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Explanation scaffolds causal learning and problem solving in childhood

Justin T.A. Busch[a], Aiyana K. Willard[b], & Cristine H. Legare[a]

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a. The University of Texas at Austin
b. University of Oxford

Abstract

Explanation provides a window into what children know and scaffolds causal learning. Here we review research on the contributions of explanation to causal knowledge acquisition and problem solving. We discuss evidence that generating explanations enhances children's understanding of causal mechanisms and increases their persistence and skill in applying new knowledge to novel contexts. In this way, explanation operates as a tool for learning and is particularly effective in the context of explaining inconsistent or ambiguous information. Explanation also enhances problem solving by allowing children to articulate their knowledge, a process which makes gaps in their current knowledge salient. The process of generating and requesting explanations facilitates the transmission of information and often occurs during interactions with others. We discuss the social context of explanation, and the implications for belief revision and for building new knowledge. Explanation works in tandem with discovery oriented behaviors like question asking and exploration to drive causal learning and improve problem solving.

Explanation scaffolds causal learning and problem solving in childhood

Explanation is at the center of the scientific enterprise. Explanations describe what is known or has been discovered about an event or outcome and serve to guide future exploration as more information becomes available. Thus, explanations are also hypotheses. Scientists can formulate an explanation for a phenomenon and through experimentation find evidence for or against their hypothesis. In this way, the process of science highlights how explanation can play an integral role in the way we acquire, organize, and interpret new knowledge. Generating explanations constrains future exploration, which in turn, generates new information relevant to current and future explanation.

Explanation is core to the scientific process, yet explanation generation is not the exclusive domain of scientists. Children and lay adults are active explanation generators (Gopnik, 2000; Hickling & Wellman, 2001; Hilton, 1988; Keil, 2006; Keil & Wilson, 2000; Wellman, Hickling, & Schult, 1997), from the mundane (e.g., why is my wifi not working?) to the existential (e.g., how did life come to exist?). In this chapter, we define explanation broadly as any attempt to understand a causal relationship through identifying relevant functional or mechanistic information (Legare, Gelman, & Wellman, 2010; Lombrozo, 2006). Similar to the way an explanation or hypothesis in science guides future studies, explanation in childhood plays an important role in scaffolding the learning process (Legare, 2012). As such, the development of causal explanation has been an important topic in psychology since Piaget (1929) and explanation presents an important avenue to understanding cognitive development (Frazier, Gelman, & Wellman, 2016).

A substantial and influential body of research has documented that children's explanations provide insight into the development of causal knowledge and conceptual understanding (Callanan & Oakes, 1992; Frazier, Gelman, & Wellman, 2009; Hickling & Wellman, 2001; Hoyos & Gentner, 2017; Keil, 2006; Keil & Wilson, 2000; McEldoon, Durkin, & Rittle-Johnson, 2012). New research supports the proposal that explanation also plays an important role in scaffolding the learning process (Bonawitz, van Schijndel, Friel, & Schulz, 2012; Brewer, Chinn, & Samarapungavan, 1998; Legare, 2012; Lombrozo, 2006; Wilkenfeld & Lombrozo, 2015) and may be developmentally privileged (Legare, Wellman, & Gelman, 2009). In problem solving tasks, generating explanations has been shown to improve performance between pre- and post-test (Fawcett & Garton, 2005).

We seek to answer two questions about children's explanations in this chapter. First, how might explanation enhance causal learning? Second, how does explanation facilitate active engagement in problem solving? If explanation serves to scaffold children's conceptual development (Bonawitz et al., 2012: Brewer et al., 1998; Legare, 2012; Lombrozo, 2006), then children's explanations should be more common in contexts that are ripe for learning and should aid in problem solving. To gain traction on these outstanding questions, it is necessary to review the literature on explanation from different angles. This chapter begins with a review of the research on how causal learning may be promoted through the process of explanation generation. Understanding what type of knowledge is promoted through explanation and what type of knowledge is not can provide insight into the mechanism that makes explanation a powerful tool for learning. We then move on to discuss what motivates children to generate explanations in the first place. The contexts in which children generate explanations provide further insight into the mechanism underlying how explanation promotes learning. Finally, we discuss how children revise explanations in response to new evidence and use explanations in problem solving. If explanation is used to increase knowledge, then we should predict that children would revise explanations to reflect new information and that explanations should also aid children in solving problems.

To answer these questions, we discuss how explanation functions in both non-social and social contexts. Much of the previous research on the topic of explanations examines self-explanation, or how children generate explanations for a phenomenon for themselves rather than explanations for the purpose of communicating ideas with others. Humans are a social species and causal learning rarely takes place in isolation (Rogoff, 2003; Vygotsky 1962). Since so much of human reasoning takes place in social contexts, the adaptive function of reasoning may be to construct an argument or explanation in the service of persuading others and to critically evaluate their arguments and explanations in turn (Mercier & Sperber, 2011). Therefore, explanation likely did not evolve for self-explanation but as a mechanism to enhance knowledge acquisition within a social group (Mercier & Sperber, 2017). Examining explanations in the context of social interaction may provide further insight into how explanation functions as a learning mechanism and for collaborative problem solving. Indeed, research has shown that argumentation and discussion with peers improves adults' reasoning on logic tasks across cultures (Mercier, Deguchi, Van der Henst, & Yama, 2016). Furthermore, individuals who receive valid arguments against their answers on intellective tasks are more likely to change their answers, and adults as well as 10-year-olds are more likely to solve intellective tasks while in groups (Trouche, Sander, & Mercier, 2014). In this chapter we seek to bring together research on explanation, how it enhances causal learning, facilitates problem solving, and operates in social and non-social contexts.

Explanation and Causal Learning

Developmental research has shown that explanations and requests for explanations are widespread in even very young children (Frazier et al., 2009; Keil, 2006; Keil & Wilson, 2000). Research examining the everyday conversations of preschool aged children and their caregivers has demonstrated that explanations increase in frequency with age but are common even at 2 to 3-years-old (Callanan & Oaks, 1992; Crowley, Callanan, Tenenbaum, & Allen, 2001). Furthermore, explanations typically serve an epistemic function by providing an interpretation for a current or past event, and do not serve an exclusively social-regulatory function (Hickling & Wellman, 2001). As such, the process of generating explanations is critical for constructing knowledge (Amsterlaw & Wellman, 2006; Cimpian & Petro, 2014; Rittle-Johnson, Saylor, & Swygert, 2008). Given the proliferation of explanatory activity through childhood and its importance in knowledge acquisition, how does explanation function in the service of causal learning?

Explanation enhances knowledge acquisition by prompting children to speculate about internal unobserved mechanism and causal functions (Legare et al., 2010; Legare & Lombrozo, 2014). Similarly, explanation can aid in the generalization of knowledge about causal mechanism to new, perceptually similar objects (Walker, Lombrozo, Legare, & Gopnik, 2014). This suggests that the act of generating a self-explanation may direct children's learning towards understanding the broad causal mechanism underlying a phenomenon and away from perceptual features specific to that given instantiation of the phenomenon. For example, Legare and Lombrozo (2014) conducted two studies with 3-6-year-old children to tease apart the unique effects of explanation from the effects of simple verbalization or attention. Children were presented with a system of gears, which included a handle that could be rotated to operate a fan at the opposite side of a gear system. Some children were asked to explain the gear toy while others were told to observe or describe the toy. They found that the effect of explanation was selective; generating a self-explanation promoted the learning of the causal mechanism underlying gears across all ages. Self-explanation also increased children's ability to generalize their knowledge of gears to a novel gear toy. In contrast, generating explanations did not enhance children's learning for the perceptual features of the gear toy. However, in this study children were asked to generate an explanation for an experimenter in a lab and there was no conversational interaction between the child and the experimenter. When children generate explanations in the context of a conversational interaction with another person, is the effect of those explanations on learning any different or more robust?

Willard, Busch, Sobel, Callanan, & Legare (2016) have extended this line of research into the social domain by examining children's causal learning about gears while engaged with a parent. Parents can guide their children to understand the mechanism of a novel set of objects either through offering explanations to their children or by encouraging their children to generate their own explanations. Both of these behaviors are pedagogical tools. Offering children a mechanism explanation has been previously found to reduce the number of alternative uses of a toy children find during future exploration (Bonawitz et al., 2011). This allows for rapid learning about objects in one's environment through social learning, and in doing so reduces the need for individual learning through more hands on experience (Kline, 2015). Recent research examines how children learn in a social interaction in which the caretaker is prompted by the experimenter to encourage their child to explain at a museum's gear exhibit (Willard et al., 2016). The data show that when parents are prompted to request explanations from their children while at the exhibit, their children generate more explanatory talk and spend more time spinning the gears.

After interacting at the gear exhibit, children were presented with a preconstructed gear machine for several follow-up tasks. One of these tasks asked children to recall from memory the color of one of the gears and another asked them to identify the proper size and shape of a missing gear. Results showed that the more time children spent troubleshooting gears at the exhibit, the better they performed on these follow-up tasks. Children were then presented with a new, novel set of gears and asked to build their own machine. Preliminary results suggest that parents who asked more questions of their child in an attempt to elicit explanations also spent less time fixing locked or unconnected gears for their children. Children of the parents who asked more questions to elicit explanation persisted for longer at the task of building their own gear machine with a novel set of gear stimuli. A potential explanation for this finding is that children who are encouraged through questioning to generate explanations may be less likely to give up when they face a challenging task on their own. This research helps us understand the type of knowledge children gain through explanation, but how does explanation affect the way children generalize this knowledge into different contexts in the future?

From previous research it is clear that explanation, both self-explanation and explanations children generate for someone else, focuses children's learning on causal mechanism. Explanation may also promote causal learning when children move to generalize their knowledge into new contexts by constraining their hypotheses to those that will be most productive for learning (Walker, Lombrozo, Williams, Rafferty, & Gopnik, 2017). In an experiment with 5-year-olds Walker et al. (2017) showed that children who were prompted to explain were more likely to favor a hypothesis that accounted for a greater number of their observations during training than children in a control condition. In a second experiment they showed that children who were prompted to explain were more likely to favor a hypothesis consistent with their prior beliefs than children in a control condition. Through a third experiment the researchers ruled out the possibility that explanation simply increases attention to the task. This work suggests that explanation prompts children to favor hypotheses that are broad in scope and account for the greatest proportion of evidence. Generating explanations that accurately represent the evidence and are broad in scope is useful for children because it allows them to learn something that can be applied to a novel context and, in a way, know something true about the world based on their past experiences. The idea that children can generate true explanations to improve their epistemic standing is consistent with "inference to the best explanation" (Wilkenfeld & Lombrozo, 2015). Wilkenfeld and Lombrozo (2015) also propose however, that an explanation need not be accurate to improve epistemic standing. The simple act of generating an explanation might in fact improve epistemic standing as well.

The research on how children learn through explanation suggests that the effects of explanation are selective. Explanation seems to focus children's learning towards unobserved causal mechanism and constrains children's hypotheses to those that account for the greatest proportion of evidence. Parents and caregivers can also prompt explanation from their children. Children whose parents attempt to elicit explanations generate more explanatory talk, show greater persistence in generalizing new causal knowledge to a novel, analogous context, and show better understanding of causal mechanism. Taken together these findings provide support for "explanation to the best inference" (Wilkenfeld & Lombrozo, 2015), or the idea that just by generating explanations, whether they are accurate or not, is a useful tool for children to acquire causal knowledge. Explanations are functional in causal learning because they seem to focus children's attention onto causal mechanism and guide future exploration. If it is true that children learn by explaining, then it is important to understand what motivates children to generate explanations in the first place.

If explanation generation can be used as a tool to improve epistemic standing, then we predict that children will be highly motivated to investigate irregular or discordant information (Legare et al., 2010). Information that conflicts with a child's prior understanding of a phenomenon may be especially fruitful for explanation because the discordant information is a cue that there is more to learn about that topic. The inherent motivation to explain inconsistent information could facilitate children's learning by focusing their attention onto events that challenge their current causal knowledge and bring about amended causal reasoning by increasing awareness of uncertainty and the potential for alternative explanations for the same information (Legare, 2014). Indeed, the proposal that inconsistent, problematic, or surprising outcomes play an important role in reasoning appears across multiple literatures—philosophy of science (Hempel, 1965), social psychology (Hilton, 1995), educational research (Chi, Bassok, Lewis, Reimann, & Glaser, 1989), and infancy research (Baillargeon, 2002). For example, in a series of studies with preschool children, Legare and colleagues examined the kinds of events that prompt explanation and how explanatory biases provide insight into the function of explaining (Legare, 2012; Legare, et al., 2010; Legare & Gelman, 2014). The results of these studies indicate that outcomes inconsistent with prior knowledge are especially powerful triggers for children's explanations and that the explanations children provide for inconsistent outcomes refer to unobserved causal mechanisms and internal causal properties, overriding perceptual biases. This suggests that explanation provides children with the opportunity to articulate new hypotheses for events that, at first, disconfirm their current state of knowledge (Legare, 2014;

Walker, Williams, Lombrozo, & Gopnik, 2012). Although these studies did not directly measure learning, the data they present are consistent with the proposal that children's explanations play an active role in the learning process and provide an empirical basis for investigating the mechanisms by which children's explanations function in the service of discovery.

But how might the process of explaining inconsistent information promote learning? One possibility is that explaining encourages learners to formulate and entertain hypotheses they would not have spontaneously considered otherwise. Generating hypotheses in the service of explanation may influence the kinds of hypotheses formulated, as well as their impact on cognition (Bonawitz, Fischer, & Schulz, 2012; Bonawitz, van Schijndel et al., 2012; Legare & Lombrozo, 2014; Walker et al., 2012; Walker, Lombrozo, Legare, & Gopnik, 2014). In particular, both children and adults have strong intuitions about what makes something a good explanation (Bonawitz & Lombrozo, 2012; Frazier et al., 2009; Lombrozo, 2007) and explanation may promote the production of hypotheses that are judged as informative. When children generate explanations for inconsistent information there are often multiple potential true explanations. Thus, inconsistency is inherently ambiguous. For example, when faced with information that appears inconsistent with prior knowledge (e.g., a person chooses not to select their favorite food), children are faced with multiple potential explanations (e.g., person's preference could have changed, something about the particular favorite item that was undesirable, the person is on a diet, etc.). Thus, the ambiguity and uncertainty of inconsistency may motivate the bias to produce new explanations for inconsistent outcomes (Foster & Keane, 2015; Lipton, 2004).

The research on what motivates children's explanations is in line with the proposal that the act of generating an explanation can improve epistemic standing. Discordant information acts as a cue to children that their current understanding may be inaccurate and prompts them to generate an explanation. Because inconsistency is inherently ambiguous, children may be forced to grapple with possibilities and hypotheses that they may not have considered. In this way, explanations serve to enhance epistemic standing by requiring children to consider multiple potential alternatives to reach the best conclusion. Implicit within the finding that inconsistent information motivates children to consider alternative explanations is the assumption that children can revise their beliefs when they encounter new information, but what empirical evidence exists to support this assumption?

Explanation and Problem Solving

If it is the case that the act of generating explanations can improve epistemic standing, then we should expect that children should flexibly adapt their explanations and that the activity of generating explanations should aid children in problem solving, even when the explanations they generate may not be true. The capacity to actively revise existing explanations when faced with new information is an essential component of knowledge acquisition (Gopnik & Schulz, 2007) and research shows that children do readily revise their beliefs when presented with new evidence. Data from two studies by Legare, Schult, Impola, and Souza (2016) demonstrate that 3-6-year-olds flexibly accommodate different kinds of information when revising their explanations. Specifically, they examined how children incorporate inconsistent information into their explanations by showing children video evidence of two actors, one of whom behaves consistently with their stated preference and one of whom behaves inconsistently with their stated preference. This study converges with previous research showing that children have a strong bias to explain inconsistency over consistency (Legare et al., 2010). Importantly, these studies also show that children are able to flexibly revise their explanation across domains when they receive new evidence. The data reveal that children who observe multiple pieces of consistent evidence will maintain their original explanation. For children who observe inconsistent evidence however, they will revise their initial explanation, even across domains of reasoning, first appealing to a psychological explanation and then revising to a biological explanation (Legare, et al., 2016). In these studies children were provided evidence by the experimenter, but to learn about the world outside the lab and to solve problems, children must also recognize when the evidence they have is incomplete. What is known about children's capacity to recognize when the information they have is incomplete and do children actively seek to gather information to solve problems?

Research suggests that not only do children revise their explanations when they are provided new evidence by an experimenter in a lab study, they also engage in broad exploration to gather more information in contexts where information is limited. Children are adept at using questions to satisfy their curiosity and accumulate additional evidence (Chouinard, 2007; Courage, 1989; Legare, Mills, Souza, Plummer, & Yasskin, 2013) and they are sensitive to the quality and completeness of the information they receive (Gweon, Pelton, Konopka, & Schulz, 2014). For example, research by Legare et al. (2013) found that the number of constraint-seeking questions, or questions that were appropriately worded to obtain the necessary information, predicted children's accuracy on a problem-solving task. Children also ask relevant questions and adapt the types of questions they ask to increase their efficiency in acquiring new evidence (Legare et al., 2013; Ruggeri & Lombrozo, 2015), a skill that improves over the course of development (Chouinard, 2007; Mills, Legare, Bills, & Mejias, 2010). In response to their causal questions, young children are dissatisfied with non-explanatory responses, prefer to question informants who provide noncircular explanations, and will selectively direct their questions to a knowledgeable informant, which improves their ability to successfully complete a problem-solving task (Corriveau & Kurkul, 2014; Frazier et al., 2009; Mills, Legare, Grant, & Landrum, 2011). This suggests that children not only have the ability to revise their explanations when they encounter new evidence, but they actively seek diagnostic evidence from a knowledgeable informant.

In much the same way that children's explanations are prompted by inconsistent or ambiguous information, their engagement in information seeking behaviors is also prompted by inconsistency or ambiguity. Recent research by Busch and Legare (under review) examines how 6-10-year-old children evaluate different types of inconclusive evidence in comparison to conclusive evidence. Using a preference paradigm where an actor selects between three different types of food, researchers were able to carefully control the evidence children saw, thereby creating three distinct types of inconclusive evidence, consistent, inconsistent, and ambiguous. Children in the three inconclusive evidence conditions were assessed on their decision to seek additional information and their accuracy in solving the task. Their performance was compared to the performance of children who received conclusive evidence. The data showed that the ability to use evidence to solve problems presents a significant cognitive challenge for young children. Across these four conditions, researchers investigated how the type of information children had influenced their decision to engage in information seeking. Across age groups, results showed that inconclusive ambiguous evidence was more likely to motivate children to seek information than conclusive evidence, whereas inconclusive consistent evidence was not.

This comports with previous research demonstrating that ambiguous evidence is more likely to motivate exploration than unambiguous evidence (Cook, Goodman, & Schulz, 2011).

Ambiguous evidence may cue children to uncertainty and prompt further information seeking. This research also found that inconclusive inconsistent evidence was more likely to motivate requests for more information than conclusive evidence, but only for older children. This is consistent with previous research demonstrating that inconsistent evidence motivates both exploration and explanation in early childhood (Legare 2014; Legare et al., 2010; Stahl & Feigenson, 2015). The type of evidence children observe when engaged in problem solving individually affects their motivation to generate explanations and seek out additional information. It remains an open question however, how children's explanations and information seeking behavior in response to evidence operate when they are engaged in a collaborative problem-solving task.

Recent research utilizing a collaborative problem-solving task promises to provide insight into how self-explanation might differ from social explanations. In one study, Busch, Eck, Mercier, and Legare (2016) examined how 6-10-year-old children engaged in a problem-solving task with a partner. To accurately complete this problem-solving task using transitive inference, children needed two pieces of information. Dyads were told that the goal of the task was to use video evidence to figure out an actor's favorite food between goldfish crackers, animal crackers, and broccoli. Importantly, each child in the dyad only received one of the two pieces of required information. As a result, both children in the dyad were required to generate an explanation for their partner about the evidence they had observed in order to draw an accurate conclusion. The research questions were twofold, 1) how detailed of explanations do children generate for their partner, and in turn how does this affect the dyad's ability to solve the problem collaboratively, and 2) does working collaboratively enhance children's overall accuracy in solving the task over children working individually? Dyad's interactions were coded according to the strength and completeness of the explanation they provided to their partner. The data show a significant positive relationship between those dyads where children generated complete explanations and accuracy on the task (Busch et al., 2016). To understand the effect of peer interaction on problem solving, researchers compared the performance of children who completed the task with a partner to children who completed the same transitive inference task individually. In both the individual and the peer case, children were prompted to provide an explanation of the evidence they observed. Preliminary findings from this work suggest that dyads generating incomplete explanations for their peer, performed significantly less accurately on the task than did children working alone. However, the effect of generating an explanation with a peer appears to be the opposite for dyads generating complete explanations. These dyads performed significantly better than children completing the task individually regardless of age. This work suggests that there are indeed important differences in the way explanation functions in the service of problem solving when used individually and when used with others.

Research from the field of education also provides evidence for the benefits of generating an explanation with a peer, above and beyond the benefits of self-explanation. In one study, 6-7-year-old children were asked to complete a card-sorting task alone or with a same-sex peer. Children who completed the task with a partner had a higher number of accurate sorts than children who completed the task alone. Furthermore, low performing children who completed the task with a partner showed significant improvement from pre- to post-test, but only when they and their partner were in the explanation condition and not when they were in the "no-talk" condition (Fawcett & Garton, 2005). Other research shows that children who engage in transactive talk with a peer while working on a scientific reasoning task obtain more complex understanding of the problem more quickly than children who generate self-explanations for the same task (Teasley, 1997). Furthermore, classrooms strategies that pair 7th-graders together and have them compare and contrast solutions to a mathematics problems lead to greater gains in procedural knowledge and comparable gains in conceptual knowledge when compared to children who simply reflect on one solution at a time (Rittle-Johnson & Star, 2007).

The research on how explanation facilitates problem solving shows that children flexibly revise their explanations to accommodate new information. Biases to generate explanations for inconsistency or ambiguity mean that children's explanations are most commonly generated in contexts where there is something new to learn. Similarly, children's exploration, question asking, and information seeking are also prompted by inconsistency and ambiguity, allowing them to deftly accumulate additional information with which to revise their initial explanations. This process of explanation generation, discovery-oriented behavior, and explanation revision guides children's early developing capacity for problem solving.

Conclusion

Causal explanation is pervasive across development (Wellman, 2011) and a vast body of research shows that explanation plays an integral role in children's causal learning and problem solving. The process of generating explanations provides children an avenue to consider evidence, formulate hypotheses, and then revise those hypotheses to integrate new evidence as it comes to light. Throughout this chapter we have focused on two core questions, 1) how does explanation promote causal learning and 2) how does explanation facilitate problem solving? This research suggests that when children generate explanations, their acquisition of knowledge regarding the underlying causal mechanism for an event or phenomenon is enhanced while their memory for idiosyncratic perceptual features specific to that instance of the event is not (Legare & Lombrozo, 2014). Furthermore, in social interaction with a caregiver, children whose parents prompted them to explain a gear machine persisted longer in building their own gear machine (Willard et al., 2016). When applying their newly acquired causal knowledge to novel contexts, children who are prompted to explain are more likely to explore hypotheses that do the best job of accounting for the information they have received (Walker et al., 2017). Thus, it is clear that explanations promote learning and therefore we expect that children's explanation generation would be most common in situations where children have the opportunity to learn something new.

In line with the proposal that explanation should be more common when children have something new to learn, inconsistency and ambiguity with prior knowledge motivate more explanations than outcomes that are consistent with prior knowledge (Baillargeon, 2002; Chi et al., 1989; Legare et al., 2010). The bias to explain inconsistency or ambiguity prompts children to consider hypotheses and explanations they might not otherwise have considered (Bonawitz, Fischer et al., 2012; Foster & Keane, 2015). This research suggests that inconsistent or ambiguous information confronts children with the possibility that their understanding of a phenomenon is incomplete or inaccurate, which then prompts them to generate an explanation. Whether the explanation is accurate or not, it provides a useful framework for children to incorporate new information and provides direction for future exploration. In this way children are "explaining for the best inference" in the sense that an explanation might not be true, but it functions to constrain children's ongoing discovery-oriented behaviors to useful dimensions thereby facilitating learning (Wilkenfeld & Lombrozo, 2015).

The second core question addressed in this chapter is how explanation operates in the service of problem solving. An important component of solving any problem is being able to recognize when our knowledge is incomplete. Research suggests that the process of generating explanations might facilitate problem solving because it prompts children to articulate what they know, and thereby makes salient, gaps in their knowledge. The same type of contexts that motivate explanation, namely inconsistency and ambiguity, also motivate children to engage in selective exploration (Schulz, 2012), ask questions (Chouinard, 2007), and seek out additional information before drawing conclusions (Busch & Legare, under review). Explanation aids children in problem solving by guiding the gathering of additional, pertinent information.

The future for research on explanation requires that psychologists examine this topic in social contexts, in informal learning environments, and across diverse cultural backgrounds. New research presented in this chapter has only begun to scratch the surface on how explanation affects learning and problem solving in social interaction. The vast majority of children's time is spent in social interaction, with peers, caretakers, and teachers in formal and informal learning environments (Rogoff, 2003). How does explanation with a peer affect children's learning and problem solving? Is the spontaneous generation of social-explanations more common than self-explanations? If peers with a wide discrepancy in skill and knowledge collaborate on a task, how does that affect learning outcomes compared to a dyad where both partners are of similar skill? Ongoing work suggests that generating explanations in collaborative problem-solving tasks might allow more skilled children to accelerate the learning of a lesser skilled partner (Busch et al., 2016). Museums and science centers often implicitly assume that children come away having learned something from the exhibits (Legare, Sobel, & Callanan, 2017). But to what extent do informal learning environments motivate spontaneous explanation generation and thereby causal learning? Future research on explanation in these environments could answer this question and also provide useful insight into how informal learning environments might seed explanation. Finally, it is important that explanation is examined across diverse cultures. Wide cultural variation exists in parental theories about learning and the extent to which parents believe that children should learn through direct pedagogy (Lancy, 2008). Children from different backgrounds may differ in their experience with generating explanations in direct response to prompting from teachers or parents. Examining explanation and learning across cultures promises to provide insight into continuity and variation in cognitive development (Legare, 2017; Legare & Harris, 2016).

Explanation has been a core topic of study since Piaget and much more research remains to be done to obtain an encompassing view of children's causal knowledge acquisition and problem solving. However, an expanding literature supports the proposal that explanation plays an integral role in the development of these capacities. From early childhood, children are sensitive to cues that their current state of knowledge is incomplete, such as inconsistency and ambiguity. Inconsistency and ambiguity motivate explanation, and explanation in turn guides exploration, question asking, and information seeking and children engage in these activities whether they are alone, with a peer, or with a caretaker. Ultimately, explanation and discovery-oriented behaviors, such as information seeking, work in tandem to drive causal learning and facilitate problem solving.

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