Enhancing Students' Ability to Correct Misconceptions in Natural Selection with Refutational Texts and Self-Explanation Training

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Abstract

Misconceptions are difficult to identify and correct. Nonetheless, refutational texts have been identified as one means of correcting students' misconceptions in science domains. This study further examines the effects of refutational texts and the extent to which they are enhanced by self-explanation. Experiment 1 compares the effects of self-explanation to think-aloud on students' conceptual understanding of natural selection as a function of text type (refutational vs. non-refutational). Individual differences in reading skill were strongly related to students' conceptual understanding, however there were no effects of text type or prompt. Hence, Experiment 2 examined whether self-explanation training using iSTART enhanced the effect of prompting students to self-explain. Individual differences in reading skill were strongly related to students' conceptual understanding, and there was a marginal effect of self-explanation prompt and a marginal interaction between self-explanation prompt and reading skill such that less skilled readers when prompted to self-explain outperformed those prompted to think-aloud. These results demonstrate that prompting students to self-explain while reading a refutational text may enhance students' ability to correct misconceptions, but under limited circumstances.

Enhancing Students' Ability to Correct Misconceptions in Natural Selection with Refutational Texts and Self-Explanation Training

Inaccurate understanding and knowledge or *misconceptions* are ubiquitous across all domains. Misconceptions are difficult to identify, resistant to change, and interfere with learning. Thus, it is important to understand the processes by which misconceptions are formed, and effective means to refute them. One technique used by educators and researches is refutational texts. Refutational texts target specific misconceptions by stating the misconception, providing the correct concept, and giving evidence on why the correct concept is true. In refutational texts, the misconception and a refutation are conveyed simultaneously, increasing the likelihood the reader identifies and confronts the error (Kendeou et al., 2014). Studies have shown students hold fewer misconceptions after reading a refutational text compared to a non-refutational text (van den Broek & Kendeou, 2008). However, because refutational texts are often difficult science texts (Allen, McNamara & McCrudden, 2015), the effectiveness of refutational texts depends on the degree to which students can comprehend the text.

One technique to improve students' comprehension while reading is prompting students to self-explain. Self-explanation is the practice of explaining the text to oneself while reading. Skilled readers self-explain naturally, and less skilled readers prompted to self-explain demonstrate gains in comprehension while reading science texts (McNamara, 2004; Magliano et al., 2005). Therefore, self-explanation prompts have the potential to enhance students' comprehension of refutational texts and reduce students' misconceptions after reading.

Allen et al. (2015) found that prompting students to self-explain while reading a refutational text increased causal reasoning and decreased misconceptions in comparison to prompting think-aloud. The results of their study implied that self-explanation may enhance conceptual change processes regardless of text type (i.e., refutational vs. non refutational). If so, prompting self-explanation could be more scalable compared to authoring and publishing refutational texts.

Experiment 1

Experiment 1 examined the extent to which prompting students to self-explain a non-refutational or refutational text affected their understanding of natural selection. The experiment replicated the study by Allen et al (2015) in using a comparison group of students who were prompted to think-aloud while reading. It was hypothesized students prompted to self-explain while reading would have fewer misconceptions about natural selection compared to students prompted to think-aloud while reading.

Method

Participants and design. Undergraduate students (n= 240) were randomly assigned in a 2(Text: non-refutational, refutational) x 2(Prompt: self-explain, think-aloud) design.

Texts. The non-refutational text (707 words, Flesch-Kincaid Grade Level: 11) is an excerpt from How the Mind Works (Pinker, 1997), which describes the concept of natural selection. The author uses the example of the eye to explain how the world can appear to be the product of intelligent design but does not have a designer.

The text was adapted by Allen, McCrudden, and McNamara (2015) to include explicit references to, and direct refutations of, alternative concepts of natural selection. The adapted version has similar length and reading difficulty (716 words, Flesch-Kincaid Grade Level: 10.5) as the original text.

Constructed response prompts. Prior to reading the text, participants were instructed to either self-explain or think-aloud during reading. The prompt contained an instruction, a sample passage, and a sample self-explanation or think-aloud.

Conceptual Inventory of Natural Selection. The Conceptual Inventory of Natural Selection (CINS; Anderson et al., 2002) is a 20-item multiple-choice test that evaluates both accurate ideas and common misconceptions related to natural selection. This assessment has been used in studies using the excerpted Pinker text (Allen, McCrudden, & McNamara, 2015; Watanabe et al., 2018).

Gates-MacGinitie Vocabulary Test. The vocabulary test from the Gates–MacGinitie Vocabulary Test served as a proxy for reading skill (GMVT; MacGinitie & MacGinitie, 1989). The test consists of 45 multiple-choice questions in which a word is presented in the context of a sentence and students must select the word or phrase most synonymous with the target word.

Procedure. The students were prompted to either self-explain or think-aloud while reading one of the texts (refutational, non-refutational). After reading, students were given the CINS and vocabulary test.

Results

Descriptive measures appear in Table 1.

Table 1. Means and standard deviations: Proportion of correct answers on the CINS by condition (n = 240)

	Think-Aloud	Self-Explain
Non-Refutational	0.47 (0.20)	0.47 (0.17)
Refutational	0.49 (0.17)	0.45 (0.17)

A linear regression was conducted to examine the extent to which condition (text type, constructed response prompt) and reading skill (GMVT) affected students' score on the CINS.

The model accounted for a significant portion of the variance, $R^2 = 0.27$, $F(7, 232) = 12.24$, $p < .001$. However, the only significant predictor was GMVT score, $t = 4.83$, $p < .0001$. Table 2 displays the regression coefficients of the full model.

Table 2. Linear regression predicting CINS score from vocabulary score, prompt, and text

	β	SE	T	P
Intercept	0.46	0.02	23.9	<0.01
Vocabulary Score	0.62	0.13	4.82	<0.01
Prompt (Self-Explanation)	-0.008	0.03	-0.29	0.77
Text (Refutation)	0.02	0.03	0.77	0.44
Vocabulary Score * Prompt	-0.17	0.18	-0.97	0.33
Vocabulary Score * Text	-0.14	0.17	-0.84	0.41
Text * Prompt	-0.005	0.03	-0.14	0.88

Note. Significant effects appear bold

When the model was calculated without GMVT score, there were no significant effects (all $t < 1$).

Experiment 2

The results of Experiment 1 did not indicate a benefit of prompting students to self-explain while reading. However, research has demonstrated that providing students training and practice in self-explanation and comprehension strategies improves the quality of students' self-explanations and text comprehension (McNamara, 2004). Experiment 2 was conducted to assess the degree to which self-explanation training influences the effect of constructed-response prompt on students' comprehension of refutational texts and students' misconceptions of natural selection. It was hypothesized that both the self-explanation prompt and self-explanation training would enhance students' comprehension of the refutational text, and by consequence their performance on the CINS.

Method

Participants and design. Undergraduate students (N=150) were randomly assigned in a 2(Training: self-explanation training, delayed training control) x 2(Prompt: self-explain, think-aloud) design. The students completed 3 sessions (4.5 hours) with no more than two days between sessions.

Self-explanation training. Students in the both the training and delayed control conditions completed two sessions (i.e., ~3 hours) of instruction and practice using iSTART (McNamara et al., 2004).

In the first session students watched video lessons describing different self-explanation strategies. Upon watching all the training videos, students were prompted to practice the strategies while reading two science texts. During practice, the students wrote self-explanations, which were automatically scored using an NLP algorithm (see McNamara et al., 2004). When a student wrote a poor self-explanation, they were provided automated feedback on the self-explanation strategies that could improve the self-explanation score.

In the second session, students were allowed to freely explore the iSTART environment which includes practice, as well as educational games.

Materials. The refutational text, conceptual test (CINS) and vocabulary test (GMVT) from study 1 were used.

Procedure. Students in the training condition were first administered the GMVT, then provided with self-explanation training across two sessions. In the third session, the students were prompted to think-aloud or self-explain while reading the refutational text. Finally, the students were given the CINS.

Students in the delayed training condition were only administered the GMVT in the first session. In their second session, the students were prompted to think-aloud or self-explain while reading the refutational text and given the CINS. The students were then provided self-explanation training across the last two sessions.

Results

Descriptive measures appear in Table 3.

Table 3. Means and standard deviations: Proportion of correct answers on the CINS by condition (n = 151)

	Think-Aloud	Self-Explain
Control	0.50 (0.20)	0.56 (0.20)
Training	0.53 (0.19)	0.49 (0.16)

A linear regression was conducted to examine the extent to which condition (training, constructed response prompt) and reading skill (GMVT) affected students' score on the CINS. The model accounted for a significant portion of the variance, $R^2 = 0.21$, $F(4, 145) = 9.49$, $p < .001$. The only significant predictor was GMVT score, $t = 1.93$, $p = .05$). There was a marginally significant main effect of prompt such that those prompted to self-explain scored higher on the CINS than those prompted to think-aloud, $t = 1.85$, $p = 0.06$. In addition, there was a marginally significant interaction between GMVT score and prompt such that low-knowledge students prompted to self-explain performed slightly better on the CINS than those prompted to think-aloud, $t = 1.81$, $p = 0.07$. Table 4 displays the regression coefficients of the full model.

Table 4. Linear regression predicting CINS score from vocabulary score, prompt, and text

	β	SE	T	P
Intercept	0.39	0.08	4.51	<0.01
Vocabulary Score	0.22	0.11	1.93	0.05
Prompt (Self-Explanation)	0.18	0.09	1.85	0.06
Training (iSTART)	-0.10	0.10	-1.01	0.31
Vocabulary Score * Prompt	0.24	0.13	1.82	0.07
Vocabulary Score * Training	0.05	0.13	0.45	0.65
Training * Prompt	0.06	0.06	1.07	0.28

Note. Significant and marginal effects appear bold.

Figure 1 shows the interaction between reading skill and prompt.

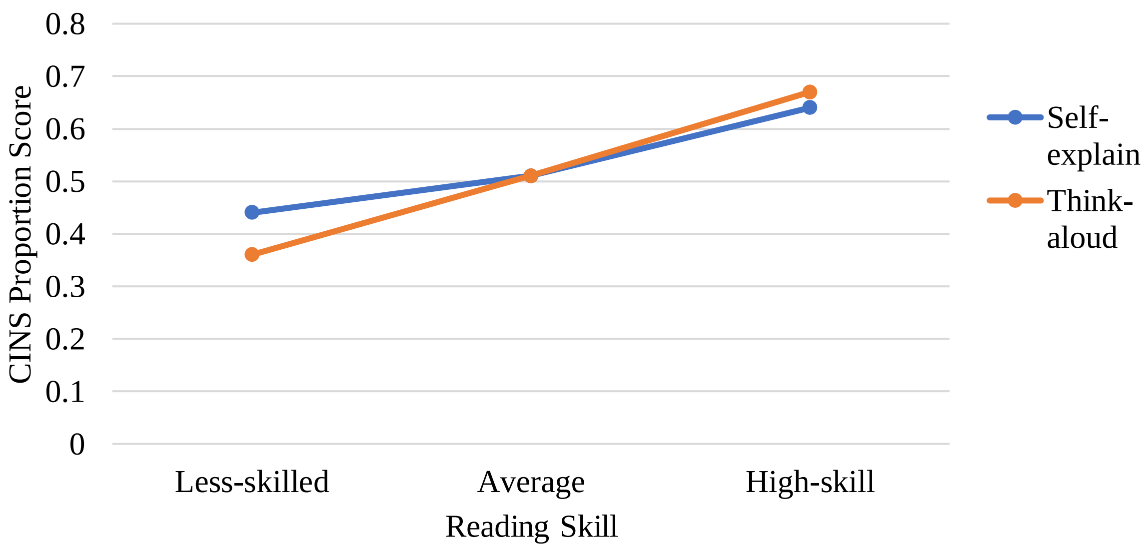

Figure 1. CINS proportion score as a function of prompt and reading skill

When the model was calculated without GMVT score, there were no significant effects (all p > 0.1).

General Discussion

Across the two experiments, neither text type nor self-explanation training affected performance on the CINS. However, in Experiment 2, prompting students to self-explain increased their conceptual understanding of natural selection. Further analyses is planned to examine the relationship between the quality of the students' constructed responses and their conceptual understanding. In both experiments, more skilled readers demonstrated fewer misconceptions, which suggests the underlying assumption of prompting and providing training in self-explanation for less skilled readers is well founded. Further research is warranted to explore the dynamic relationship of text, prior knowledge, and reading skill, and their unique contributions to conceptual change.

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