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### Effects of Argument Scaffolding and Source Credibility on Science Text Comprehension

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## LEARNING, INSTRUCTION, AND COGNITION

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### Effects of Argument Scaffolding and Source Credibility on Science Text Comprehension

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This study investigated the effects of argument scaffolding and source credibility on science text comprehension. Eighty-seven college students were randomly assigned to an argument scaffolding activity, or no scaffolding, and read 2 science texts, attributed to a high- or a low-credibility source. The argument-scaffolding group recalled less text-based information but generated more knowledge-based inferences than did the no-scaffolding group. High source credibility enhanced readers' text-based recall but had little effect on knowledge-based inferences or situation models. Overall, results suggest that argumentation facilitates deeper text comprehension and better argument understanding, while at the same time reducing the effect of source credibility on text processing.

**Keywords** *argumentation, argument schema, source credibility, text comprehension*

THEORETICALLY, ARGUMENTATION IS AN ENRICHED intellectual discourse to pursue truth and knowledge through rational analysis. It embodies a style of thinking that the ancient Greeks called the *dialectic*, meaning that people think by modifying positions through questioning and confrontation with opposing ideas. Confronting opposing ideas is supposed to help uncover weakness in ideas so that people are more likely to become aware of problems and to relinquish their original ideas. Argumentation is a tool to find better solutions with justifiable reasons. These

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The Chinese version of the text materials is available upon request.

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properties of argumentation make it a way of problem solving (Siegel, 1995), a tool for knowledge acquisition (Meiland, 1989), and a strategy of metacognition (Kuhn, 2001).

An *argument schema* is knowledge of the structure and purpose of an argument (Cheng & Holyoak, 1985; Kintsch, 1998; Reznitskaya & Anderson, 2002). The following components are usually considered to be the central elements of an argument (e.g., R. C. Anderson et al., 2001; Angell, 1964; Kuhn, 1991; Kuhn & Pearsall, 2000; Reznitskaya & Anderson, 2002; Toulmin, 1958; Voss, Blais, Mean, Greene, & Ahwesh, 1986):

1. A *claim* is the central idea of an argument, defined as an assertion about a fact, definition, value, or policy (Rybacki & Rybacki, 1996).
2. An *explanation* is a type of backing for a claim that proposes a mechanism that forms a causal bridge from the claim to empirical data (Kuhn & Pearsall, 2000).
3. *Evidence* is the backing for a claim and consists of empirical data or facts that are objective and public to the world. Toulmin (1958) defined *data* as “the facts we appeal to as a foundation for the claim” (p. 97). Kuhn (1991) further distinguished *genuine evidence* from *pseudoevidence*, stating that *genuine evidence* is the empirical data showing the existence or nonexistence of a causal relation between antecedents and consequences, whereas *pseudoevidence* is a scenario or story that, at best, illustrates a causal relation without proving it (pp. 44–96).
4. A *counterargument* is an opposing idea that discounts the validity of a claim. Types of counterargument can be classified into three categories (Shaw, 1996): assertion based, argument based, and alternative based. An *assertion-based objection* counters the truth of the premise or conclusion of an argument, an *argument-based objection* opposes the causal or correlational relationship between the premise and the conclusion, and an *alternative-based objection* raises other possible causes or consequences beyond those specified in the original theory.
5. A *rebuttal* is a reason advanced to negate a counterargument in order to justify an arguer’s original claim. Constructing a rebuttal may be more effortful than constructing a counterargument. This is suggested by the finding that students generate more successful counterarguments than rebuttals (Kuhn, 1991; Reznitskaya et al., 2008).

According to Johnson (2000), an arguer must fulfill two tiers of obligation. The first tier of an argument consists of a premise–conclusion structure: a set of acceptable premises adduced in support of a controversial conclusion. This is called the *illative core*. The illative core is meant to initiate the process of converting others’ beliefs, persuading them to believe in the arguer’s position, but the illative core itself is not enough to serve the purpose of argument unless the arguer also takes into account possible objections and alternative positions, which is the second tier of obligation called the *dialectical tier*. This dialectical process can also occur within the arguer him- or herself (Reznitskaya et al., 2008). Research has shown that an effort to persuade others or oneself is a means of knowledge acquisition (e.g., Asterhan & Schwarz, 2007). This is because when people attempt to convince others, they engage in additional processing to resolve conflicts by evaluating the pros and cons of different positions, generating explanations to fill in conceptual gaps, and constructing a coherent explanatory model to justify their own perspective. Arguers with a well-developed argument schema are those who are fully aware of the two tiers of obligation in the process of argumentation.

Few studies have focused on the relationship between argumentation and text comprehension. The purpose of present study was to investigate whether deeper text comprehension and better quality of argumentative thinking could be facilitated through scaffolded argumentation. Our proposal is that an argument schema occupies a plane beyond the *situation model*, a coherent mental representation that integrates text-based information and the reader's prior knowledge (Kintsch, 1988, 1998). An argument schema is a type of control structure that places constraints on the situation model, which must be satisfied along with constraints that come from domain knowledge and the text itself. An argument schema enables critical reading, not just an interpretation of the text but an interpretation that meets strict standards. An argument schema directs readers to tag propositions as credible or less credible and to evaluate the overall goodness of fit of the situation model to the data.

Kintsch's construction-integration model (Kintsch, 1988, 1998, 2005; van Dijk & Kintsch, 1983) is one of the most influential theories of text comprehension. According to the construction-integration model, text comprehension is accomplished by cycling through two cognitive processes: construction and integration. The construction process refers to spreading activation across meanings of words in readers' long-term memory. An integration process through constraint satisfaction then takes place to inhibit meanings that are inconsistent with the meanings of other words in the text and to generate a text-based microproposition that constitutes a coherent sentence meaning. This text-based microproposition serves as a unit of input to the construction-integration process of the following sentence. Macropropositions representing the central meaning of the sentences in a paragraph are formed through integration of micropropositions. The aforementioned processes are generally bottom-up, driven by the text, and automatic and effortless.

While the text-based representation is obtained from the semantic and syntactic analyses of the text, a situation model is constructed using a schema-driven, top-down construction and integration process. During this process, knowledge-based inferences are constructed to integrate text-driven propositions with readers' world knowledge to form a coherent mental model that goes beyond the literal meaning of the text (McNamara, Kintsch, Songer, & Kintsch, 1996).

In the construction-integration model, comprehension is constrained, on the one hand, by what we read from the text; on the other hand, it is also guided by what we expect to read. The construction-integration model, however, does not explicitly address the processes involved in evaluating the validity of the situation model. We suggest that this is a function ideally fulfilled by reasoned argumentation. Consequently, we propose a two-level model of text comprehension. At the first level, a situation model is constructed by integrating text-based information and knowledge-based inferences. At the second level, readers evaluate the situation model in terms of an argument schema. The argument schema assists a reader in monitoring and regulating the formation of a situation model. Thus, the two levels of comprehension proceed in parallel. In the best case, the two levels interact with each other to form a coherent and justified mental representation of the text.

The following excerpt (based on Smith, 2008) is one that might appear in a popular newspaper or magazine report of a scientific advance:

Vitamin C can destroy cancer when injected rather than swallowed, scientists have discovered. It halves the growth of aggressive tumors in mice, killing cancer cells while leaving healthy tissue

unharmful. The therapy could provide a new lifeline for patients with a poor prognosis and few treatment options, said researchers. The body usually restricts vitamin C levels passing from the digestive system into the blood. But American scientists found this can be bypassed if the vitamin is injected into the bloodstream. It then generates hydrogen peroxide that is lethal to tumors. Dr. Qi Chen of the National Institutes of Health in Bethesda, Maryland, said: "It decreased growth rates of ovarian, pancreatic and brain tumors established in mice." Vitamin C has been part of alternative cancer treatments for more than 30 years.

According to the C-I model, text-based propositions (such as "Vitamin C can destroy cancer," "Vitamin C can be injected," "Vitamin C can be swallowed") are constructed in the mental representation as a reader reads from words, sentences, to the paragraph level. The text also activates the reader's prior knowledge (such as "fruits are rich in vitamin C," "cancer cells grow into tumors," "injected drugs go to blood directly"), which further enriches, modifies, or restructures the text base to form a coherent situation model (Scientists discovered that vitamin C in blood is able to generate hydrogen peroxide that would decrease growth rate of cancer cells in mice with ovarian, pancreatic and brain tumors without harming the healthy issue. This provides a new life line for cancer patients. However, because the body would restrict vitamin C levels passing from the digestive system into the blood, the treatment requires vitamin C to be injected rather than swallowed.)

Concurrently, to validate the claims in the text, an argument schema needs to be activated, which directs the reader to look for the elements of the text that are essential parts of an argument. Presumably, a reader with a well-developed argument schema would encode the thesis or claim, namely that vitamin C injections can destroy cancer without harming the patient; that the experimental study in mice is backing for the claim; that introduction of the idea that only a fixed amount of vitamin C can be absorbed daily by the digestive system is a preemptive strike against a possible counterclaim; and that the quote from an expert is a further attempt to substantiate the original claim.

Reading a text as an argument entails deeper cognitive processing than most other forms of reading (Wiley & Voss, 1999). A reader with a well-formed argument schema may raise doubts about the soundness of a claim or the strength of evidence, for instance, whether the study with mice can be generalized to human patients, whether a vitamin C injection could cause side effects, or whether vitamin C can destroy all kinds of cancer cells. As the reader constructs inferences such as these, the mental representation of the text is continuously updated and elaborated (Blanc, Kendeou, van den Broek, & Brouillet, 2008).

We propose that arguing with a text is a particularly efficacious form of deeper processing. Students need to doubt what they read based on knowledge of argumentation. However, previous research suggests that students generate inferences only when the information needed to compute the inferences is explicitly presented in the text (Wiley & Myers, 2003). Moreover, Bock and Brewer (1985) found that readers usually process expository texts on a more descriptive level in comparison to narrative texts. One reason why students are often passive or nonstrategic readers is that they may fail to recognize the appropriateness of a strategy in a given setting (Lorch, Lorch, & Klusewitz, 1993). These findings imply that students are not inclined to spontaneously apply what they know about argumentation when reading. The argument scaffolding technique employed in this study aimed to trigger students' existing argument schema and prompt them to make the best use of it.

The term *scaffolding* is a metaphor to describe a process in which the learner receives some kind of support from teachers, peers, or technology. Several studies have examined types of argument scaffolding to foster students' argumentative thinking and reasoning skills. Some of them involved computer programs or integrative diagrams to provide visual aids for the spatial representation of argument structure (e.g., Carr, 2003, Nussbaum et al., 2008). Some studies investigated instruction that systematically guided the participants from generating reasons to conducting two-sided arguments (e.g., Kuhn & Udell, 2003). Other studies immersed students in extended argumentative discourse in which teachers occasionally prompted for elements of sound arguments (e.g., Anderson et al., 2001; Jadallah et al., 2011).

Compared to these approaches, students in the present study were engaged in an argument scaffolding activity in which thought processes were guided by a sequence of prompts for argument elements, such as evidence and counterarguments. We anticipated that the prompts would activate students' existing argument schema and promote qualitatively different processing. Presumably college students already possess at least a partially formed argument schema, but they may read casually without bringing it into play. Argument scaffolding may serve to activate the argument schema, increasing the likelihood that students would critique the credibility of claims, the logic of explanations, the strength of evidence, and the plausibility of counterarguments or alternatives; in other words, promoting critical reading and evaluation of whether the situation model under consideration gives a good account of everything known to the student.

Science texts are difficult to comprehend because of technical terms, complicated theoretical explanations, logical/mathematical proofs, and the empirical evidence load. Such texts have strict and specialized standards of coherence. Even reading popular scientific reports usually involves critical analysis in which high cognitive demands are imposed. It is perhaps not surprising, therefore, that the ability of educated young adults to properly interpret science reports falls short (Norris & Phillips, 1994; Phillips & Norris, 1999).

When people encounter a science text, especially one in an unfamiliar field, the source of information can play a role in evaluating the validity of the arguments. However, readers may too readily accept an expert's opinions (Walton, 1997). For the example text, Dr. Qi Chen's opinion might be highly valued by laypersons because he apparently is an expert. However, even experts may err. Blind reliance on source credibility may result in failure to identify the leakage in their arguments.

In this age of specialization, it is impossible to escape reliance on expertise (Walton, 1997). The status of speakers and writers may therefore influence how one receives an argument. That is, people may expect an argument to be valid if it is delivered by an expert rather than a non-expert, which in turn affects how people perceive and evaluate the argument. For example, Cialdini and Trost (1998) found that speakers with higher social status were more likely to persuade their audience. Kolstø and colleagues (2006) found that the source of information influenced how readers judge the soundness of an argument.

Inglis and Mejia-Ramos (2009) investigated effect of source credibility on the persuasiveness of mathematical arguments. Research-active mathematicians and undergraduate students were exposed to three types of argument in a random order: a heuristic argument, an inductive argument, and a visual argument. Each of the arguments was said to be written by a credible source (i.e., renown mathematicians or taken from an undergraduate textbook) or said to be written by an anonymous figure. Heuristic and visual arguments were more likely to be accepted when the credible source was ascribed, while source credibility did not affect how the researchers

and undergraduates rated the inductive argument. Inglis and Mijia-Ramos (2009) speculated that subjects relied on expert's opinions only when they were uncertain about an argument, because the heuristic and visual arguments either required more complex explanations or were not sufficient to support the conclusion, compared with the inductive argument. Arguments said to have been made by experts were given more weight because the participants believed it was reasonable to assume that well-known mathematicians would have thoroughly evaluated arguments before announcing a conclusion.

Research on persuasion shows that source credibility mediates depth of text processing. Chaiken and Maheswaran (1994) asked college students to read a description of a new telephone answering machine and give their opinions about the machine. Students were told that the product description was either excerpted from a well-known consumer reporting service (high source credibility) or from a sales staff presentation (low source credibility). Task motivation and message type were also manipulated. Results showed that when students who were highly motivated were asked to read an *ambiguous* text, source credibility influenced processing. However, when motivated students read an *unambiguous* text, the effect of source credibility was attenuated. In a similar fashion, we anticipated that argument scaffolding might attenuate the influence of source credibility in the processing of science texts.

To recapitulate, the primary research questions addressed in this research are as follows: (a) Does a scaffolded argumentation activity facilitate a deeper level of science text comprehension? (b) To what extent does source credibility affect readers' text comprehension? (c) Does argumentation play a role in reducing the influence of source credibility? On the basis of the two-level model proposed, we hypothesize that students who received a scaffolded argumentation activity would construct a better situation model to represent the text, and be better able to evaluate the claim, evidence, and explanations in the text regardless of the credibility of its author.

## METHOD

### Participants

Participants were 87 undergraduate students (34 women, 53 men) with an average age of 21 years (age range = 18–24 years) from a public university in Hsinchu, Taiwan. There were 6 freshmen, 24 sophomores, 29 juniors, and 28 seniors. Of the students, 48% came from the Colleges of Electrical and Computer Engineering, Computer Science, Engineering, or Science; 43% came from the College of Management; and 9% came from the College of Humanities and Social Sciences. The subject pool represented the distribution of the student population of this technology-oriented university.

### Materials

Two scientific texts were selected from the Chinese versions of *Scientific American* and *Science Development* magazines. One text (Wang, 2006) addressed a life science topic, the cause of depression, which we will call the depression topic in the remainder of the paper. The other text (Rillings, 1997) addressed a technology topic, the effectiveness of an automated highway system, hereinafter called the highways topic. Each text was approximately 600 Chinese characters in length.

The texts were restructured to the canonical argument schema. The revised texts contained five elements presented in the following order: (a) an author's claim, (b) explanation, (c) supporting evidence, (d) a counterargument to the claim, and (e) the author's rebuttal of the counterargument. Because the original articles failed to contain some of these argument components, we filled in the missing elements to assure that participants were exposed to all of the argument elements in both texts. The restructured texts were expected to intensify the argument scaffolding effect, because participants who received an argument scaffolding treatment could more easily apply their argument knowledge to the restructured argument than to the original texts (see Appendix A).

### Experimental Treatments and Procedure

Students were tested individually in a quiet room. At the beginning of each session, the experimenter briefly introduced a topic and an author's claim. For example, students were told a claim about the cause of depression. Half of the students were told that this claim came from a neuroscience professor, with an English name, and the other half were told that the claim came from a college student, with a Chinese name. Then, students were asked to read the argumentative text which was said to be written by the person who made the claim. Before reading, students were informed that they would need to answer some questions about the text later. They were instructed to read for comprehension at their own pace. The average reading time was approximately 2.5 min.

After reading, all students were asked to recall (pretest recall) the argumentative text with the following directions, "Please write down as many details of the text as you can. If you can't remember the detail, try to address the meaning in your own words as close to the original as possible." The purpose of the pretest recall was to make sure students did pay attention to the text. Next, half of the students completed an argument scaffolding task, in which five open-ended questions were given to structure students' thinking on both sides of the issue and guide them in the generation of an explanation, evidence, counterargument, and rebuttal. These questions include (a) what are the reasons that support the author's claim; (b) is there evidence that can support these reasons; (c) what are the reasons that are against the author's claim; (d) is there evidence that can support these opposing reasons; (e) think of reasons that would discount or disconfirm your reasons to support the author's claim.

The original text was available for students to refer to. The other half of the students were assigned to the no scaffolding condition, in which they were given the argumentative text again and were asked to thoroughly review it. Then both the argument scaffolding group and the no scaffolding group were asked to recall the text again (posttest recall). Last, a reflective essay task in which students were asked to write down their own evaluation of the issue was given to both groups.

The whole procedure was repeated again in a second session but with a different topic. In other words, students read about one of the two topics in each of the two sessions of the experiment. The order of two topics was counterbalanced and students within conditions were randomly assigned to orders. The entire experiment lasted for about 2 hr.

### Data Analysis and Measures of Dependent Variables

The primary data of this study included students' text recall and reflective essays. The posttest recall task was used to assess the extent to which argument scaffolding and source credibility affect number of text-based propositions recalled and number of knowledge-based inferences generated.



The essay task was used to assess whether students produced better situation models and greater argument quality when they completed the argument scaffolding activity. We hypothesized that argument scaffolding would enhance text-based recall, knowledge-based inferences, and the quality of the situation model and arguments.

### *Coding Posttest Recall*

The two science texts read by the students were parsed into macropropositions. The depression text was decomposed into 10 propositions, and the automated highway system text into 11 propositions. These propositions were matched to students' recalls to determine the quantity and quality of students' text-based and knowledge-based comprehension.

We define text-based recall as macropropositions that were extracted from the original text. Text-based recall was further coded according to a three-level rubric. The first level is *correct and complete* text-based recall, which means students clearly and comprehensively expressed the meaning of a proposition. The second level is *correct but incomplete* text-based recall, which means partial recall of a proposition. The third level is *incorrect* text-based recall, which means the recalled proposition shared some superficial similarities to the original text, but the deeper meaning was distorted. For example, some of the students in the study recalled that Prozac, an antidepressant, could extend the reuptake of serotonin. However, in the original text, Prozac was said to *inhibit* the reuptake of serotonin so that serotonin could have a longer time to interact with dendrites. The students apparently did not catch the correct idea of how the antidepressant functions.

Text-based recalls were blindly coded by three native Chinese-speaking raters. A coding scheme and examples were provided and explained to each rater before coding. Table 1 lists some examples of the coding categories. Recall essays were randomly assigned to the raters who coded recall independently. Each rater also coded additional 10% of the recalls to check reliability. Average interrater percentage of agreement was 89% (Cohen's kappa = .87).

Knowledge-based inferences are macropropositions that were not explicitly stated in the text but generated by students themselves on the basis of their prior knowledge. We observed four types of inferences in this data set—*new link*, *generalization*, *integration*, and *causality*. *New link* means an inferred relation between two argument elements (e.g., claim – rebuttal, evidence—rebuttal) that the author addressed in the text. In other words, these links connected text-based information in a way not explicitly mentioned in the text. Figure 1 contains two diagrams showing concepts of the argument elements in the texts, accompanied with all the text-based links and possible new links. The second category is *generalization*, which means students enlarged a specific concept into a more general concept. For example, when recalling the rebuttal sentence from the depression text, a few students replaced the concept “melancholy” with “depression” in an attempt to say that depression can cause stress. This example shows how students use generalization when constructing their situation models.

The third category is *integration*, which refers to a combination of two or more concepts. In the highways text, the counterargument stated that as the rate of car flow increases, the frequency with which people change lanes and get on/off the highway also increases, in turn lowering overall car speed. This counterargument was rebutted by the author with another experimental finding that when the car flow stays at a rate of 3,500 cars per hour, the AHS system reduces the collision incidence. A student integrated these two claims and concluded that when the car flow increases,

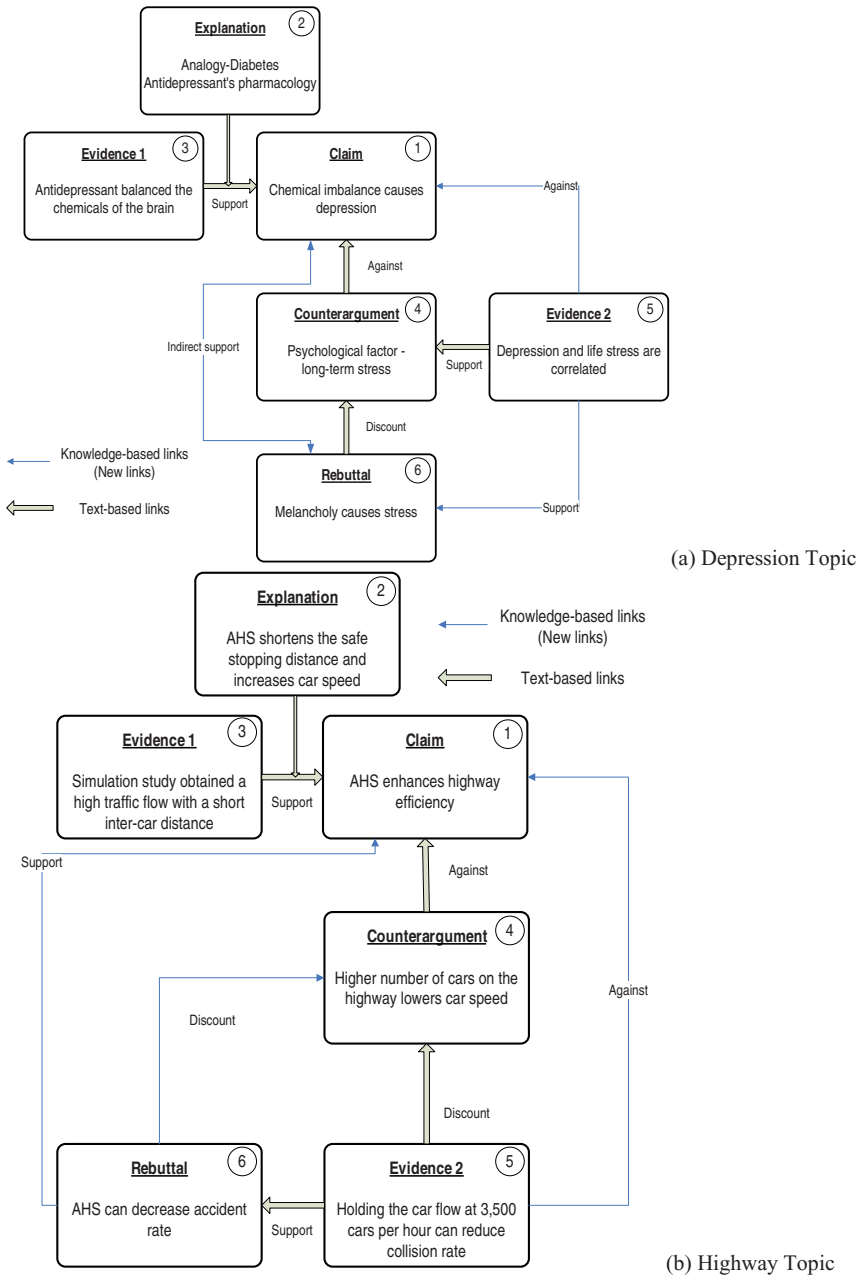


FIGURE 1 Ideal situation model. (Color figure available online.)

TABLE 1  
Examples of the Coding Rubrics for Students' Text-Based Recall and Knowledge-Based Inference

Category	Examples
Text-based recall	
Original sentence	Doctors often use antidepressants like Prozac (also called selective serotonin reuptake inhibitors) to slow down the removal of serotonin so as to extend its effects on the synapse.
Correct and complete recall	Taking antidepressants inhibits the reuptake of serotonin and extends its effects on the synapse.
Correct but incomplete recall	Prozac can extend the effect of serotonin.
Incorrect recall	The experiment showed that after taking medicine that extended the reuptake of serotonin, depression patients recovered significantly.
Knowledge-based inference	
New link	Holding a car flow of 3,500 cars per hour can reduce accident rates, which in turn enhances highway efficiency.
Generalization	Generally speaking, there are two explanations for the cause of depression: a biological cause and an environmental cause.(Original text: Depression is caused by a chemical imbalance in the brain. However, some psychologists consider that the psychological factor of long-term stress causes depression.)
Integration	The higher the car flow, the more frequent cars change lanes, which lowers car speed and increases car accidents.(Original text: The higher the number of cars on a highway, the more frequently cars change lanes and go on and off the highway, which in turn lowers the car speed..... This implies AHS can further decrease accident rates.....)
Causal inference	It is likely that higher life stress causes the deficiency of serotonin. Therefore, stress is the cause of depression, whereas the deficiency in serotonin is the symptom of depression.

Note. AHS = Automated Highway System.

so does the accident rate. The fourth category is *causal inference*, which readers generated in the aim of building a hypothesis or theory. For example, one student attributed the insufficient serotonin as a symptom rather than a cause of depression. That is, contrary to the author's idea that chemical imbalance in the brain causes depression, the student claimed that depression may in fact cause the chemical imbalance (see Table 1 for more examples).

Knowledge-based inferences were first coded by one rater; 18% randomly selected recalls were then coded by another rater who was not involved in the study. Interrater percentage of agreement on new links, integration, generalization, and causal inference was 92% (Cohen's  $\kappa = .81$ ).

Last, we tested effects of argument scaffolding and source credibility on recall of the source of information. Students' source recall was coded into three categories. Source recall that was complete and accurate according to the original text, such as "Dr. Neils, an American neuroscience professor," was coded as *complete source recall*. Recall that contained only partial source information, but was clear enough to distinguish it from the other sources, was coded as *incomplete source recall*, such as "a professor said." Sources that were confused with the other sources were coded as *incorrect source recall*. Average interrater percentage of agreement on source recall was 89% (Cohen's  $\kappa = .86$ ).

TABLE 2  
Situation Model and Argument Quality Indicators

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*Depression*

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Situation model

1. The data showed that both the placebo and Prozac had effects on depression.
2. Despite chemical imbalance in the brain, psychological factors could also be the cause of depression (e.g., life stress).
3. The study cannot exclude the possibility that psychological factors may also cause depression, because the placebo had an influence on depression.

Argument quality

1. The evidence was not sufficient.
  2. The evidence may support other alternatives.
  3. The explanation of the evidence is logically flawed. A causal relationship between depression and the chemical imbalance of the brain is not tenable.
- 

*Automated Highway System*

---

Situation model

1. AHS uses computers to control cars at a steady speed and keep a minimum distance from other cars.
2. Manual driving is replaced by computer driving so that the situation in which drivers speed up to change lanes is less likely to happen.
3. However, AHS deprives drivers of the flexibility to control cars and adapt to traffic conditions.
4. A car must lower its speed when getting on or off the highway or changing lanes. This implies that other cars also need to lower their speed. Then there would be no highway efficiency gains if cars frequently get on and off the highway.

Argument quality

1. The evidence is not sufficient.
  2. The reasons are insufficient to support the claim. Highway efficiency was merely measured by number of cars on the highway and collision rates.
  3. The arguments cannot successfully counter other alternative arguments.
- 

*Note.* AHS = Automated Highway System.

### *Coding Reflective Essays*

The goal of the reflective essay analysis was to investigate the extent to which students incorporate the main ideas of the text in their situation model, and whether they can critically evaluate the situation model in terms of criteria for a sound argument. An ideal situation model contains core meanings of the entire text. Argument quality is represented by critiques of the claims, evidence, and explanations in the text. It reflects participant's evaluation of argument validity. We derived three core meanings from the depression text and four from the highways text. We also derived three principal comments/critiques for each science text (Table 2). These core meanings and principal critiques were matched to students' essays to determine the quantity and quality of their global comprehension and argumentative thinking. The interrater percentage of agreement for the coding was 96% (Cohen's kappa = .92).

### Design and Statistical Approach

The study had an Argument Scaffolding (argument scaffolding vs. no scaffolding)  $\times$  Source Credibility (high-credibility source vs. low-credibility source)  $\times$  Position (first vs. second) design,

TABLE 3  
Means and Standard Deviations of Text Comprehension Measures

Measure	Position	Argument scaffolding				No scaffolding			
		High credibility		Low credibility		High credibility		Low credibility	
		M	SD	M	SD	M	SD	M	SD
From recalls									
Text-based recall (%)	1st	0.44	0.26	0.37	0.18	0.49	0.15	0.38	0.17
	2nd	0.46	0.19	0.44	0.20	0.66	0.15	0.51	0.19
Knowledge-based inferences (n)	1st	1.05	0.90	1.05	0.92	0.83	0.65	0.76	1.18
	2nd	1.41	1.18	0.86	1.01	0.82	0.85	0.73	0.77
Source recall (n)	1st	1.27	1.12	1.05	1.32	1.65	1.40	0.76	0.83
	2nd	1.06	1.18	1.20	1.03	2.18	1.14	1.15	1.42
From reflective essays									
Situation model (%)	1st	0.28	0.33	0.31	0.33	0.22	0.24	0.26	0.28
	2nd	0.32	0.26	0.44	0.33	0.20	0.16	0.21	0.19
Argument quality (%)	1st	0.35	0.24	0.37	0.23	0.29	0.16	0.32	0.19
	2nd	0.29	0.26	0.32	0.27	0.18	0.20	0.24	0.23

with argument scaffolding and source credibility as between-subject variables, and position as the repeated measure. We used three-way repeated measures analysis of variance when an outcome variable conformed to a normal distribution. However, the outcome variables were counts and the distributions were often non-normal. When the normality assumption was violated, a generalized Poisson log linear regression model was fit to the data. The assumptions of this model are that the relationship between the outcome variable and predictors is exponential and that the variance of the variable is approximately equal to its mean (C. J. Anderson, 2009; Nussbaum, Elsadat, & Khago, 2008). Since the outcomes involved repeated measures, the regression analysis used the generalized estimated equations technique (Liang & Zegar, 1986). Hypothesis testing employed the Wald test ( $z = (\hat{\beta}/SE)^2$ ) and confidence intervals.

## RESULTS

### Analysis of Students' Recall

The quality and quantity of students' posttest recall were represented by three dependent measures: text-based recall, knowledge-based inferences, and source recall. Text-based recall was derived from the sum of correct-and-complete and correct-but-incomplete recall. The knowledge-based inference measure was the sum of new links, generalization, integration, and causal inferences. Means and standard deviations of these indicators are shown in Table 3.

#### *Text-Based Recall*

Pretest recall took place before the argument scaffolding treatment. The major finding of the pretest recall from the first session was that there was no source credibility effect or argument

scaffolding effect. This suggests any argument scaffolding effect revealed in the posttest would not be attributable to preexisting group differences such as preexisting text comprehension ability or argumentative knowledge. Hence, we analyzed only the posttest measures in this study.

Posttest text-based recall from two sessions of the experiment conformed to a normal distribution. A three-way repeated measures analysis of variance showed that in the posttest recall, both argument scaffolding,  $F(1, 83) = 5.84, p < .05, \eta_p^2 = .07$ , and source credibility,  $F(1, 83) = 6.90, p = .01, \eta_p^2 = .08$ , had significant effects on the text-based recall, but there was no interaction between the two factors. Students who were told the author of the text was a professor recalled more text-based information than those told the author was a college student. Unanticipated is the fact that students who received the argument scaffolding activity recalled *less* text-based information than the no scaffolding group. A possible explanation is that argument scaffolding shifts the strategy of text comprehension from memorization to critical thinking, from shallow to deeper processing. This explanation is consistent with the finding regarding knowledge-based inferences reported in the next section.

There was a significant position effect,  $F(1, 83) = 21.03, p < .001, \eta_p^2 = .20$ , with Geisser-Greenhouse correction for lack of sphericity, and an interaction of Position  $\times$  Argument Scaffolding,  $F(1, 83) = 6.93, p = .01, \eta_p^2 = .08$ , again with correction for lack of sphericity. Students recalled more text-based information in the second session than in the first session, suggesting that students tended to work harder in the second session. The increase was higher for the no scaffolding group than for the argument scaffolding group. One reason may be that the no scaffolding group allotted more cognitive resources to the text base level than to deeper levels of text comprehension, compared to the argument scaffolding group. This was confirmed by the knowledge-based analysis described in the next section.

### *Knowledge-Based Inferences*

A generalized estimated equations Poisson log linear regression analysis using a full model overfit the data, probably because of correlations among the predictor variables. The model without interaction terms showed the best model fit. There was a significant argument scaffolding effect ( $\exp(\hat{\beta}) = 1.46$ , 95% CI of  $\exp(\hat{\beta})$  [1.10, 1.94],  $z = 2.63, p < .01$ ) on total number of knowledge-based inferences. The number of knowledge-based inferences was 1.46 times larger in the argument scaffolding group than in the no scaffolding group. Neither source credibility nor position had a significant effect. Therefore, results with text-based recall, described above, and knowledge-based inferences support the hypothesis that argument scaffolding shifts text comprehension from a superficial to a deeper level.

### *Source Recall*

The source recall variable was considered over-dispersed for a Poisson distribution, ( $M = 1.30, SD = 1.54$ ), so we assumed a negative binomial distribution. The predictor variables included argument scaffolding, source credibility, position, and all the two-way and three-way interactions. Fitting a full model to the data, there was a nearly significant Argument Scaffolding  $\times$  Source Credibility interaction ( $\exp(\hat{\beta}) = 2.18$ , 95% CI of  $\exp(\hat{\beta})$  [0.98, 4.89],  $z = 1.90, p = .06$ ). Figure 2 shows that in the low-credibility condition, source recall did not differ between

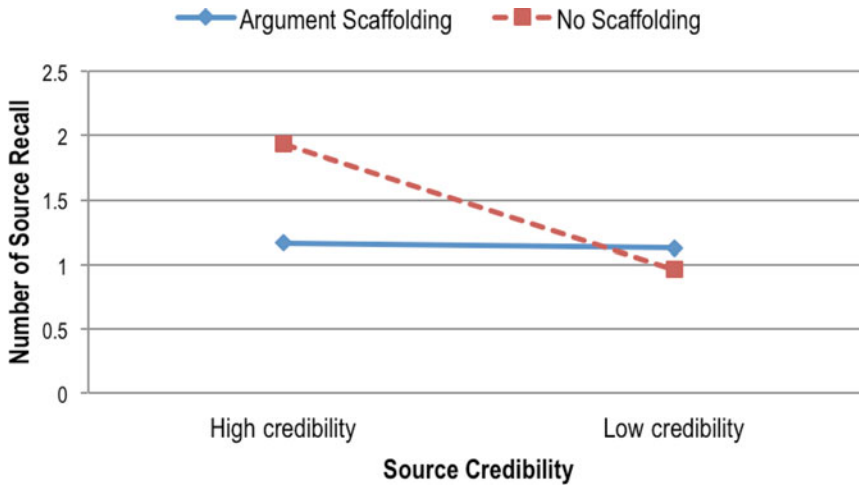


FIGURE 2 Source recall as a function of argument scaffolding and source credibility. (Color figure available online.)

the argument scaffolding and the no scaffolding group. However, there was a trend toward an argument scaffolding effect when texts were said to have been written by an expert. Under the high-credibility condition, no scaffolding students tended to recall more sources than those who performed the argument scaffolding task before recalling the text. This result suggests that argument scaffolding reduced the influence of source credibility.

### Analysis of Students' Reflective Essays

The generalized estimated equations Poisson regression analysis using the full model showed that argument scaffolding had a significant effect on the situation model ( $\exp(\hat{\beta}) = 2.11$ , 95% CI of  $\exp(\hat{\beta})$  [1.28, 3.49],  $z = 2.93, p < .005$ ). The same saturated regression model failed to predict argument quality, but a reduced model with only the three main effects did show a significant argument scaffolding effect ( $\exp(\hat{\beta}) = 1.24$ , 95% CI of  $\exp(\hat{\beta})$  [1.01, 1.52],  $z = 2.06, p < .05$ ). The argument scaffolding group generated 2.11 times more core meanings than the no scaffolding group, and generated 1.24 times more principal critiques than the control. This result indicates that a scaffolded argumentation activity can promote a deeper level of text comprehension.

According to our two-level theory of text comprehension, an argument schema serves as a control structure that constrains a situation model. Thus, a better situation model would suggest a better argument schema, and vice versa. Consistent with this hypothesis, there was a significant though small positive correlation between argument quality and completeness of the situation model (Pearson correlation coefficient = 0.19,  $p = .01$ ).

Last, there was a significant position effect on argument quality ( $\exp(\hat{\beta}) = 1.24$ , 95% CI of  $\exp(\hat{\beta})$  [1.03, 1.50],  $z = 2.29, p < .05$ ) but not on the situation model. Students generated 1.24 times more critiques reflecting argument quality in the first session than the second. A possible explanation is that after the first session of the experiment, students were aware that they would be asked to recall and reflect on the second text. Being aware of the task demands prior to

reading would change students' reading strategy. Position also significantly affected recall of text-based information. These significant position effects suggest that no scaffolding students tended to memorize more text-based information while generating fewer critical comments in the second session, whereas argument scaffolding students shifted to a deeper level of text comprehension.

## GENERAL DISCUSSION

This study shows that argument scaffolding enhances science text comprehension. There was less text-based recall but more knowledge-based inferencing among students who practiced argumentation than the no scaffolding group. This indicates that argumentation helped students go beyond text details and focus more on knowledge integration. The term "knowledge integration" here is similar to Linn, Davis, and Bell's (2004) definition—a knowledge-acquisition process in which learners add information, distinguish between ideas, link ideas, and identify weaknesses in their representation. Our interpretation places more emphasis on the interaction between levels of mental representation: argument schema, content knowledge, and the text. According to our interpretation, knowledge integration in text comprehension is a continuously top-down and bottom-up process (Kintsch, 2005), in which the highest level, the argument schema, directs lower-level knowledge construction.

Source credibility affected only the surface level but not the deeper levels of text comprehension, suggesting that once students become involved in a deeper level of text comprehension, source credibility loses importance as a criterion for text evaluation. Without argument scaffolding, students were less likely to think deeply when they read a text from an alleged expert. This phenomenon might occur frequently in daily life when people hear or read information from experts and simply accept the claims without a thorough evaluation.

Although source credibility can enhance text comprehension by prompting readers to allocate more cognitive effort to evaluate text information, the effects of source credibility in this study were on the negative side, which is attributable to the way we manipulated it and measured its effects. There are other ways to look at how people make use of source credibility and some of these may be positive. For example, source credibility may help people target trustworthy evidence within a massive amount of information, such as that generated in a Web search, which is an important skill in this era of information explosion.

In Petty and Cacioppo's (1986) elaboration likelihood model, extensive elaboration of issue-relevant information is characteristic of message processing through the so-called "central route;" Message processing which relies on cues irrelevant to the message content, such as the author's affiliation, occurs via the "peripheral route" (pp. 1–24). Similarly, Chaiken, Liberman, and Eagly's (1989) heuristic-systematic model defines systematic processing as a comprehensive and analytic information processing process, whereas heuristic processing is viewed as a more limited processing mode that demands much less cognitive effort than systematic processing. Both theories posit that motivation is a factor that influences which process will be involved in processing messages. When people are motivated, they process materials systematically through the central route regardless of source credibility. The effect of source credibility will come into play only when people are less motivated and thus process materials heuristically or through the peripheral route.

To explain the results of our study, we proposed that argument scaffolding encourages students to process messages in a more a rational and deliberate manner and thus decrease the effect of



source credibility. Argumentation requires cognitive effort and deep analysis, or in other words, central route processing (Petty & Cacioppo, 1986). Source credibility in our study seemed to prompt students to process a message in a shallow or peripheral way. Thus, the abovementioned dual-processing theories give an account of the decline in the effects of source credibility observed in the argument scaffolding condition.

Argument scaffolding helped students generate inferences. This is consistent with the findings of Wiley and Voss (1999), who investigated effects of writing tasks on college students' memory for and understanding of historical texts. They found that students who wrote arguments generated significantly more inferences than those who wrote narratives, summaries, or explanations. Wiley and Voss (1999) theorized that writing arguments help students achieve a more causally-connected mental model and better conceptual understanding of the subject matter.

The argument scaffolding group outperformed the no scaffolding group in generating more complete and correct global mental representations of the science texts. The positive correlation between situation model and argument quality further supports our two-level model in that students who read a text as an argument are evaluating the validity of a text, which in turn help them to construct a better situation model. A better situation model may also enhance the quality of arguments, as suggested by the correlation.

We attribute the argument scaffolding effect to the activation of an argument schema that students already possessed. Our hypothesis is that once an argument schema is activated, it provides a structured framework for readers to analyze and integrate various argument components in the text so as to produce better and deeper understanding. Whether, or under what conditions, readers will spontaneously apply an argument schema to expository scientific texts is an intriguing issue for future research. Science texts usually rely on an argumentative structure to safeguard logic and coherence. In the current study, students in both argument scaffolding and no scaffolding conditions were asked to read two scientific texts that had been restructured to conform to a canonical argument schema. It is possible that presenting the texts in this way induced argumentative thinking, reducing the argument scaffolding effect. However, as mentioned earlier, readers tend to process expository texts in a shallow manner (Bock & Brewer, 1985; Wiley & Myers, 2003). Thus, previous research suggests that readers require strong cues to process a scientific text at a deeper level in terms of its argumentative structure.

It is evident from the present study that being pushed to read a text as an argument improves understanding and learning (see also Kintsch, 1994). Instruction and practice with scaffolded argumentation could change reading patterns. Text comprehension and argumentation share a common theme in that both are continuous processes of integrating old and new information (Gueraud, Harmon, & Peracchi, 2005). This gives educators, especially science educators, a way to enhance students' text comprehension. Students must learn to argue with the author to get the most benefits from reading (Beck & McKeown, 2001; Beck, McKeown, Sandora, Kucan, & Worthy, 1996).

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## APPENDIX A

## Science Text Materials [Translation]

Science Topic: What causes depression? [High source credibility]

Dr. Neils, an American neuroscience professor, claimed that “Depression is caused by a chemical imbalance in the brain.” Below are Dr. Neil’s reasons for this claim:

Depression, like diabetes, has its biological basis. As we already know, diabetes mellitus occurs when there is not enough of the hormone called insulin in our body. The cause of depression is generally thought to be a lack of a certain neurotransmitter, serotonin, in our brain. Doctors often use antidepressants like Prozac (also called Selective Serotonin Reuptake Inhibitors) to slow down the removal of serotonin so as to extend its effects on the synapse. By changing the chemical structure of the brain, these drugs can have a great impact on patients’ behavior. One of our studies conducted in the year 2000 investigated the medical effects of Prozac, in comparison to a placebo, on depression. Results showed that a placebo had a therapeutic effect on 38% of the patients, but this healing effect quickly declined after these patients were told that they had received an inert treatment. In comparison, Prozac had a therapeutic effect on 52% of the patients, and this effect lasted relatively longer than the control condition. This study suggests that controlling chemicals in the brain treats depression better than not controlling chemicals in the brain. Therefore, depression is caused by a chemical imbalance in the brain. However, some psychologists consider that it is the psychological factor of long-term stress that causes depression. For example, a clinical psychologist, Dr. Towsk, found that many depression patients were under higher life pressure than healthy people. However, melancholy may also lead to pessimism, in turn causing stress. Therefore, it is very difficult to say whether stress causes depression or not.

Highways Topic: Will an automated highway system enhance highway efficiency? [Low source credibility]

In the final project, Yu-Ting claimed that “An automated highway system can enhance highway efficiency.” Below are Yu-Ting’s reasons for this claim:

When the number of cars on the highway increases, usually drivers will lower their speed in order to keep a “safe stopping distance” from the other cars. However, this distance is in fact a waste of space. With an automated highway system (AHS), people are able to drive fast while keeping a relatively short distance from each other. Since 1991, our government and a research institution formed an AHS research team to conduct a series of research projects on AHS. In the year 2000, a simulation study was conducted on interstate highway 12 (I-15) between San Diego and Los Angeles. They embedded 92,000 magnetic markers on the surface of the road to guide a platoon of eight automated vehicles. Each vehicle was equipped with magnetic sensors to detect its location and laser ranging sensors to detect car speed and obstacles. The speed limit per lane for these vehicles was set at a speed of 100 kilometer per hour, and the inter-car distance was about one car’s length. Results showed that AHS could obtain a traffic flow of 2,300 to 11,000 cars per hour per lane, which is five times the flow of manual driving. However, another simulation study directed by a transportation engineering professor, Dr. Carson, in the year 2000, showed that the higher the number of cars on the highway, the more frequently cars change lanes and go on and off the highway, which in turn lowers the car speed. However, the simulation study conducted by the AHS team in 2000 showed that if the car flow stays at a rate of 3,500 cars per hour, the AHS system would cause fewer collision incidences than would be caused by manual driving. This implies AHS can further decrease accident rates, which is also beneficial to traffic smoothness.