Training Reading Strategies

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Abstract

Readers who self-explain texts aloud understand more from a text and construct better mental models of the content. This study examined the effects of providing self-explanation training on text comprehension, as well as course grades. Effects of prior knowledge and reading skill were also examined in relation to the benefits of self-explaining and self-explanation training. In general, low-knowledge readers gained more from training than did high-knowledge readers.

Introduction

We often read in order to learn new information. In these situations, compared to when we read for pleasure, the texts tend to be more difficult to understand and the information tends to be more difficult to learn. This research focuses on providing readers with reading strategies to help them understand more and learn more from difficult expository texts. Thus, the primary purpose of this research is to examine the effectiveness of a training intervention designed to improve learning from texts and to determine whether the success of this intervention depends on readers' individual differences. Specifically, we examine the following individual differences: reading skill, working memory capacity, and prior domain knowledge. Reading skill is considered important to learning from text because it makes available resources for higher-level processing (e.g., Perfetti, 1985). The availability of resources is also assumed to be at least partially determined by the individual's working memory capacity. This latter assumption stems from research showing correlations between reading comprehension measures and working memory tasks (e.g., LaPointe & Engle, 1990; Daneman & Carpenter, 1980; cf. McNamara & Scott, 1999).

Perhaps the most influential factor in learning from texts is the reader's prior domain knowledge (e.g., Chiesi, Spilich, & Voss, 1979). Students with more domain knowledge better understand difficult text material from that domain. However, actually using this prior knowledge is also a key to learning. Readers can be induced to actively engage their prior knowledge by introducing gaps in the text, which require knowledge-based inferences (e.g., McNamara & Kintsch, 1996; McNamara, Kintsch, Songer, & Kintsch, 1996). Alternatively, this active engagement can emerge from reading strategies. Individuals who more actively read text also tend to comprehend more and learn more from text (e.g., Chi & Bassok, 1989). Active processing has long been recognized as critical for ensuring superior and stable retention because it results in the integration of new information with prior knowledge.

However, our theoretical understanding of the relationship and interdependency between prior knowledge and active processing remains incomplete, and we are unable to reliably predict the specific conditions under which prior knowledge and skill will play a role during learning. One premise of this research is that developing a better understanding of the relationship between prior knowledge and instructional techniques is a key to improving training methodologies.

One intervention that has been found to increase the reader's use of prior knowledge, and thus improve comprehension during reading, is called *self-explanation*. Self-explanation is the process of actively explaining the text to yourself while reading (e.g., Chi, de Leeuw, Chiu, & LaVancher, 1994). Chi and her colleagues have found that readers who explain the text, either spontaneously or when prompted to do so, understand more from a text and construct better mental models of the content. However, some readers are better self-explainers than others; less-skilled self-explainers offer little to the text to help them better understand it. One question addressed by this research is whether readers can be trained to become more-skilled self explainers (see also, Bielaczyc, Pirolli, & Brown, 1995). We address this question by providing reading strategy instruction combined with practice using the self-explanation technique. Secondly, we investigate how prior knowledge impacts the benefits of self-explanation. In Experiment 1, we first examine the effects of self-explanation in comparison to reading aloud during a training phase. We then test the benefits of training by having all of the participants self-explain a text aloud and examining their comprehension of the text. Experiment 2 looks further at the effects of this strategy training on students' course grades.

General Method

In each experiment, approximately half of the participants were randomly assigned to a self-explanation training condition, and the other half to a control condition. During two sessions of the training phase, participants in both conditions read four science texts (each concerning a different topic in science). The participants in the self-explanation training condition first received a brief instruction in self-explanation and reading strategies. The instruction focused on the benefits of using logic to understand the text, predicting what the text would say, making bridging inferences, and monitoring comprehension. For each strategy, a description of the strategy and examples were provided. The participants in the training condition then read and self-explained aloud four science texts. During this training phase, the experimenter prompted the participant to provide additional explanation for the text when necessary (e.g., when simply paraphrasing the text). After reading each text, the participants answered three to six open-ended questions about the text. For each text, the participants in the training condition then watched a video of another student self-explaining the text and identified strategies used by the student in the video. Control participants read aloud the same four science texts and answered the same questions about the texts, but did not self-explain the texts and did not watch the videos. The control condition affords the comparison of reading aloud to both reading aloud and self explanation during the training phase. It also allows us to compare individuals with and without reading strategy training.

After the training phase, all of the participants self-explained a low-coherence, difficult text about cell mitosis. The participants were told to self-explain while reading the text, but were not prompted to do so by the experimenter. The participants then answered written questions about the text. The test comprised two types of comprehension questions, text-based and bridging inference questions. To answer text-based questions, the participant must only remember one particular sentence, or idea, from the text. However, on bridging inference questions, the participant must remember separate portions of the text and understand the relationships between those ideas. The participants also answered questions designed to assess their prior knowledge of cells and cell mitosis. These questions were also related to cells and cell division, but the information to answer the questions was not presented in the text (e.g., Name three reasons for, or purposes of, cell reproduction).

Experiment 1

In Experiment 1, the participants were 43 undergraduate psychology and biology students. In addition to the measures described in the General Method section, participants were administered the Nelson Denny reading comprehension test and a working memory (WM) capacity test. The WM capacity test used was a reading span test (e.g., La Pointe & Engle, 1990). This test requires the participant to read two to six sentences, each followed by an unrelated word. After the sentences are presented, the participant is to recall the unrelated words. WM capacity is estimated on the basis of the number of words recalled in order.

Comprehension Performance During Training

An ANOVA was conducted on the proportion of questions answered correctly during training including the between-subjects variable of condition (self explain, read aloud) and the within-subjects variable of text (i.e., four texts). Participants who self-explained while they read the text answered more questions correctly ($M=0.56$) than those who simply read aloud ($M=0.47$), $F(1,41)=5.7$, $p=.021$. There was also a reliable effect of text, $F(3,39)=82.5$, $p<.001$, and a marginal interaction of text and condition, $F(3,39)=2.6$, $p=.067$. As shown in Figure 1, the effect of text was primarily due to low comprehension performance for the second and fourth texts; these texts concerned more difficult topics than did the other two texts. The interaction of text and condition seems to be due to a pronounced effect of condition for the second text. Indeed, post-hoc comparisons confirmed that the only text for which self-explanation had a reliable effect was the second text, $F(1,41)= 9.3$, $p<.01$ (all other $p >.10$). It is noteworthy that in addition to its difficulty in terms of content, the second text also seemed to require more causal inferences.

Did individual differences mediate these effects? WM capacity as measured by the reading span test did not; it failed to correlate with comprehension performance during training, and did not interact with any of the variables. However, reading skill, in terms of Nelson Denny performance ($M=28.5$), reliably correlated with overall comprehension ($r=.35$, $p=0.02$) during training. Although skilled readers better understood the four texts ($n=21$; $M=0.58$) than did less-skilled readers ($n=22$; $M=0.49$), $F(1,41)=5.4$, $p<.02$, an analysis of covariance indicated that this effect was marginal, $F(1,39)=4.0$, $p=.06$, when reading condition was also considered, $F(1,39)=8.2$, $p=.04$. Thus, self-explanation seemed to have a stronger effect than reading skill.

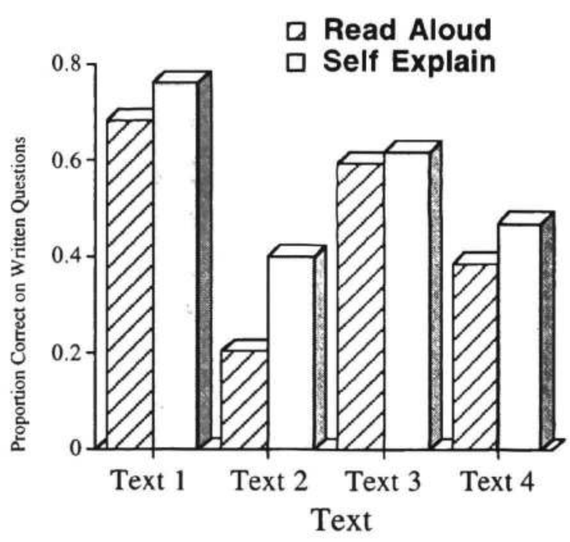


Figure 1: Comprehension performance during training across the four texts. There was little effect of self-explanation in comparison to reading aloud, except for the second text concerning the role of plants in the carbon cycle.

Prior knowledge of cells also correlated with overall comprehension performance during training (r=.44, p<.01). Prior knowledge of cells was measured to determine its effects for the fifth target text that was read after training; however, this specific knowledge also reflected general science knowledge. This correlation reflects the finding that high-knowledge readers better understood the four texts (n=23; M=0.58) than did low-knowledge readers (n=20; M=0.48), F(1,41)=10.0, p<.01. Utilizing an analysis of covariance, there were reliable effects of condition, F(1,39)=4.6, p<.01, and prior knowledge, F(1,39)=14.4, p<.01. Thus, in contrast to the effects of reading skill, the effects of prior knowledge were accentuated by reading condition. This makes sense given that the primary activity during self-explanation is the use of prior knowledge.

In summary, it appears that reading condition and prior knowledge have the strongest effects on comprehension during training. Indeed, regression analyses confirm that when all three variables were considered (i.e., reading condition, prior knowledge, reading skill), only reading condition and prior knowledge reliably predicted performance. That is, reading skill was not a reliable predictor when prior knowledge was also entered into the equation (regardless of text).

Post-training Comprehension Performance

Correlations and regression analyses indicated that neither reading skill nor WM capacity contributed to comprehension of the fifth text, self-explained by all participants (one participant was excluded from these analyses due to ceiling performance on both the post-training comprehension and the prior knowledge questions). On the other hand, prior knowledge correlated highly with comprehension (r=0.63, p<.001). Therefore, an analysis of covariance was conducted including the between-subjects variables of condition (trained, control) and prior knowledge, and the within-subjects variable of question type (text-based, bridging). This analysis yielded a reliable effect of prior knowledge, F(3,38)=29.6, p<.01, and a marginal effect of training condition, F(3,38)=3.7, p=.06. There was also a reliable difference between the two types of questions, F(1,38)=55.5, p<.01.

In addition, it appeared that the effects of prior knowledge and training condition depended somewhat on the type of comprehension question, F(1,38)=3.1, p=.08. As shown in Figure 2a, for bridging inference questions, only prior knowledge affected performance: Low-knowledge readers answered fewer questions correctly (M=0.16) than high-knowledge readers (M=0.38), F(1,38)=30.4, p<.01. As shown in Figure 2b, the results for text-based questions were quite different. For text-based questions, both prior knowledge, F(1,38)=15.5, p<.01, and training condition, F(1,38)=4.1, p=.05, reliably impacted comprehension. There was also a marginal interaction, F(1,38)=3.8, p=.06. This interaction indicated that training had little effect for high-knowledge participants (F<1), but had a large effect for low-knowledge participants, F(1,18)=9.4, p<.01. Thus, self-explanation training greatly benefited low-knowledge readers, but only in terms of their textbase level of understanding. In contrast, low-knowledge participants who had been in the read aloud, control condition comprehended very little of the text.

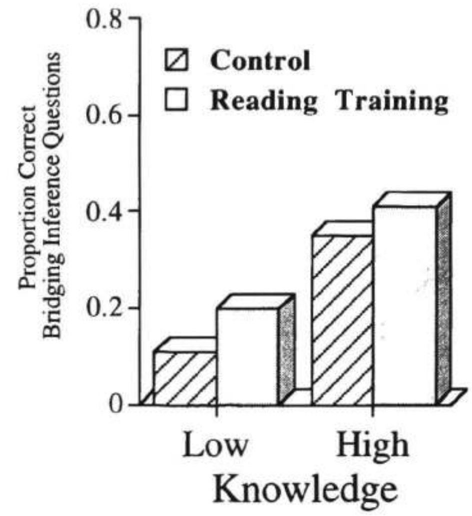


Figure 2a: Post-training comprehension performance on bridging inference questions as a function of condition and prior knowledge in Experiment 1.

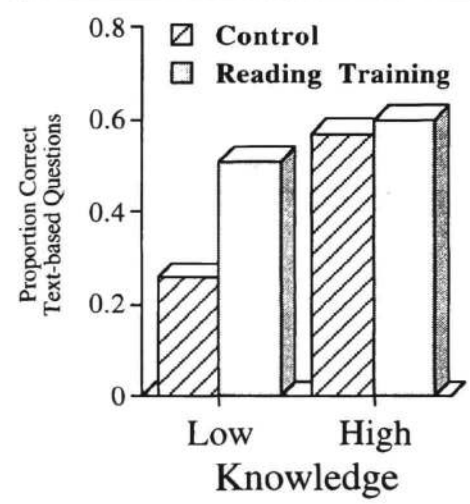


Figure 2b: Post-training comprehension performance on text-based questions as a function of condition and prior knowledge in Experiment 1.

Experiment 2

The primary purpose of Experiment 2 was to examine whether our training program would improve students' course grades in an introductory biology course. This course is a life sciences course in which students learn about living organisms and cells. A total of 360 students in the course were administered reading skill and prior knowledge tests, including the Nelson Denny reading comprehension test and a prior knowledge test including 31 multiple choice questions concerning scientific concepts, and 20 multiple choice questions concerning general knowledge (e.g., humanities, literature, art, etc.). The questions for the prior knowledge test were selected from published test banks based on the experimenters' judgment that skilled (or high-knowledge) freshman college students should be able to answer them. The students completed the tests in small groups. Of the total 360 students, 41 students participated in the training study. The students participated in the training study for extra credit in the course and were randomly assigned to either the self-explanation training condition or the comparison condition. The same training procedure was used as described in the General Method section.

Comprehension Performance During Training

An ANOVA was conducted on proportion correct during training including the between-subjects variable of condition (self explain, read aloud) and the within-subjects variable of text (i.e., the four texts). In contrast to Experiment 1, there was not a reliable effect of self-explanation (M=0.42) in comparison to reading aloud (M=0.46) (all $F<2$). Once again, the advantage of self-explanation was more pronounced for the text concerning plants (i.e., the second text), but this effect was not reliable. (No individual difference variables interacted with training condition either).

Correlational analyses were preformed to determine the effects of individual differences during training. Performance on the Nelson Denny (M=29.0) correlated with comprehension ($r=.45$, $p<.01$), reflecting better overall comprehension for skilled readers (M=0.55) than less-skilled readers (M=0.39). In addition, all three measures of knowledge correlated reliably with comprehension performance: domain knowledge of cells ($r=.43$, $p<.01$), general science, ($r=.49$, $p<.01$), and general humanities ($r=.37$, $p<.02$). In terms of predicting comprehension performance, regression analyses indicated that the best model resulted from entering in the model only two variables, reading comprehension ($F(1,38)=9.0$) and prior domain knowledge of cells ($F(1,38)=8.2$) (Model $F(2,38)=10.0$, $p<.001$, $R^2=.36$). However, the effect of knowledge was somewhat different than in Experiment 1. This is because the average level of prior domain knowledge for these participants was considerably greater (M=0.48) than the participants in Experiment 1 (M=0.26). Therefore, knowledge in this case was better characterized in terms of three levels. Accordingly, low-knowledge participants performed less well on the comprehension questions (n=15, M=0.38) than either medium (n=13, M=0.55) or high-knowledge participants (n=13, M=0.56).

Post-training Comprehension Performance

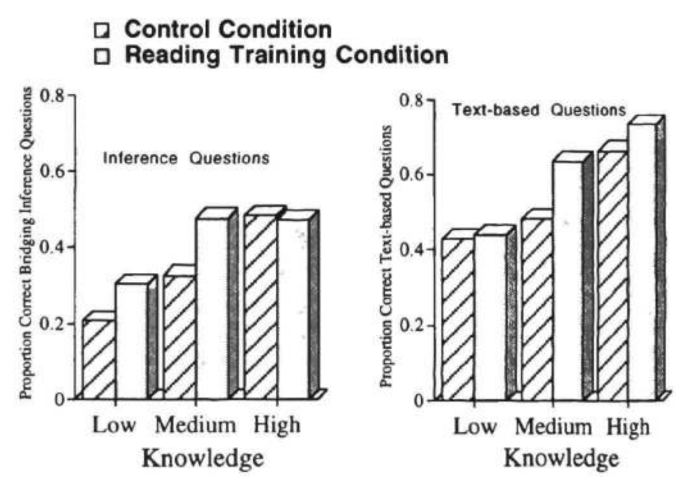
Correlations were examined between individual difference variables and performance on comprehension questions after training (see Table 1). The strongest correlation for both types of questions was with prior knowledge of cells. General Science knowledge also correlated reliably with both types of questions, but more so with text-based questions. Nelson Denny scores correlated only with the text-based questions. These latter two findings support (to some extent) the idea that understanding a text at the textbase level relies more on reading skill. These findings collectively indicate that an individual difference measure correlates with comprehension performance during self-explanation largely to the extent that it taps into the reader's prior knowledge of the domain; and open-ended, domain-specific questions do so better than other types of measures.

Table 1: Correlations between questions and tests in Experiment 2.

	Question Type	
	Text-based	Bridging Inf.
Nelson Denny Comprehension	0.329 *	0.172
Prior Knowledge of Cells	0.651 **	0.562 **
Science Knowledge	0.484 **	0.335 *
Humanities Knowledge	0.227	0.081

*p<.05, **p<.01

As in Experiment 1, an analysis of covariance was conducted including the between-subjects variables of condition (trained, control) and prior knowledge (of cells), and the within-subjects variable of question type (text-based, bridging). This analysis yielded a reliable effect of prior knowledge, $F(3,37)=30.7$, $p<.01$, and a marginal effect of training condition, $F(3,37)=3.0$, $p=.09$. There was also a reliable difference between the two types of questions, $F(1,37)=9.0$, $p<.01$. This difference depended on prior knowledge, $F(1,37)=4.1$, $p=.05$, but not experimental condition.



Figures 3a and 3b: Figure 3a, on the left, shows post-training comprehension performance on bridging inference questions. Figure 3b shows post-training comprehension performance on text-based questions.

Figures 3a and 3b show participants' performance on comprehension questions after training. These graphs indicate that there is a moderate effect of training for low and medium-knowledge participants. Indeed, further analyses showed that training condition reliably improved performance for these participants, but only for the bridging inference questions, $F(1,24)=4.6$, $p=.04$. Thus, although Experiment 2 is showing an effect of training for participants with relatively less domain knowledge, in contrast to Experiment 1, the effect emerges on the situation model level of understanding rather than the textbase level.

Course Performance

Students in the Biology 108 course took six quizzes, a midterm and a final exam. Thirty-nine of the participants completed the course. A comparison of course scores between control (n=20) and trained (n=19) participants revealed no reliable effects of training. There were no differences on any of the course quizzes or exams between the two groups of students. However, within a questionnaire administered at the end of the course, many of the students in the control condition reported using the self-explanation strategy and that this strategy had been useful in the course. Although they had not been provided with strategy training nor had they extensively practiced the technique, they had been given a brief description of the technique and had used self-explanation while reading the text about cell mitosis. It was hypothesized that the lack of difference between the participants in the training and comparison conditions was because the participants in the comparison condition had been provided sufficient exposure to the technique to use it for their course readings. The control participants' self-reports of using the self-explanation strategy in the course supported that assumption. In contrast, the remaining 319 students in the course who had not participated in the study also had not been introduced to the self-explanation technique. Therefore, 39 non-participant students were identified who matched the 39 participants in terms of both prior knowledge and reading skill. These students are referred to here as *matched controls*.

First, which measures best predicted performance in the course? To answer this question, correlations were computed including all of the students in the course. The three individual difference measures, reading comprehension, science knowledge, and humanities knowledge, reliably correlated with course performance without exception ($r=.18$ to $r=.30$). The strongest relationship to course performance was with general science knowledge ($r=.30$, $p<.001$). (This result should be of little surprise.) However, the best predictor of performance was found to be a combination of all three variables ($r=.35$, $p<.001$). Thus, for further analyses, *skill* was defined in terms of a multiplicative function of the three individual difference variables in order to capture the effects of all three variables. The multiplicative function assumes a network-like relationship between the variables. This definition also assumes that either variable can add to performance, but that they are somewhat interdependent. Hence, if you can read well and have knowledge, you will perform very well in the course; but if you can only read well, or only have knowledge, you will do less well.

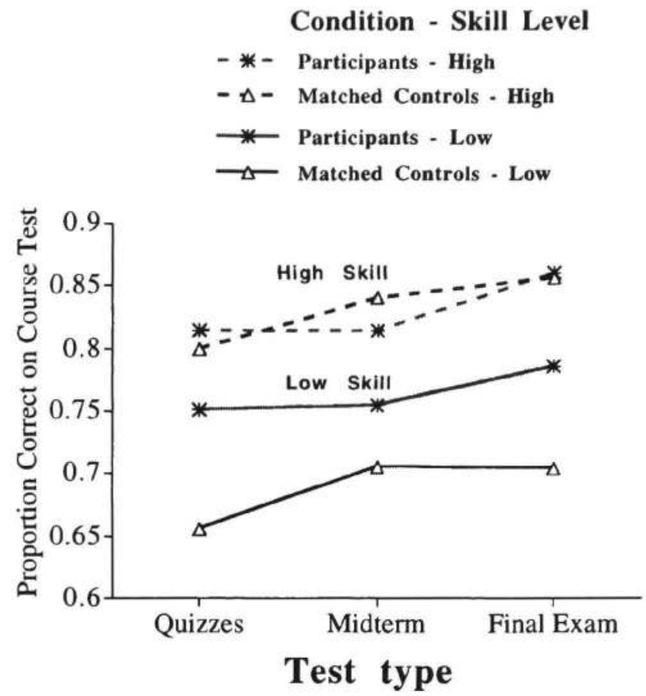


Figure 4. Participants' and matched control students' (who had not participated) course performance as a function of prior skill. Participants with less prior skill particularly benefited from the self-explanation training on course tests and exams.

Based on the three individual difference variables, the students were classified as high, medium, and low skill. This classification resulted in 26 students per skill level, with an equal number of students from each skill level (i.e., n=13) in the participant and matched control group. There was little difference between the high- and medium-skilled students' performance; thus, this analysis focuses on only the high- and low-skill students. Figure 4 shows the participants' and matched control students' performance on three quizzes (i.e., quizzes after training occurred), the midterm, and the final as a function of skill. It is evident that there were no differences during the course between high-skill participants and their matched controls (the result was similar for medium-skill students). However, low-skill participants (who had been trained or introduced to the self-explanation technique) performed better in the course ($M=0.76$) than did their matched controls ($M=0.68$). For these students, there was a 10% advantage on the quizzes and a 9% advantage on the final exam. This advantage was reliable for the overall course performance, $F(1,24)=4.3$, $p=.04$, and for quiz performance, $F(1,24)=4.7$, $p=.04$, and marginal in terms of performance on the final exam, $F(1,24)=3.0$, $p=.09$. It was not reliable for performance on the midterm exam, $F<2$.

These results indicate that both self-explanation training and a brief exposure to the self-explanation technique improved course performance for low-knowledge participants in comparison to low-knowledge students who did not learn about the technique.

Conclusions

Is self-explanation beneficial in comparison to reading aloud? Experiment 1 indicated that it was beneficial, but primarily for more difficult text. Experiment 2, however, showed little advantage for self-explanation. This absence of an effect was probably because the students in Experiment 2 possessed more domain knowledge than did those in Experiment 1. Indeed, both experiments indicated that the strongest predictor of comprehension during training was prior knowledge. These findings qualify previous findings showing little effect of knowledge during self-explanation (e.g., Chi et al., 1994). In contrast, here we see a large effect of prior knowledge, compared to moderate effects of self-explanation.

Was self-explanation training effective? We answered this question by having all of the participants self-explain a text after the training phase. In Experiment 1, training had a positive effect on text comprehension but only for low-knowledge participants, and only at the textbase level of understanding. However, in Experiment 2, there was a moderate effect of training for low and medium-knowledge participants, but this time only for bridging questions. Once again, perhaps this finding is a function of the relative level of knowledge of the participants between the two experiments. Indeed, the best predictor of comprehension in both experiments was prior domain knowledge. In any case, both experiments demonstrated that self-explanation training helped the low-knowledge reader to exercise what knowledge they had, such as logic and common sense, to construct a meaningful representation of the text. In comparison, the active processing during self-explanation was not successful for the low-knowledge readers who were not provided with the training.

Experiment 2 further indicated that either training or exposure to self-explanation improved course performance, but only for low-skilled students. Although there were no differences in course performance between participants who received self-explanation training and control participants who only self-explained one text, it was found that exposure to the self-explanation technique in the control condition led those participants to use this method in their course. Thus, the 39 participants were compared to 39 students in the course (matched to each participant in terms of prior knowledge and reading skill). This analysis showed that for less skilled students, but not skilled students, exposure to the self-explanation reading technique led to superior scores (and grades) in the course in comparison to their counterparts.

Why does self-explanation primarily help low-knowledge readers? Primarily because the knowledge is readily available to the high-knowledge reader - there is no need to use strategic processing, particularly when a difficult, low-coherence text (as used here) forces the reader to use prior knowledge (see e.g., McNamara & Kintsch, 1996). On the other hand, the low-knowledge reader cannot readily access knowledge to understand the difficult text. Self-explanation, and self-explanation training teaches the reader in that situation to use what knowledge is available -- that is, logic and common sense. Thus, self-explanation training will be particularly helpful for readers when they encounter a text from an unfamiliar, and difficult domain.

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