback were provided in the middle of the text rather than only at the end. This could explain why previous studies with children found benefits of feedback during reading over at the end only [3,38].

Efficiency

One can infer the amount of cognitive processing of the information of a text based on reading time [39]. Of particular concern when considering feedback is whether the time spent processing the feedback results in benefits to learning from the text. It is particularly important to consider how the type of feedback may affect efficiency. Correct-response-only feedback is less information to process than elaboration feedback and may subsequently be processed faster. However, elaborative feedback could provide helpful information to better learn from the text. This may be why a previous study did not find a difference between correct-response only and elaborative feedback in cognitive processing time or self-reported mental effort when learning from an instructional video [40]. Therefore, the time per correct answer (efficiency; [41]) is examined in this study.

Overall, the findings indicate a need for scientifically and

theoretically-grounded comparisons of feedback targeted to help college students' reading of textbooks. There are studies of feedback timing for reading with children [3,4,38] and studies on feedback type for video learning or in domains outside of reading comprehension (e.g., mathematics and science; [28,35,40]). Textbooks are ubiquitously assigned as course readings in college [7]. It is critical to determine effective ways to support college students' comprehension of their textbooks due to its importance in succeeding academically in postsecondary institutions [42,43]. Examining the effective design of etextbooks is particularly important due to their growing popularity [44].

The current study

The overarching purpose of this study is to examine what type of feedback placed where in the text is best for readers. To address this purpose, two different placements of feedback (middle-and-end of text versus end only) and two different types of feedback (correct-response only and elaborative) were randomly assigned. The main and interactive effects of feedback type and feedback placement on learning, efficiency, metacomprehension accuracy, and difficulty were examined. Because elaborative feedback may provide background knowledge [27], there may be an interaction between background knowledge and type of feedback (correct-answer only or elaborative). Therefore, interactions with feedback conditions and background knowledge are explored regarding their relation to learning from the text.

An open educational resource (OER) was purposefully selected for this study. In general, OER allow for editing and redistribution of content [45]; therefore, instructors may add questions with feedback to an OER and then share it with others for broader use. Knowing where to place feedback and whether adding elaboration to the correct response is helpful for learning would guide customization of OER.

The following research questions guide this study:

1. How do the placement and content of feedback for review questions affect learning from the text? For this, learning will be examined in terms of accuracy and efficiency.
2. Does background knowledge vary the effects of the placement and content of feedback for review questions for learning from the text?
3. How do the placement and content of feedback for review questions affect metacomprehension accuracy?
4. How do the placement and content of feedback for review questions affect the perceived difficulty of the task? Both the perceived difficulty of reading the text and answering the review questions are examined in terms of the difficult of the task.

Methods

Data and materials availability statement

The deidentified data and materials for this study are publicly available on Open Science Framework [46].

Participants

Prior to data collection, this study was approved on January 16, 2024 by the author's Institutional Review Board (Protocol Number IRB0006007). College and high school students ($N = 400$) over the age of 18 signed up to participate in this study via the Prolific platform (payment of USD 10) in January 2024. If participants' survey completion time was less than one-third the median completion time, their data was removed before analysis (<705 s in this study; [47,48]). This led to the removal of 10 participants' data; therefore, the analytic sample had 390 participants. In terms of gender identities, 10.5 % were agender, 49.7 % were cisgender men, 34.1 % were cisgender women, 2.6 % were nonbinary, 1.3 % were transgender, and the remaining participants were gender fluid, nonconforming, two-spirit, or some combination of gender identities. In terms of racial identities, 5.4 % were Asian, 23.6 % were Black, 0.8 % were Native American, 60.8 % were white, 6.9 % reported another identity, and the remaining indicated multiple racial identities. In terms of ethnic identities, 10.3 % indicated Hispanic/Latino identity and 6.2 % indicated Middle Eastern identity. In terms of native languages, 34.8 % indicated their native language was English (the language used in the experiment), and the remaining indicated a range of other native languages. The average age was 24.21 years (SD = 5.27 years), and the average number of years in college was 2.76 (SD = 2.63).

Materials

An excerpt from OpenStax's Psychology textbook (second edition) on classical conditioning was used as the reading material for this study. The excerpt is five pages long, with 2679 words. Psychology was chosen because introduction to psychology is a high-enrollment, general education course for high school and postsecondary students [49,50]. Classical conditioning was chosen because it is high in difficulty and overconfidence and thus a bottleneck concept in introduction to psychology courses [51]. Classical conditioning is also frequently covered in introduction to psychology classes and textbooks [52] and relates to many other concepts in psychology [49]. For correct-response-only conditions, participants received feedback on whether their answer was correct and, if incorrect, what the correct answer was. For elaboration feedback, participants received feedback on whether their answer was correct and a one-to-two-sentence explanation of why the correct answer was correct. The elaboration with the explanation for the correct answer was provided for both correct and incorrect answers (see Fig. 1 for an example).

Measures

Psychology background knowledge

A general psychology assessment was used to assess background knowledge. The measure was originally used in Jhangiani and colleagues' (2018) study [53] and has 22 multiple-choice items on various psychology content. The items were multiple-choice, with one correct answer and three distractors. Internal consistency was poor (omega = 0.52; calculated using the "psych" function in R; [54]).

Posttests

Ten items from OpenStax's Psychology testbank were used to assess learning from the textbook excerpt (OpenStax, 2022). This included four literal (memorization for facts and definition) and six inferential (application and analysis) items. Internal consistency was acceptable (omega = 0.73; calculated using the "psych" function in R; [54]). The items were multiple-choice, with one correct answer and three distractors.

Efficiency

Efficiency was calculated by dividing the time in seconds spent reading and answering the review questions in the textbook excerpt by the number correct on the posttest (i.e., seconds per correct answer; [41]).

Metacomprehension accuracy

After reading and answering the review questions and before seeing the posttest, participants were asked to predict their percent correct on the posttest using a slider scale ranging from 25 to 100. The slider began at 25, which is chance accuracy, with four possible options on the multiple-choice posttest items. Metacomprehension was calculated by subtracting the predicted percent accuracy from the actual percent

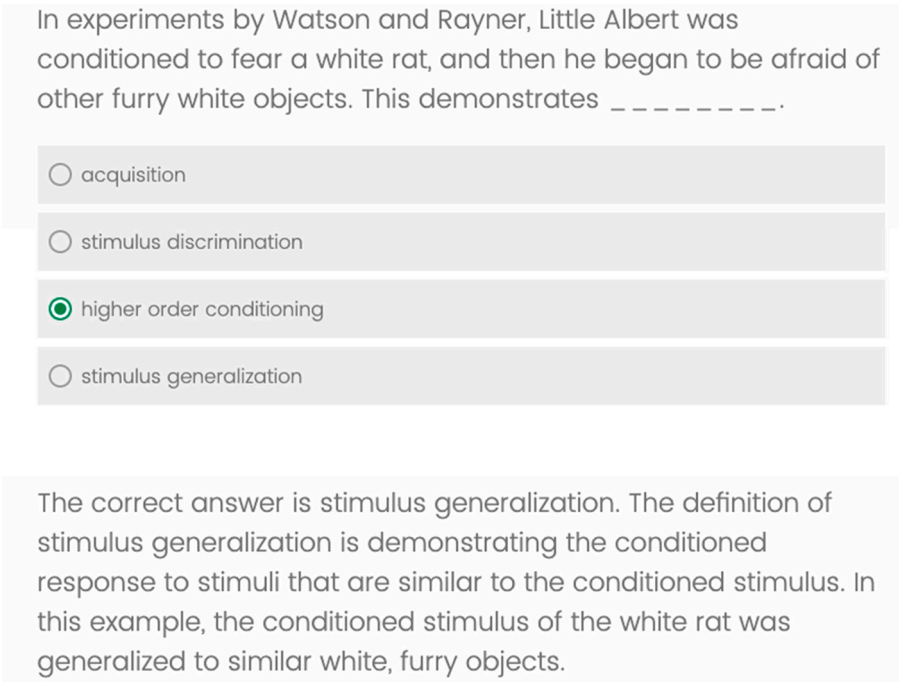

Fig. 1. Example of review question with elaborative feedback
Note. In the correct-answer-only condition, only the first sentence is shown. In all conditions, feedback appears after an answer is selected.

accuracy on the posttest. Scores greater than zero indicate overconfidence in predicted performance, and scores less than zero indicate underconfidence in predicted performance.

Perceived difficulty

Participants were asked to report the perceived difficulty of reading the textbook excerpt and answering the review questions. For the reading difficulty measure, there were four items in which participants indicated their level of agreement on a five-point Likert scale (1 is strongly disagree to 5 strongly agree). The review question difficulty measure had three items on the same scale. Internal consistency for the reading difficulty scale was good (omega = 0.89), as was the review question difficulty scale (omega = 0.82).

Procedure

Participants completed the psychology background measures after agreeing with the informed consent document. Then, they were randomly assigned through the Qualtrics algorithm to one of the four feedback conditions (correct-response only, middle-and-end of text; correct-response only; end-of-text only; elaborative feedback, middle-and-end of text; elaborative feedback, end-of-text only). Their time reading the textbook excerpt and answering the review questions was recorded. The directions for the review questions encouraged the participants to look back at the text to answer the review questions. The directions also clarified that there would be a posttest on the text content, and they would not be allowed to look back at the text to answer the posttest questions. After they finished reading and answering review questions, participants were asked to predict how well they would do on the posttest and report the difficulty of both the text and review questions. Then, they completed the posttest and reported their demographics. They were thanked for their participation and directed back to the Prolific platform for their payment.

Results

Table 1 displays the Pearson correlations to note the interrelationships among the variables. Efficiency was square root transformed as it was positively skewed. Posttest accuracy was negatively correlated with efficiency, metacomprehension accuracy, reading difficulty, and review difficulty but positively correlated with psychology background knowledge.

See Table 3 for regression coeffients and significance testing for main and interactive effects of question placement and feedback type on dependent variables.

To examine the effects and interaction of review question placement (middle and end or end only) and feedback type (correct-response only or elaborative feedback) on posttest accuracy, a mixed-effects model was estimated using the lme4 package in R studio (Bates et al., 2015). Participant and item were random factors. Review question placement and feedback type were fixed factors, as well as the interaction between review question placement and feedback type. Accuracy on the posttest was the dependent variable. There was no indication of a difference based on review question placement, $b = -0.01$, SE = 0.03, $p = .79$. There was only a marginally significant difference by feedback type, $b = -0.06$, SE = 0.03, $p = .06$. However, there was a reliable interaction between review question placement and feedback type, $b = 0.09$, SE = 0.04, $p = .04$. To investigate the interaction, models to test simple main effects for question placement were examined separately for correct-response only and elaborative feedback. When the feedback type was correct-response only, there were no differences in question placement, $b = -0.01$, SE = 0.03, $p = .79$. When the feedback type was elaborative, participants with questions only at the end of the text had better accuracy than did participants with questions in the middle and the end of the text, $b = 0.08$, SE = 0.03, $p = .01$, Cohen's $d = 0.40$. See Table 2 for descriptive statistics.

Because participants only had one efficiency data point each, mixed models with item as a fixed factor were not appropriate. Instead, a general linear regression model was estimated with question placement, feedback type, and the interaction of question placement and feedback type as factors. Seconds per correct response was the dependent

Table 1
Correlation matrix of study variables.

	Posttest accuracy	Efficiency	Meta-comprehension	Psych knowledge	Reading difficulty
Efficiency	−0.40**				
Meta-comprehension	−0.68**	0.28**			
Psych knowledge	0.35**	−0.14**	−0.22**		
Reading difficulty	−0.33**	0.01	−0.08	−0.17**	
Review question difficulty	−0.27**	0.07	−0.14**	−0.09	0.64**

Note: *$p < 0.05$, **$p < 0.01$.

Table 2
Means and standard deviations of study variables by condition.

Review question placement	Feedback type	Posttest accuracy M (SD)	Efficiency M (SD)	Meta-comprehension accuracy M (SD)	Reading difficulty	Review question difficulty
Middle and end of text	Correct response only	7.28(2.35)	139.08(131.78)	−9.94(23.30)	2.41(0.89)	2.58(0.89)
	Elaboration	6.70(2.21)	173.15(104.90)	−4.41(22.67)	2.30(0.96)	2.33(0.83)
	Total	6.99(2.30)	155.75(120.28)	−7.22(24.14)	2.35(0.93)	2.46(0.87)
End of text only	Correct response only	7.20(2.08)	151.63(133.34)	−8.30(20.35)	2.35(0.88)	2.51(0.86)
	Elaboration	7.53(2.11)	123.10(99.56)	−6.79(19.97)	2.22(0.92)	2.41(0.97)
	Total	7.36(2.10)	137.44(118.31)	−7.54(20.12)	2.29(0.90)	2.46(0.91)
Total	Correct response only	7.24(2.22)	145.29(132.34)	−9.13(22.95)	2.38(0.88)	2.54(0.87)
	Elaboration	7.11(2.20)	147.99(105.01)	−5.59(21.34)	2.26(0.94)	2.37(0.89)
	Total	7.18(2.21)	146.62(119.49)	−7.38(22.22)	2.32(0.91)	2.46(0.89)

Table 3
Regression coefficients for main and interactive effects of question placement and feedback type on dependent variables.

	Beta	SE	*p* value
Posttest accuracy			
Question placement	−0.01	0.03	.79
Feedback type	−0.06	0.03	.06
Interaction of placement and type	0.09	0.04	.04
Efficiency			
Question placement	12.55	1.739	.47
Feedback type	34.08	17.49	.052
Interaction of placement and type	−62.61	24.76	.01
Metacomprehension			
Question placement	1.64	3.17	.60
Feedback type	5.23	3.17	.08
Interaction of placement and type	−4.01	4.50	.37
Text difficulty			
Question placement	−0.06	0.13	.66
Feedback type	−0.10	0.13	.43
Interaction of placement and type	−0.02	0.19	.90
Review question difficulty			
Question placement	−0.07	0.13	.59
Feedback type	−0.24	0.13	.06
Interaction of placement and type	0.15	0.18	.41

variable. Participants whose time to read and answer review questions were outliers (more than two standard deviations above the mean) were not included in efficiency analyses ($n = 23$). These outliers were removed because time on a task that is overly long likely indicates the participants were distracted or interrupted during the study and is not indicative of actual processing time. However, it should be noted that it is possible that there were legitimate processing times that were lengthy due to reading disabilities, concentration difficulties, or reading in one's second language. There were no reliable differences in efficiency by review question placement, $b = 12.55$, SE = 17.39, $p = .47$. There was a marginally significant effect of feedback type, $b = 34.08$, SE = 17.49, $p = .052$. However, there was a significant interaction between review question placement and feedback type, $b = -62.61$, SE = 24.76, $p = .01$. To understand the nature of the interaction, simple main effects of feedback placement were examined for correct-response only and elaboration feedback type conditions. When the feedback only provided the correct answer, there were no differences in efficiency by review question placement, $b = 0.09$, SE = 0.13, $p = .52$. However, for elaborative feedback, seconds per correct answer were longer for placement in the middle and end of the text compared to only at the end of the text, $b = -50.05$, SE = 15.20, $p = .001$, Cohen's $d = 0.042$. This indicates that elaborative feedback only at the end of the text was the most efficient condition.

The potential interactions with the experimental conditions and prior knowledge were also tested. A similar model to test the conditions and their interactions on accuracy was conducted with the addition of prior knowledge as a random factor as well as its interactions with the experimental conditions. Prior knowledge was a significant predictor of accuracy, $b = 0.03$, SE = 0.007, $p < .001$. When the prior knowledge was included in the model, there were no reliable effects of review question placement, $b = 0.03$, SE = 0.12, $p = .75$, feedback type, $b = 0.08$, SE = 0.11, $p = .50$, nor a reliable interaction between the experimental conditions, $b = -0.08$, SE = 0.16, $p = .63$. Prior knowledge did not reliably interact with review question placement, $b = -0.00$, SE = 0.01, $p = .78$, feedback type $b = =0.01$, SE = 0.01, $p = .27$, nor with an interaction of the experimental conditions (three-way interaction), $b = 0.01$, SE = 0.01, $p = .37$. For efficiency, prior knowledge was not a significant predictor, $b = -5.57$, SE = 4.35 $p = .20$. Review question placement and type of feedback were not reliable predictors, $b = 79.49$, SE = 68.54, $p = .25$ and $b = 69.50$, SE = 67.75, $p = .31$, but the interaction of the two was significant, $b = -195.75$ SE = 94.52, $p = .04$. There were no reliable interactions between prior knowledge and review question placement, $b = -6.93$, SE = 6.40, $p = .28$, prior knowledge and type of feedback, $b = -3.79$, SE = 6.31, $p = .55$, not a three-way interaction between prior knowledge and the experimental conditions, $b = 13.62$, SE = 8.80, $p = .12$. Therefore, there does not seem to be evidence that prior knowledge interacts with either experimental condition on posttest performance.

Metacomprehension was examined with a general linear model with question placement, feedback type, and the interaction of question placement and feedback type as factors and metacomprehension accuracy as the dependent variable. There were no reliable effects of review question placement, $b = 1.64$, SE = 3.17, $p = .60$, feedback type, $b = 5.23$, SE = 3.17, $p = .08$, nor an interaction of the two, $b = -4.01$, SE = 4.50, $p = .37$.

Perceived difficulty of reading the text and of answering the review

questions were similarly analyzed. For perceived difficulty of reading the text, there were no reliable effects of feedback placement, $b = -0.06$, SE = 0.13, $p = .66$, feedback type, $b = -0.10$, SE = 0.13, $p = .43$, nor an interaction of the two, $b = -0.02$, SE = 0.19, $p = .90$. For perceived difficulty of answering the review questions, there were no reliable differences by feedback placement, $b = -0.07$, SE = 0.13, $p = .59$, only a marginally significant difference for feedback type, $b = -0.24$, SE = 0.13, $p = .06$, and no evidence of a reliable interaction of the two, $b = 0.15$, SE = 0.18, $p = .41$.

Discussion

The primary purpose of this study was to compare different placements of feedback (middle-and-end of text versus end-of-text only) and two types of feedback (correct-response only versus elaborative) on student learning from an etextbook excerpt. Based on the study findings, there was an interaction between placement and type of feedback. The interaction was such that elaborative feedback at the end of the textbook excerpt was the most effective for learning. This conclusion is based both on the accuracy of the posttest and efficiency (seconds per correct posttest answer).

The secondary purpose this study was to examine if there are differences in metacomprehension and perceived difficulty among feedback types that may explain any differences found in learning. The motivation behind this purpose was to better understand the mechanisms for effective feedback [5]. Knowledge of these mechanisms could be used to optimize feedback design and develop theoretical frameworks about feedback [5,24]. The placement and types of feedback did not appear to affect metacomprehension accuracy or perceived difficulty of the text and review questions. Therefore, there is no reliable evidence from this study that improvements in metacomprehension or reductions in perceived difficulty explain the benefits of elaborative feedback only at the end of the text on learning compared to the other feedback conditions.

Previous research findings

In a meta-analysis of reading feedback, providing feedback only at the end of the text was more beneficial than during reading [1]. However, there was not a clear difference between correct response only and elaborative feedback regardless of placement. Notably, there were few comparisons within a single study of feedback placement or feedback type in the meta-analysis [1]. In the current study's findings, end-of-text placement with elaborative feedback was the best for learning. In other words, readers had better accuracy and efficiency when they only had the review questions at the end of the text and were provided with explanations for why answers were correct.

The benefit of elaborative over correct-response-only feedback (for feedback at the end of the text) converges with previous findings in physics on elaborative feedback [35]. The explanation for why the answer was correct provided in the elaborative feedback may have provided helpful scaffolding for understanding the text (see [55], for a review on scaffolding). This is analogous to teacher-provided scaffolding in read-alouds with children in which teachers provide support for determining the correct answers to questions [56]. Moreover, there was no evidence that the elaborative feedback was more difficult to process due to the additional information than the correct-answer only feedback. This concern was based on the overarching agreement across theories of cognition that human information processing capacity is limited (e.g., limited capacity hypothesis, [31]; capacity model, [32]; cognitive load theory, [33]), and subsequently additional information could potentially overload these limited systems. Regarding cognitive processing, there was less time reading and answering review questions per correct answer on the posttest for elaborative feedback than correct-response-only feedback at the end of the text. Moreover, there were no reliable differences in self-reported difficulty ratings based on feedback type. However, there was a trend suggesting answering review questions with elaborative feedback was less difficult than correct-response only. Although this was not significant, the direction of the effect counters concern that the extra information caused more difficulty in processing in the text, particularly when considered alongside the efficiency benefits of elaborative feedback at the end of the text.

One proposed reason for the hypothesized benefits of elaborative feedback over correct-response only was that elaborative feedback may provide helpful background knowledge to construct a situation model. Given that difficulty ratings, cognitive processing in terms of efficiency, and overall accuracy were best for elaborative feedback at the end of the text; it can be inferred that the additional information provided in the elaborative feedback was indeed helpful. However, unlike other findings in which elaborative feedback was only or particularly helpful for individuals with lower levels of background knowledge or skill [28,27]. However, the interventions in these studies focused on discrete skills, such as solving a specific type of math problem or learning a type of syntax [28,27]. With specific skills, background knowledge prior to the intervention may be measured more precisely than the general psychology knowledge assessed in the current study. Moreover, the specific content covered in the textbook excerpt, classical conditioning, is considered particularly challenging [51]. Therefore, it is feasible that students could understand many psychology concepts quite well and still benefit from the scaffolding of elaborative feedback for a challenging topic within the field.

The benefits of elaborative feedback compared to correct-response only were limited to feedback only at the end of the text rather than split in two locations. Based on prior research and theory, there were compelling reasons for expecting both benefits for middle-and-end feedback and end-only feedback. By providing feedback in the middle, readers could have misunderstandings of the text corrected as they develop their situation model. Corrections of misunderstandings may be particularly useful for metacomprehension accuracy. Furthermore, the text would have been segmented into smaller units for processing. Previous findings with children indicated the benefits of feedback during the text rather than only at the end [3,4]. However, having feedback only at the end does not interrupt the reading process and has been shown to be more effective in a previous meta-analysis [1]. In addition, feedback only at the end may have been due to the recency effect in which information processed right before the assessment is easier to recall [57,58]. The current study's findings showing the benefits of elaborative feedback at the end indicate that college readers, who logically have more experience with texts than children, may benefit from fewer interruptions due to feedback. Children may be more used to feedback during reading (e.g., teacher feedback during read-alouds in the classroom [56]). Given that most of the studies in the feedback meta-analysis with similar findings were with secondary or college students [1], age appears to be a likely explanation for why the findings from this study differ from those with children.

Implications

This study's findings have clear implications for etextbook design. Instructors who use OER may use these findings to incorporate review questions with feedback into their course readings (see [59], and [60], for examples of interactive psychology OER textbooks). In addition, many commercial textbook publishers (e.g., Pearson, Cengage, Macmillan) have courseware available to purchase, which includes interactive features of etextbook publishers, including review questions with feedback. Finally, videos are commonly provided to students to support their content learning. There is evidence that, similar to reading textbooks, questions with feedback support learning from videos [61,62]. An important area for inquiry would be specific and controlled testing of feedback for learning from videos, similar to what the current study examined with learning from text. In each of these scenarios, instructors

may assign students to answer the review questions and a subsequent assessment of the reading as homework.

Limitations and future directions

Although this study included measures of metacomprehension accuracy and difficulty, these did not reliably vary by condition and thus did not provide explanations for why a combination of elaborative feedback at the end of the text had the highest accuracy and efficiency. In other words, it does not appear that this combination of feedback type and placement made the text easier to understand or improved metacomprehenson accuracy. However, difficulty ratings were generally low (all cell means below the midpoint of 3; see Table 2), which could indicate that there was not sufficient difficulty to detect an effect. This is surprising given that the topic was selected due to its difficulty and the lack of a ceiling effect with accuracy on the posttest. Also surprising was that readers indicated underconfidence in their prediction of how well they would do on the posttest given the previous findings that readers tend to be overconfident when reading from screens [8,15,16]. It is possible that having feedback of any type or placement improves metacomprehension accuracy and eases perceived difficulty. However, the current study's design did not allow for testing that possibility. This shortcoming of the current study could be addressed with a future study with a control condition without feedback.

The design of this study using a recruiting platform allowed for a range of student backgrounds in a controlled experiment. However, the content was not part of an actual course, and their performance did not have any academic consequences. Therefore, a future experiment testing these types of feedback within an actual course-assigned reading is needed to establish ecological validity. Such studies should be across different disciplines and ideally be throughout an entire course to understand generalizability and scalability. The findings from such studies would provide robust evidence for when and where feedback is best, thereby providing direction for etextbook design, particularly with OER development.

It is likely that some of the participants had a reading disability such as dyslexia. Approximately 4.7 % of college students have learning disabilities, and dyslexia occurs in 80–90 % of individuals with learning disabilities [63,64]. In the current study, participants were not asked to report whether they had a learning or reading disability. In order for research on designing questions with feedback to be equitable, future studies should consider the needs of students with learning disabilities.

There was a lack of reliable effects for metacomprehension and perceived difficulty by feedback condition. Therefore, the current study did not indicate clear mechanisms for why elaborative feedback at the end of the text was more effective for learning, at least in the current study's context. The perceived difficulty findings are consistent with previous studies that did not note any effects of feedback on reader attitudes (such as perceived difficulty; [21]). However, there were some marginal effects due to feedback type on metacomprehension and perceived difficulty. This could indicate that the current study lacked the power to detect effects, and future studies may yield reliable results with larger samples.

Conclusion

Providing immediate feedback to review questions on text content is an affordance of etextbooks over paper textbooks. There is empirical support from meta-analyses that feedback in etextbooks fosters learning; however, it was unclear what type of feedback in which location is the most beneficial for readers ([1,2,21]). The findings of this study indicated that elaborate feedback in which an explanation of why an answer is correct at the end of the textbook excerpt had the most accurate and efficient learning from the text. Future studies could expand this work across disciplines and entire textbooks to determine how etextbooks should be designed to best support student learning.

Declaration of AI-assisted technologies

During the preparation of this work the author used Thrix and Grammerly in order to check references and correct typos and other writing mechanics issues. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

CRediT authorship contribution statement

Virginia Clinton-Lisell: Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Virginia Clinton-Lsell reports financial support was provided by William and Flora Hewlett Foundation. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Swart EK, Nielen TMJ, Sikkema - de Jong MT. Supporting learning from text: a meta-analysis on the timing and content of effective feedback. Educ Res Rev 2019; 28:100296. https://doi.org/10.1016/j.edurev.2019.100296.
[2] Clinton-Lisell V, Seipel B, Gilpin S, Litzinger C. Interactive features of e-texts' effects on learning: A systematic review and meta-analysis. Interact. Learn. Environ. 2023;31(6):3728–43. https://doi.org/10.1080/10494820.2021.1943453.
[3] Carlson SE, Broek Pvan den, McMaster KL. Factors that influence skilled and less-skilled comprehenders' inferential processing during and after reading: exploring how readers maintain coherence and develop a mental representation of a text. Elem Sch J 2022;122(4):475–501. https://doi.org/10.1086/719477.
[4] Peverly ST, Wood R. The effects of adjunct questions and feedback on improving the reading comprehension skills of learning-disabled adolescents. Contemp Educ Psychol 2001;26(1):25–43. https://doi.org/10.1006/ceps.1999.1025.
[5] Winstone NE, Nash RA. Toward a cohesive psychological science of effective feedback. Educ Psychol 2023;58(3):111–29. https://doi.org/10.1080/00461520.2023.2224444.
[6] Greco AN. College bookstores and college textbook publishers confront dramatic developments and challenges: 2019–2021. In: Greco AN, editor. The college textbook publishing industry in the U.S. 2000-2022: the search for competitive marketing strategies. Springer Nature Switzerland; 2023. p. 53–90. https://doi.org/10.1007/978-3-031-30415-6_4.
[7] Seaman JE, Seaman J. Turning point for digital curricula: educational resources in US Higher Education, 2022. Bay View Analytics 2022. https://eric.ed.gov/?id=ED622348.
[8] Clinton V. Reading from paper compared to screens: A systematic review and meta-analysis. J. Read. Res. 2019;42(2):288–325. https://doi.org/10.1111/1467-9817.12269.
[9] Delgado P, Vargas C, Ackerman R, Salerón L. Don't throw away your printed books: a meta-analysis on the effects of reading media on reading comprehension. Educ Res Rev 2018;25:23–38. https://doi.org/10.1016/j.edurev.2018.09.003.
[10] Kong Y, Seo YS, Zhai L. Comparison of reading performance on screen and on paper: a meta-analysis. Comput Educ 2018;123:138–49. https://doi.org/10.1016/j.compedu.2018.05.005.
[11] Salmerón L, Altamura L, Delgado P, Karagiorgi A, Vargas C. Reading comprehension on handheld devices versus on paper: a narrative review and meta-analysis of the medium effect and its moderators. J Educ Psychol 2024;116(2): 153–72. https://doi.org/10.1037/edu0000830.
[12] Clinton-Lisell V. Reading medium and interest: Effects and interactions. Educ. Psychol. 2022;42(2):142–62. https://doi.org/10.1080/01443410.2021.2016635.
[13] Clinton-Lisell V. Investigating reading from screens and mind wandering in the context of standards of coherence. Sci Stud Read 2023;27(2):169–86. https://doi.org/10.1080/10888438.2022.2125320.
[14] Mizrachi, D., Salaz, A. M., Kurbanoglu, S., Boustany, J., & ARFIS Research Group. (2018). Academic reading format preferences and behaviors among university students worldwide: A comparative survey analysis. *PloS one, 13*(5), Art. e0197444. doi: 10.1371/journal.pone.0197444.
[15] Lauterman T, Ackerman R. Overcoming screen inferiority in learning and calibration. Comput Human Behav 2014;35:455–63. https://doi.org/10.1016/j.chb.2014.02.046.
[16] Ackerman R, Lauterman T. Taking reading comprehension exams on screen or on paper? A metacognitive analysis of learning texts under time pressure. Comput Human Behav 2012;28(5):1816–28. https://doi.org/10.1016/j.chb.2012.04.023.

[17] Yang C, Zhao W, Yuan B, Luo L, Shanks DR. Mind the gap between comprehension and metacomprehension: meta-analysis of metacomprehension accuracy and intervention effectiveness. Rev Educ Res 2023;93(2):143–94. https://doi.org/10.3102/00346543221094083.
[18] Kuklick L, Greiff S, Lindner MA. Computer-based performance feedback: effects of error message complexity on cognitive, metacognitive, and motivational outcomes. Comput Educ 2023;200:104785. https://doi.org/10.1016/j.compedu.2023.104785.
[19] Cain K. Making sense of text: skills that support text comprehension and its development. Perspect Lang Lit 2009;35:11–4. https://eprints.lancs.ac.uk/id/eprint/26618.
[20] Oakhill J, Cain K, Elbro C. Reading comprehension and reading comprehension difficulties. In: Kilpatrick D, Malatesha J, Wagner RK, editors. Reading development and difficulties: bridging the gap between research and practice. Springer; 2019. p. 83–115. https://doi.org/10.1007/978-3-030-26550-2_5.
[21] Swart EK, Nielen TMJ, Sikkema-de Jong MT. Does feedback targeting text comprehension trigger the use of reading strategies or changes in readers' attitudes? A meta-analysis. J Res Read 2022;45(2):171–88. https://doi.org/10.1111/1467-9817.12389.
[22] Sweller J, van Merrienboer JJG, Paas FGWC. Cognitive architecture and instructional design. Educ Psychol Rev 1998;10(3):251–96. https://doi.org/10.1023/A:1022193728205.
[23] Mayer RE, Wells A, Parong J, Howarth JT. Learner control of the pacing of an online slideshow lesson: does segmenting help? Appl Cogn Psychol 2019;33(5):930–5. https://doi.org/10.1002/acp.3560.
[24] Winstone NE, Nash RA, Parker M, Rowntree J. Supporting learners' agentic engagement with feedback: a systematic review and a taxonomy of recipience processes. Educ Psychol 2017;52(1):17–37. https://doi.org/10.1080/00461520.2016.1207538.
[25] Kintsch W. Comprehension: a paradigm for cognition. Cambridge University Press; 1998.
[26] Kintsch W. Psychological models of reading comprehension and their implications for assessment. In: Sabatini J, Albro E, O'Reilly T, editors. Measuring up: advances in how we assess reading ability. Rowman & Littlefield Publishers, Inc; 2012. p. 21–38.
[27] Benton L, Joye N, Sumner E, Gauthier A, Ibrahim S, Vasalou A. Exploring how children with reading difficulties respond to instructional supports in literacy games and the role of prior knowledge. Brit J Educ Technol 2023;54(5):1314–31. https://doi.org/10.1111/bjet.13318.
[28] Attali Y, van der Kleij F. Effects of feedback elaboration and feedback timing during computer-based practice in mathematics problem solving. Comput Educ 2017;110:154–69. https://doi.org/10.1016/j.compedu.2017.03.012.
[29] Kendeou P, Muis KR, Fulton S. Reader and text factors in reading comprehension processes. J Res Read 2011;34(4):365–83. https://doi.org/10.1111/j.1467-9817.2010.01436.x.
[30] Kendeou P, Van Den Broek P, Helder A, Karlsson J. A cognitive view of reading comprehension: implications for reading difficulties. Learn Disabilit Res Pract 2014;29(1):10–6. https://doi.org/10.1111/ldrp.12025.
[31] Baddeley AD, Scott D, Drynan R, Smith JC. Short-term memory and the limited capacity hypothesis. Brit J Psychol 1969;60(1):51–5. https://doi.org/10.1111/j.2044-8295.1969.tb01175.x.
[32] Kahneman D. Attention and effort. Prentice Hall; 1973.
[33] Sweller J. Cognitive load theory and educational technology. Educ Technol Res Develop 2020;68(1):1–16. https://doi.org/10.1007/s11423-019-09701-3.
[34] Greving CE, Richter T. Distributed learning in the classroom: effects of rereading schedules depend on time of test. Front Psychol 2019;9. https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2018.02517.
[35] Wagner S, Sibley L, Weiler D, Burde J-P, Scheiter K, Lachner A. The more, the better. Learning with feedback and instruction. Learn Instr 2024;89:101844. https://doi.org/10.1016/j.learninstruc.2023.101844.
[36] Koriat A, Bjork RA. Illusions of competence in monitoring one's knowledge during study. J Experim Psychol: Learn, Memory Cognit 2005;31(2):187–94. https://doi.org/10.1037/0278-7393.31.2.187.
[37] Dunlosky J, Rawson KA. Overconfidence produces underachievement: inaccurate self evaluations undermine students' learning and retention. Learn Instr 2012;22(4):271–80. https://doi.org/10.1016/j.learninstruc.2011.08.003.
[38] Candel C, Máñez I, Cerdán R, Vidal-Abarca E. Delaying elaborated feedback within computer-based learning environments: the role of summative and question-based feedback. J Comput Assist Learn 2021;37(4):1015–29. https://doi.org/10.1111/jcal.12540.
[39] Rapp DN, Van Den Broek P. Dynamic text comprehension: an integrative view of reading. Curr Dir Psychol Sci 2005;14(5):276–9. https://doi.org/10.1111/j.0963-7214.2005.00380.x.
[40] van Brussel S, Timmermans M, Verkoeijen P, Paas F. 'Consider the Opposite' – effects of elaborative feedback and correct answer feedback on reducing confirmation bias – a pre-registered study. Contemp Educ Psychol 2020;60:101844. https://doi.org/10.1016/j.cedpsych.2020.101844.
[41] Su S, Davison ML. Improving the Predictive Validity of Reading Comprehension Using Response Times of Correct Item Responses. Applied Measurement in Education 2019;32(2):166–82. https://doi.org/10.1080/08957347.2019.1577247.
[42] Author et al. (2022). Masked for review.
[43] Stahl NA, Armstrong SL. *Re*-claiming, re-inventing, and re-reforming a field: the future of college reading. J Coll Read Learn 2018;48(1):47–66. http://doi.org/10.1080/10790195.2017.1362969.
[44] Picton I. Teachers' use of technology to support literacy in 2018. National Literacy Trust; 2019.
[45] Green C. Open licensing and open education licensing policy. In: Jhangiani R S, Biswas-Diener R, editors. Open: the philosophy and practices that are revolutionizing education and science; 2017. p. 29–41. https://www.jstor.org/stable/j.ctv3t5qh3.7.
[46] Clinton-Lisell, V. (2024, June 21). feedback study. Retrieved from osf.io/cef6a.
[47] Belliveau J, Yakovenko I. Evaluating and improving the quality of survey data from panel and crowd-sourced samples: a practical guide for psychological research. Exp Clin Psychopharmacol 2022;30(4):400–8. https://doi.org/10.1037/pha0000564.
[48] Greszki R, Meyer M, Schoen H. The impact of speeding on data quality in nonprobability and freshly recruited probability-based online panels. In: Callegaro M, Baker R, Bethlehem J, Goritz AS, Krosnick JA, Lavrakas PJ, editors. Online panel research: data quality perspective. Wiley; 2014. p. 238–62. https://doi.org/10.1002/9781118763520.ch11.
[49] Gurung RAR, Hackathorn J, Enns C, Frantz S, Cacioppo JT, Loop T, Freeman JE. Strengthening introductory psychology: a new model for teaching the introductory course. Am Psycholog 2016;71:112–24. https://doi.org/10.1037/a0040012.
[50] Richmond AS, Boysen GA, Hudson DL, Gurung RA, Naufel KZ, Neufeld G, Beers M. The Introductory Psychology Census: a national study. Scholarsh Teach Learn Psychol 2021;7(3):163. https://doi.org/10.1037/stl0000277.
[51] Gurung RAR, Landrum RE. Bottleneck concepts in psychology: exploratory first steps. Psychol Learn Teach 2013;12:236–45. https://doi.org/10.2304/plat.2013.12.3.236.
[52] Slade JJ, Gurung RAR. Not quite on the same page: comparing key terms in introductory psychology textbooks. Teach Psychol 2022:00986283221111749. https://doi.org/10.1177/00986283221111749.
[53] Jhangiani RS, Dastur FN, Le Grand R, Penner K. As good or better than commercial textbooks: students' perceptions and outcomes from using open digital and open print textbooks. Can J Scholarsh Teach Learn 2018;9(1):n1. https://files.eric.ed.gov/fulltext/EJ1176381.pdf.
[54] Revelle W. psych: procedures for psychological, psychometric, and personality research. Evanston, Illinois: Northwestern University; 2024. R package version 2.4.1, https://CRAN.R-project.org/package=psych.
[55] Reynolds D. Interactional scaffolding for reading comprehension: a systematic review. Liter Res: Theory Method, Pract 2017;66(1):135–56. https://doi.org/10.1177/2381336917718820.
[56] Deshmukh RS, Pentimonti JM, Zucker TA, Curry B. Teachers' use of scaffolds within conversations during shared book reading. Lang Speech Hear Serv Sch 2022;53(1):150–66. https://doi.org/10.1044/2021_LSHSS-21-00020.
[57] Baddeley AD, Hitch G. The recency effect: implicit learning with explicit retrieval? Mem Cognit 1993;21(2):146–55. https://doi.org/10.3758/BF03202726.
[58] Osth AF, Farrell S. Using response time distributions and race models to characterize primacy and recency effects in free recall initiation. Psychol Rev 2019;126(4):578–609. https://doi.org/10.1037/rev0000149.
[59] Lazzara J. Introduction to psychology. MCCCD; 2021. https://open.maricopa.edu/intropsychme/.
[60] Spielman RM, Dumper K, Jenkins W, Lacome A, Lovett M, Perlmutter M. Psychology-H5P edition. BC Campus; 2021. https://opentextbc.ca/h5ppsychology/.
[61] Szpunar KK, Jing HG, Schacter DL. Overcoming overconfidence in learning from video-recorded lectures: implications of interpolated testing for online education. J Appl Res Mem Cogn 2014;3(3):161–4. https://doi.org/10.1016/j.jarmac.2014.02.001.
[62] Welhaf MS, Phillips NE, Smeekens BA, Miyake A, Kane MJ. Interpolated testing and content pretesting as interventions to reduce task-unrelated thoughts during a video lecture. Cogn Res Princ Implic 2022;7(1):26. https://doi.org/10.1186/s41235-022-00372-y.
[63] American College Health Association. American College Health Association-National College Health Assessment III: undergraduate Student Reference Group Data Report Spring 2022. American College Health Association. https://www.acha.org/documents/ncha/NCHA-III_SPRING_2022_UNDERGRAD_REFERENCE_GROUP_DATA_REPORT.pdf.
[64] Yale Center for Dyslexia and Creativity. Dyslexia FAQs. 2023. https://dyslexia.yale.edu/dyslexia/dyslexia-faq/.