INSTRUCTION BASED ON SELF-EXPLANATION

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INTRODUCTION

Asking students to generate explanations is a recommended study strategy (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Pashler et al., 2007) and a recommended instructional practice (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Indeed, prompting people to explain new information often leads them to learn more than people who are not prompted to explain across a variety of topics and age groups (e.g., Chi, de Leeuw, Chiu, & LaVancher, 1994; Rittle-Johnson, 2006; Siegler & Chen, 2008).

In this chapter, we focus on self-explanation—generating explanations for oneself in an attempt to make sense of new information (Aleven & Koedinger, 2002; Bielaczyc, Pirolli, & Brown, 1995; Chi et al., 1994; Rittle-Johnson, 2006). Explanations are inferences by the learner that go beyond the given information, and they may be focused on the reasoning of experts presented in worked examples or text or on one’s own problem solving efforts (Ainsworth & Burcham, 2007; Berthold, Eysink, & Renkl, 2009; Siegler & Chen, 2008). Self-explanations are generated by the learner, rather than by an instructor, parent or other person who already knows the content, and are generated for the learner, not intended to teach the content to other people (Chi et al., 1994; Ionas, Cernusca, & Collier, 2012).

HISTORICAL OVERVIEW

The term self-explanation was coined by Chi and colleagues (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). In the study, college students were asked to think aloud while studying worked examples of physics problems and then to solve a set of related problems. Worked examples include step-by-step actions for solving problems, but often do not include the rationale for each step (Atkinson, Derry, Renkl, & Wortham, 2000; also see Chapter 15 in this volume). Verbalizations from the think aloud protocols were coded as self-explanations when they included “ideas which say something substantive.
about the physics discussed in the example statement” (p. 161). Learners who were successful in solving the problems had spontaneously generated an average of 15 explanations per worked-out example compared to an average of 3 explanations per example among poor learners. Similarly, college students who spontaneously generated more self-explanations when studying worked examples to probability problems had greater problem-solving success (Renkl, 1997). Of course, these individual differences in frequency of spontaneous self-explanation could reflect a variety of individual differences, including general ability, prior knowledge, or learning style, rather than be a direct result of explanation efforts.

A potential causal impact of self-explanation was first supported by early experimental research on explaining one’s own solution methods during problem solving. These studies demonstrated that prompting learners to explain their solution methods on relatively easy problems improved success on subsequent harder problems, relative to no prompting. In particular, high-school boys were either asked to provide a reason for each problem-solving step they made when solving relatively easy problems or to solve the problems without providing explanations (Gagné & Smith, 1962). Those who had explained their solution methods had greater success on subsequent, more difficult problems. Similarly, college students who were prompted to explain their solution methods to logical reasoning problems were more successful on subsequent harder problems (Berry, 1983). Although these authors used the term verbalization, not explanation, in this early work, the experimental manipulation of verbalization focused on a particular type of verbalization—explaining one’s solution method. Explaining one’s solution method forces participants to infer reasons for their mental processes, not just report them. Thus, this manipulation is different from prompts to report what one’s solution method was (i.e., strategy reports). Strategy reports are typically “direct articulation of information stored in a language (verbal) code,” and are already active in working memory when working on a task without overt verbalization (Ericsson & Simon, 1980, p. 227). Unlike self-explanations, strategy reports do not involve inferences and typically do not impact learning (Ericsson & Simon, 1980; McGilly & Siegler, 1990; Rittle-Johnson & Siegler, 1999; Siegler, 1987).

Decades of subsequent experimental research confirmed that prompting for self-explanation can improve comprehension (knowledge of facts, concepts and ideas, going beyond recall of the learning material) and transfer (success applying rules or solution procedures to unfamiliar problems and/or contexts) across a broad range of ages and tasks. For example, prompts to self-explain helped 4-year-olds learn about patterns (Rittle-Johnson, Saylor, & Swygert, 2008), middle-school students comprehend the circulatory system (Chi et al., 1994) and medical-school students make more accurate diagnoses (Chamberland et al., 2011). A majority of research has focused on math and science topics, and two meta-analyses of the self-explanation literature on math and science learning confirmed a moderate effect of self-explanation, relative to no explanation, on transfer performance (Durkin, 2011; Mugford, Corey, Bennell, & Martens, 2009). Both meta-analyses also reported substantial heterogeneity of effects, indicating substantial variability in the effect sizes across studies. Self-explanation has been shown to improve knowledge of a few other academic topics, including marketing (Hilbert & Renkl, 2009), argumentation (Schworm & Renkl, 2007), designing worked examples for instruction (Schworm & Renkl, 2006), and flight techniques (Molesworth, Bennett, & Kehoe, 2011).
THEORETICAL FRAMEWORK

Self-explanation is thought to promote learning via two primary processes. First, self-explanation aids comprehension by promoting knowledge integration (Chi, 2000). In particular, explanations often integrate pieces of new information together or integrate new information with prior knowledge. For example, when studying text with worked examples, learners’ explanations often linked solution steps to prior knowledge or information in the text (Atkinson, Renkl, & Merrill, 2003; Chi et al., 1989; Renkl, 1997). Further, when new information conflicts with prior knowledge, students have multiple opportunities to notice this conflict and attempt to resolve it (Chi, 2000). For example, explanations sometimes include integration of critical features that were originally overlooked or misinterpreted (Durkin & Rittle-Johnson, 2012).

Second, self-explanation aids comprehension and transfer by guiding attention to structural features over surface features of the to-be-learned content (McEldoon, Durkin, & Rittle-Johnson, 2013; Rittle-Johnson, 2006; Siegler & Chen, 2008). This makes knowledge more generalizable because it is less tied to particular problem features, so it is more likely to be transferred to new problems and situations (e.g., Gick & Holyoak, 1983). For example, generating explanations can make learners more attentive to general characteristics of the solution method that are less tied to particular problem features (McEldoon et al., 2013; Rittle-Johnson, 2006; Siegler & Chen, 2008).

Overall, self-explanation supports knowledge integration or knowledge generalization, which should improve future performance. Thus, it is the cognitive processes engaged by self-explanation prompts that facilitate learning. Chi and colleagues concluded that “we do not think that articulating an explanation per se is the critical factor (as suggested by Gagné & Smith, 1962); rather, what the students articulated is the most important factor” (Chi et al., 1989, p. 177). Indeed, both the quantity and quality of prompted explanations are correlated with learning outcomes (Chi et al., 1994; Neuman & Schwarz, 1998; Pillow, Mash, Aloian, & Hill, 2002; Rittle-Johnson et al., 2008; Tajika, Nakatsu, Nozaki, Neumann, & Maruno, 2007). Further, in studies that have failed to find a benefit for self-explanation prompts, prompted-explanations were often of low quality with few inferences (e.g., DeCaro & Rittle-Johnson, 2012; Matthews & Rittle-Johnson, 2009; Mwangi & Sweller, 1998). Prompting for self-explanation is likely only effective when it spurs people to make inferences (although the explanations do not need to be clearly articulated).

CURRENT TRENDS AND ISSUES

Current research highlights three core issues surrounding the use of self-explanation as an instructional technique: (a) constraints on when prompting for self-explanation will aid learning, (b) the effectiveness of prompting for self-explanation relative to other instructional techniques, and (c) methods for integrating self-explanation in the classroom.

First, there is increasing evidence for constraints on when prompting for self-explanation aids learning. A growing number of studies have reported that self-explanation prompts improved some aspects of learning, but harmed other aspects. This research revealed that explanation prompts influence the focus of learners’ attention and cognitive effort in particular ways. For example, across two studies, explanation prompts that focused attention on key concepts increased comprehension of domain principles, but also reduced success on transfer problems (Berthold & Renkl, 2009;
The explanation prompts supported more detailed explanations than unguided note taking, including a greater number of elaborations on domain principles. However, the explanation prompts also decreased the number of calculations performed during learning (Berthold et al., 2011). In other words, the prompts focused attention on concepts while detracting attention from solution procedures. The reverse trade-off occurred in Große and Renkl (2006), in which self-explanation prompts harmed comprehension and had no effect on transfer. The explanation prompts in this study focused attention on solution procedures. These findings highlight that explanation prompts focus attention on particular aspects of the to-be-learned material, reducing attention to other aspects.

Similarly, explanation prompts can focus students’ attention on their preexisting ideas, which can reduce attention to new information and evidence that contradicts their preexisting ideas. Prompting children to explain their own, often incorrect, ideas about causal effects harmed their subsequent causal inference performance on a transfer task (Kuhn & Katz, 2009).

Explanation prompts can also promote better comprehension of a principle but overgeneralization of the ideas. Prompting college students to explain why examples were members of a particular category caused them to overlook exceptions to the general category rule (Williams, Lombrozo, & Rehder, 2013). It can also support better transfer but poorer recall of details (Legare & Lombrozo, 2014; Williams & Lombrozo, 2010). For example, children who were prompted to self-explain had better transfer to a new task but poorer recall of details of the materials than children who observed without explaining (Legare & Lombrozo, 2014).

Overall, explanation prompts focus attention on particular things, and thus can improve learning of some content but reduce learning of other content. Self-explanation prompts must be designed carefully so that they guide attention to information that matches the target learning outcomes.

A second trend is to compare self-explanation prompts to alternative instructional activities. In past research, the self-explanation condition was typically compared to a condition that completed the same task without guidance (see Rittle-Johnson & Loehr, 2015). Most often, this meant that the self-explanation condition spent considerably longer on the task than the control condition (e.g., 2 hours 5 minutes vs. 1 hour 6 minutes on average in Chi et al., 1994). Sometimes, time-on-task was fixed across conditions, and learners in the control condition studied the material for the fixed amount of time without guidance (e.g., Alevin & Koedinger, 2002; Chou & Liang, 2009; Legare & Lombrozo, 2014; Leppink, Broers, Imbos, Vleuten, & Berger, 2012; Mwangi & Sweller, 1998). Given the considerable time it takes to self-explain, instructors need to know when to use self-explanation prompts rather than other instructional techniques.

When compared to other instructional techniques, the impact of self-explanation prompts is mixed. Compared to providing instructional explanations (explanations provided by an expert verbally or in writing), some studies favor instructional explanations, others favor self-explanations and others find no difference (Cho & Jonassen, 2012; Crowley & Siegler, 1999; De Koning, Tabbers, Rikers, & Paas, 2010; Larsen, Butler, & Roediger, 2013; Tenenbaum, Alfieri, Brooks, & Dunne, 2008; Wittwer & Renkl, 2010). Why might the evidence be so mixed? The quality of the self-explanations seems to be a key factor. In studies that have found an advantage for self-explanations over instructional explanations, the learners were fairly successful in generating reasonable self-explanations (e.g., Brown & Kane, 1988; Schworm & Renkl, 2006). For example, in Schworm and Renkl (2006), student teachers generated over forty elaborations...
on average when studying examples. In contrast, in studies that have not found an advantage, learners in the self-explanation condition had difficulty generating correct inferences and generalizations (Cho & Jonassen, 2012; Crowley & Siegler, 1999; De Koning et al., 2010; Larsen et al., 2013). For example, high-school students in the self-explanation condition often provided one-sided explanations, erroneous explanations, and/or failed to make inferences when studying biology diagrams (Cho & Jonassen, 2012). Thus, it seems that self-explanation may be more effective than instructional explanations if learners are able to generate reasonable-quality explanations, but that doing so is a considerable challenge in many contexts. In addition, generating self-explanation can take considerably more time than receiving instructional explanations (e.g., Schworm & Renkl, 2006).

Compared to solving additional non-routine problems, findings are also mixed. One study found greater comprehension and transfer for the self-explanation condition (Aleven & Koedinger, 2002), another found better learning on some subscales, but not others (McEldoon et al., 2013), and still others found comparable transfer and comprehension when students in the control condition spent an equivalent time solving more problems (DeCaro & Rittle-Johnson, 2012; Matthews & Rittle-Johnson, 2009). For example, McEldoon and colleagues (2013) found that elementary-school children who were prompted to self-explain tended to have greater procedural transfer, but not better learning or comprehension in general. Solving unfamiliar problems can be a constructive instructional technique, as it requires responses that go beyond what is provided in the original material (Chi, 2009; Fonseca & Chi, 2011). Both self-explanation prompts and solving unfamiliar problems can provide opportunities for thinking about correct procedures, including when each is most appropriate. This is especially true when problem-solving exercises are designed with problems sequenced to support noticing of underlying concepts (Canobi, 2009; McNeil et al., 2012). Additional research is needed to identify when self-explanation prompts are more effective than spending a comparable amount of time solving unfamiliar problems.

Finally, a recent study suggests that self-explanation is less effective than repeated-testing (i.e., retrieval practice) for supporting comprehension over a long delay (Larsen et al., 2013). Medical students who repeatedly tested themselves on assigned readings (without self-explanation) had better comprehension after a 6-month delay than students who had self-explained the material without testing themselves. Repeated-testing may be less dependent on individual differences in ability to successfully engage in the technique and/or may be more effective at promoting knowledge retention over a long delay. Future research should contrast prompting for self-explanation to other evidence-based study strategies reviewed in this Handbook, such as cooperative learning (Chapter 18) and visualization (Chapter 22), and should consider both short-term and long-term retention of knowledge.

A third current trend is research on how to support self-explanation in classroom contexts. A majority of research on self-explanation has been conducted on educationally relevant content, but in a laboratory context with close supervision of an experimenter (Dunlosky et al., 2013). Integrating self-explanation in the classroom requires additional considerations, such as how individual students provide explanations and how to hold students accountable for generating reasonable explanations.

Classroom-based research on self-explanation has largely occurred within computer-based tutoring systems that are integrated into math and science courses. For example, within a computer-based fractions tutor, middle-school students were prompted to select appropriate explanations for their solution steps from a drop-down
menu (Rau, Aleven, & Rummel, 2015). Students who were prompted to self-explain had better comprehension on an immediate and (one-week) delayed posttest than students who only solved problems within the tutoring system for the same amount of time. Similar benefits for self-explanation prompts within computer-tutoring systems have been reported for high school students learning about the circulatory system (De Koning, Tabbers, Rikers, & Pass, 2011), algebra (Kramarski & Dudai, 2009), and geometry (Aleven & Koedinger, 2002); for undergraduates learning physics (Hausmann & VanLehn, 2010) and computer science (Yeh, Chen, Hung, & Hwang, 2010); and for adults learning grammar rules (Wylie, Sheng, Mitamura, & Koedinger, 2011). In a majority of these computer-based studies, rather than providing open-ended explanations, students selected an explanation from a menu or glossary. Such an approach constrains learners to reasonable explanations and supports feedback on the accuracy of the selected explanation. Simply prompting high-school students and undergraduates to verbally self-explain worked examples within a web-based learning tool, without scaffolding or feedback, improved learning in a few studies (De Koning et al., 2011; Hausmann & VanLehn, 2010; Kramarski & Dudai, 2009) but did not improve learning in one study (Crippen & Earl, 2007).

A few studies have explored methods for supporting self-explanation during individual seatwork or homework. For example, Booth and colleagues have created Algebra assignments that integrate prompts for explanations of correct and incorrect worked examples, interspersed with problems to solve (Lange, Booth, & Newton, 2014). Algebra students who completed these assignments had greater comprehension and transfer than students who completed traditional assignments that contained only problems to solve (Booth et al., in press). Teachers embraced this approach and reported that they felt their students learned more from these assignments compared to traditional assignments. Written self-explanation prompts during individual seatwork in a classroom also helped high-school students learn a new skill (concept mapping; Hilbert & Renkl, 2009). Hodds and colleagues created a training booklet on using self-explanation when studying mathematical proofs that included the benefits of self-explanation, its key components, an example proof with sample self-explanations, and a practice proof with self-explanation prompts. Undergraduate mathematics students who studied the training booklet during class and then studied a new proof understood the new proof better than students who did not receive the self-explanation training booklet, and this benefit persisted on a 3-week delayed posttest (Hodds, Alcock, & Inglis, 2014). This is particularly promising because self-explanation prompts were not given when studying the new proof, suggesting that at least college students can adopt the technique without continued prompting.

Of course, group work and peer tutoring are natural contexts for encouraging explanation in a classroom context (although they are not self-explanations since they are not generated for the self). Talking with peers often leads to greater learning than working by oneself (Coleman, Brown, & Rivkin, 1997; King, 1992; Manion & Alexander, 1997; O’Donnell, Dansereau, Hall, & Rocklin, 1987; Roscoe & Chi, 2007; Teasley, 1995; see also Chapter 17 in this volume). In particular, frequency of generating explanations in small groups positively predicts learning (Webb, 1991; Webb et al., 2014). Teachers can support student explanation in group work and tutoring contexts by setting expectations, modeling high-quality explanations, and asking follow-up questions (Fuchs et al., 1997; Webb et al., 2014).

In summary, a variety of issues have arisen surrounding the use of self-explanation as an instructional technique. Current research indicates that self-explanation
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Prompts can improve some aspects of learning, but harm other aspects, and that self-explanation prompts are not consistently more effective than some other instructional techniques, such as instructional explanations or retrieval practice. Research has also identified methods for integrating self-explanation in the classroom, such as prompting for explanation of problem-solving steps in computer-based tutors and prompting for explanation of worked-examples on assignments and homework.

PRACTICAL IMPLICATIONS

Promoting self-explanation often improves comprehension and transfer. However, it is not universally effective, and can even improve learning of some information at the expense of other information. Thus, it is critical to have instructional guidelines for effectively promoting self-explanation. Based on our review of the literature, we have developed four instructional guidelines, outlined in Table 16.1.

Table 16.1 Evidence-Based Guidelines for Effectively Promoting Self-Explanation

Guideline 1: Select Self-Explanation Activities Based on the Target Domain and Learning Outcomes

Self-explanation prompts are best suited to promote particular learning outcomes in particular types of domains. In general, self-explanation prompts are well suited for promoting comprehension or transfer in domains with core general principles. Over 80 studies have confirmed that prompting for self-explanation can improve comprehension and transfer across a broad range of ages and tasks (Rittle-Johnson & Loehr, 2015). In contrast, explanation prompts have been shown to improve factual recall in only a few studies (Ainsworth & Burchem, 2007; O’Reilly, Symons, & MacLatchy-Gaudet, 1998). Recall assessments often are not included in self-explanation studies, likely because they do not map well to the intent of self-explanation (to generate inferences that go beyond the given information). Further, self-explanation prompts can even harm recall of details (Legare & Lombrozo, 2014; Williams & Lombrozo, 2010).

Guideline 2: Scaffold High-Quality Explanations via Training on Self-Explanation or Structuring the Self-Explanation Responses.

Providing training on self-explanation consistently improves self-explanation quality and learning outcomes, and even limited training can be useful. In addition, structuring self-explanation responses through fill-in the blank explanations or a menu of potential explanations can increase the likelihood of high-quality explanations and improve learning.

Guideline 3: Prompt Learners to Explain Correct Information.

Prompting learners to explain correct information, such as worked-out examples, text or exemplars, is more likely to support learning than prompting them to explain their own solutions or reasoning.

Guideline 4: Prompt Learners to Explain Why Incorrect Information Is Incorrect if There Are Common Errors or Misconceptions in the Domain.

If there are common incorrect ways of thinking in a domain, prompting for explanations of both correct and incorrect examples can improve comprehension and transfer. However, care must be taken not to overload novice learners when using this technique.
When the target outcome is improved recall, prompting for self-explanation is not the appropriate instructional technique.

Further, explanation prompts can draw attention away from details and support overgeneralization of ideas (Williams & Lombrarozo, 2010; Williams et al., 2013). This may explain why self-explanation prompts are most often used to support math and science learning. Self-explanation prompts are not well suited for topics with few broad principles and many exceptions to the rules, such as English grammar learning (Wylie et al., 2011).

Finally, explanation prompts must be designed with the learning goal in mind. The content focus of the prompts guides students’ attention, and thus pushes them to attend to select information. For example, explanation prompts that focused attention on concepts inadvertently detracted attention from solution procedures and reduced transfer in two studies (Berthold & Renkl, 2009; Berthold et al., 2011), while prompts that focused attention on solution procedures harmed comprehension in a third study (Große & Renkl, 2006). In other studies, explanation prompts have successfully supported both comprehension and transfer (Aleven & Koedinger, 2002; Berthold et al., 2009; Hilbert, Renkl, Kessler, & Reiss, 2008; Kramarski & Dudai, 2009; McEldoon et al., 2013; Yeh et al., 2010). For the most part, the latter studies have used prompts that ask learners to link principles and procedures, guiding attention to comprehension of principles as well as knowledge of procedures. For example, in Aleven and Koedinger (2002), high-school students were prompted to explain their solutions to geometry problems by identifying the geometry principle that justified each solution step. More generally, explanation prompts should focus students’ attention on the information central to developing the target-learning outcome.

Overall, explanation prompts are best used when the target-learning outcome is comprehension and/or transfer of a domain with core general principles. Explanation prompts direct students’ attention to particular aspects of the to-be-learned material, so they must be designed with care to not inadvertently draw attention away from important information.

Guideline 2: Scaffold High-Quality Explanations via Training on Self-Explanation or Structuring the Self-Explanation Responses

The quality of the elicited self-explanations also matters. Explanation quality is correlated with learning outcomes (Chi et al., 1994; Neuman & Schwarz, 1998; Pillow et al., 2002; Rittle-Johnson et al., 2008; Tajika et al., 2007). However, sometimes learners struggle to generate reasonable explanations (e.g., Broers & Imbos, 2005; Hsu & Tsai, 2013; Matthews & Rittle-Johnson, 2009; Mwangi & Sweller, 1998). Thus, scaffolding high-quality explanations can help boost the effectiveness of self-explanation prompts.

Providing training on self-explanation is one way to improve self-explanation quality. Self-explanation training often includes: (a) describing and motivating self-explanation strategies, (b) modeling use of the strategies, and (c) coaching students while they practice using the strategies (e.g., Bielaczyc et al., 1995; McNamara, 2004; Renkl, Stark, Gruber, & Mandl, 1998). For example, the instructor can provide a description of specific self-explanation strategies high-performing students use when studying, highlighting the learning benefits of engaging in self-explanation. Next, students can watch a videotape or listen to an audiotape of someone modeling use of self-explanation on similar content and be asked to identify and/or discuss the self-explanation strategies that were used (Bielaczyc et al., 1995; McNamara, 2004; Wong,
Lawson, & Keeves, 2002). Students can also practice self-explaining with coaching on warm-up problems (Bielaczyc et al., 1995; Renkl et al., 1998). Coaching often involves the instructor providing guiding hints on what to explain and reminders on specific things to explain when important content is omitted. Some studies have included limited training, providing brief training using only one or two components, such as listening to an audiotape of a model of effective self-explanation for a few minutes (Chamberland et al., 2011; Wong et al., 2002), or generating self-explanations on a practice problem without coaching (De Koning et al., 2011; Hodds et al., 2014). Other studies have included extensive training, incorporating multiple components (describing, modeling and coaching) and often lasting around 45 minutes (Bielaczyc et al., 1995; McNamara, 2004). Studies that included self-explanation training have consistently reported better comprehension or transfer relative to a no-explanation control condition (Ainsworth & Burcham, 2007; Bielaczyc et al., 1995; Chamberland et al., 2011; De Koning et al., 2011; Hausmann & VanLehn, 2010; Hodds et al., 2014; Kramarski & Dudai, 2009; McNamara, 2004; Renkl et al., 1998; Wong et al., 2002). Both extensive and limited training seemed to be effective, suggesting that even limited self-explanation training is worthwhile.

Structuring the self-explanation response format is another way to improve self-explanation quality. Students can fill in blanks in partially complete explanations or select an explanation from a menu or glossary. Two studies that directly contrasted a structured self-explanation format to an open-ended response format reported better comprehension or transfer when self-explanation responses were structured (Berthold et al., 2009; Johnson & Mayer, 2010). For example, college students who sometimes self-explained by filling in blanks with missing information for partially provided explanations rather than typing in open-end responses to every explanation prompt gained better comprehension and transfer (Berthold et al., 2009). In part, this was because scaffolding increased the frequency of principle-based explanations. Structured responses are commonly used in computer-based tutors and may be particularly important as an alternative to typing explanations. Structured response formats also facilitate providing feedback on the accuracy of the explanations, which can increase the usefulness and accuracy of students’ inferences (e.g., Aleven & Koedinger, 2002; Rau et al., 2015; Wylie, Koedinger, & Mitamura, 2010; Yeh et al., 2010).

Overall, scaffolding can improve self-explanation quality and learning. Training on self-explanation and structuring the self-explanation response format increase the probability that learners will make useful and correct inferences and generalizations when they explain, in turn improving learning.

**Guideline 3: Prompt Learners to Explain Correct Information**

Prompting learners to explain known-to-be-correct information also improves the effectiveness of self-explanation prompts. Correct information includes worked examples, answers to problems and scientific texts. Several studies have directly contrasted learning from prompts to explain correct information to prompts to explain one’s own reasoning prior to feedback, and all have reported better transfer when learners explained correct information (Calin-Jageman & Ratner, 2005; Siegler, 1995, 2002; Siegler & Chen, 2008). For example, 5-year-old children were (a) prompted to explain correct solutions after first attempting to solve each problem, (b) prompted to explain their own solution prior to feedback on its accuracy or (c) solved the problems without prompts to explain. Children who explained correct solutions solved substantially
more problems correctly than children who explained their own solutions, who did not differ from children who were not prompted to explain (Siegler, 1995). Children’s own solutions were often incorrect, and thus children in the explain-own condition spent time justifying and making inferences about information that was not correct.

Prompting learners to explain their own reasoning can even harm learning if it is likely to be incorrect. When predicting outcomes on a scientific reasoning task, middle-school students were prompted to self-explain why they thought each variable in an experiment would or would not have a causal impact on the predicted outcome or completed the prediction task without explaining. Prompting children to explain their own, often incorrect, predictions harmed their subsequent success at making evidence-based claims relative to a no-explanation condition (Kuhn & Katz, 2009). The authors suggested that the self-explanation prompts focused students’ attention on their preexisting theories, which were often incorrect, and reduced attention to new information and evidence that contradicted their theories.

Overall, prompting learners to explain correct information, such as worked examples, text or exemplars, aids learning, likely because the explanations include more correct inferences and generalizations. Prompting learners to explaining their own solutions or reasoning without feedback can improve learning (e.g., Berry, 1983; Chamberland et al., 2011; Larsen et al., 2013), but it is less likely to improve learning if the solutions and inferences are often incorrect.

**Guideline 4: Prompt Learners to Explain Why Incorrect Information Is Incorrect if There Are Common Errors or Misconceptions in the Domain**

Finally, including prompts to explain why incorrect information is incorrect, as well as why correct information is correct, often improves comprehension and transfer (de Bruin, Rikers, & Schmidt, 2007; Howie & Vicente, 1998; Huk & Ludwigs, 2009; McEldoon et al., 2013; Pillow et al., 2002; Rittle-Johnson, 2006; Siegler, 2002; Siegler & Chen, 2008; Yeh et al., 2010). For example, elementary-school children were prompted to explain both why the answer to a math problem was correct as well as why a common incorrect answer to the problem was incorrect (McEldoon et al., 2013; Rittle-Johnson, 2006). Prompting learners to self-explain correct and incorrect information rather than correct information alone leads to greater comprehension or transfer in domains with common incorrect ways of thinking (Booth, Lange, Koedinger, & Newton, 2013; Durkin & Rittle-Johnson, 2012; Gadgil, Nokes-Malach, & Chi, 2012; Große & Renkl, 2007; Siegler, 2002; Siegler & Chen, 2008; Yeh et al., 2010). In a few of the studies, sufficient prior knowledge was needed to learn more from explaining both correct and incorrect information than only explaining correct information (Große & Renkl, 2007; Yeh et al., 2010). In these studies, students with limited prior knowledge seemed to struggle with the demands of considering both correct and incorrect information, which seemed to overwhelm their cognitive resources at times. Novices in a domain may need additional supports to consider both correct and incorrect information simultaneously.

Self-explanation of correct and incorrect examples seems to engage and enhance the typical mechanisms of promoting inferences and generalizations as well as an additional mechanism specific to explaining incorrect ideas. In particular, contrasting correct and incorrect examples can help learners distinguish correct and incorrect ideas by supporting inferences about their differences (Durkin & Rittle-Johnson, 2012). In addition, incorrect examples may surprise learners and can spark greater attempts to explain than correct examples alone (Legare, Gelman, & Wellman, 2010). Further, even
after learning correct ideas and strategies, incorrect ideas and strategies persist and compete with correct ways of thinking (Siegler, 1996). Addressing incorrect ideas and strategies directly helps reduce how likely they are to be selected in the future.

Overall, to effectively use self-explanation as an instructional technique, self-explanation prompts must be designed and implemented with care. Although it aids comprehension and transfer across a broad range of topics, it is not well suited for some topics and learning outcomes (e.g., domains that are not guided by general principles or when recall of factual information is the goal). Designing prompts to guide attention to the target learning outcomes, scaffolding high-quality explanations, prompting for explanation of correct information, and prompting for explanation of why incorrect information is incorrect can each improve the effectiveness of self-explanation as an instructional technique.

**FUTURE DIRECTIONS**

Despite decades of research on self-explanation, additional research is needed to better harness self-explanation as an instructional technique. First, we need to identify additional ways to scaffold self-explanation quality given the importance of explanation quality for learning. For example, can structured self-explanation formats be used effectively outside of computer tutors (e.g., on in-class and homework assignments)? Integrating structured self-explanation responses with open-ended self-explanations may be another fruitful technique. In one study, students alternated between structured responses and open-ended responses (Berthold et al., 2009); fading from structured responses early in instruction to open-ended responses later in instruction is another promising alternative. Given the importance of the content of explanations, we predict that a variety of ways to scaffold high-quality explanations will be beneficial in many contexts.

Second, too little research has compared self-explanation to other viable instructional techniques. Other techniques, such as repeated-testing and providing instructional explanations, may be less dependent on individual differences in ability to successfully engage in the technique. For example, future research should evaluate whether self-explanation is consistently more beneficial than instructional explanations or repeated-testing when self-explanation quality is scaffolded. Future research should also consider the effectiveness of integrating instructional explanations and self-explanations. For example, Cho and Jonassen (2012) included a third condition that first generated self-explanations and then compared them to instructional explanations and wrote about their differences. Students in this condition tended to have better recall and comprehension than students who only self-explained or read the instructional explanations. Alternatively, instructional explanations could be used to model high-quality explanations, followed by prompting learners to self-explain, or learners could be asked to make inferences and generalizations about instructional explanations (i.e., to self-explain instructional explanations).

Finally, more research is needed in classroom contexts, especially in effective ways to promote self-explanation in non-computer-based activities. Algebra assignments that integrate prompts for written explanations of correct and incorrect worked examples, interspersed with problems to solve, have been shown to improve student learning (Lange et al., 2014). However, elementary-school students will likely struggle to write reasonable explanations on their own. Explaining homework to a parent is a context worth exploring; doing so improved the quality of second-grade students’
written explanations on a subsequent in-class test, but not their word-problem solving accuracy (Loehr, Rittle-Johnson, & Rajendran, 2014). Generating reasonable explanations is becoming a target outcome in and of itself (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). However, additional scaffolds may be needed for explaining homework to a parent to improve transfer.

In summary, prompting learners to self-explain can improve comprehension and transfer. However, prompts to explain in of themselves do not lead to greater learning; rather, the prompts need to spur students to make inferences and generalizations. We propose four guidelines for effectively prompting for and scaffolding self-explanation. Future research needs to refine and expand these guidelines.

NOTE

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REFERENCES


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