Chapter 2
Young Children's Motivation for Learning Science

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Young children generally epitomize motivated learners. They are interested in everything around them, are optimistic that they can learn more and improve their skills, and are usually not deterred by experiencing initial difficulties or failures (Freedman-Doan et al., 2000). However, after children begin school their initial enjoyment of learning declines, as does their view of themselves as being competent and able to master concepts and skills (Eccles, Wigfield, Harold, & Blumenfeld, 1993; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002). This motivational decline continues throughout schooling, or at least in the case of reading and math (Archambault, Eccles, & Vida, 2010; Jacobs et al., 2002). Surprisingly little is known about children's motivation for learning science during the early school years (Mantzicopoulos & Patrick, 2013). What *is* well documented is that young children begin school with an avid interest in science (Brown, 1997; Chouinard, 2007), but by the middle and high school grades are considerably less positive about the subject (Gottfried, Marcoulides, Gottfried, & Oliver, 2009; Hendley, Stables, & Stables, 1996; Vedder-Weiss & Fortus, 2011). What happens between those points—the trajectories that children's science motivation typically take, reasons for those trajectories, and the practices that tend to sustain or stifle science motivation—has received very little attention by researchers.

The dearth of empirical research about young children's motivation for science is quite striking. Perhaps because of efforts to increase the number and diversity of people in STEM-related careers (e.g., National Academy of Sciences & National Academy of Engineering, and Institute of Medicine, 2010), most science motivation research involves students in high school (e.g., Aschbacher, Li, & Roth, 2010; Britner, 2008; Cleaves, 2005; Nieswandt, 2007) or college (e.g., Black & Deci, 2000; Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013; Sadler, Sonnert,

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Hazari, & Tai, 2012)—the time when educational and vocational decisions predominate. Researchers have also addressed students' science motivation in the middle grades (i.e., 5th–8th; e.g., Britner & Pajares, 2006; Lee & Brophy, 1996; Swarat, Ortony, & Revelle, 2012; Vedder-Weiss & Fortus, 2011), possibly reflecting the importance of adolescence in terms of the development of personal, academic, and vocational identities (Schwartz, 2001). For the most part, motivation is not the focus of science research until science instruction is routinely included in curricula schedules and testing programs, usually in 3rd or 4th grade.

However, what if children's science motivation typically begins to decline in the early school years, like it does with reading and math, rather than being an issue primarily during adolescence? Does children's motivation diminish even if the content area is not systematically taught? What if it is most effective to nurture and sustain, during the beginning grades, the enthusiasm for science that young children enter school with? And if so, what would such science instruction look like? These are just some of the many crucial questions still to be answered about young children's motivation for learning science.

In this chapter we provide an overview of the research findings about young children's motivation to learn and understand science-related concepts and processes. We also discuss the nature of this research, in terms of both its theoretical underpinnings and methodological approaches, and provide reasons for why research into young children's motivation is so vital. Finally, we consider implications of science motivation research for teaching practices used in preschool and the early school grades. First, however, we begin by briefly noting how we and other motivation researchers conceptualize motivation.

Conceptualizing Motivation and Theoretical Frameworks

Motivation—what people are motivated to do and where they put their efforts—is expressed by their behaviors: the choices they make, energy they expend, the extent to which they persist at something, and the care and thoughtfulness that they put into their work. People with high quality motivation, therefore, take on challenges, put forth effort, continue with a problem, topic, or issue even after making errors or incurring set-backs, and use strategies thoughtfully. It is no wonder, then, that high motivation is associated with learning and achievement (Schunk, Pintrich, & Meece, 2008)!

People who, from their behavior, appear highly motivated also hold particular beliefs about what it is they are motivated to do. They believe that the activity process or its outcome (or both!) is worthwhile, important, interesting, or enjoyable, and that they are good at the activity or will become skilled with practice (Schunk et al., 2008). It is these beliefs, therefore, that fuel the behavior we noted in the previous paragraph.

The predominant theories of motivation are social-cognitive. That is, they emphasize the primacy of individuals' perceptions and beliefs in influencing their behavior. Motivated behavior, according to these theories, depends in large part on how individuals construe: (1) the *task or subject* (e.g., how enjoyable, interesting, useful, important, or difficult is it?), (2) their own *ability or skills* (e.g., are they likely to succeed, how hard will they have to work, will they likely perform significantly better or worse than others?), (3) their *goals and desires*, (4) the *likely consequences* of their success or failure (e.g., not being accepted for a coveted position, receiving financial rewards, being ridiculed or disparaged) and (5) *reactions of people* around them (will someone be available to help if necessary, will social relationships be affected by their performance?) (for reviews see Graham & Weiner, 2012; Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2006).

In line with the indicators of motivation and beliefs related to them, motivation researchers investigate a range of students' behaviors and beliefs. Although all motivational theories seek to explain the same types of behavior (e.g., choices, persistence, effort), they focus on different beliefs (e.g., self-efficacy or self-competence, importance of the task or subject, current enjoyment or future desires, personal and situational interest). Therefore, findings have to be synthesized across multiple theories. In doing so, what does research tell us about young children's motivational beliefs and behavior towards learning science?

Children's Science Motivation During Preschool and the Early Grades

Although research directly addressing young children's science motivation in early educational settings is sparse, there is a considerable body of developmental research that establishes that young children are inherently motivated to learn about science.

Children's Curiosity and Questions About Science

Young children are intrinsically interested in the world around them, as reflected by the number and types of questions that they ask (Brown, 1997; Piaget, 1955). Children seem to ask questions almost incessantly. When talking with adults, young children ask between 76 and 95 information-seeking questions per hour—an average of about three questions every 2 min! (Chouinard, 2007). Some of their questions involve physical science and technology, such as, "How does the barcode in the supermarket work?" (Baram-Tsabari, Sethi, Bry, & Yarden, 2006, p. 808). Young children, however, are especially curious about the natural world.

The questions that young children ask indicate that they wonder about a diverse range of natural phenomena that cover all science content areas—life science, physical science, Earth and space science, and technology. These wonderings include: what makes flowers grow in the summer, how do clouds or rainbows form, why does rain fall, why do babies stay inside their mothers for so long, why don't animals use words, where does the sky end, and what is the difference between shooting stars and regular stars (Baram-Tsabari & Yarden, 2005; Callannan & Jipson, 2001; Mantzicopoulos & Patrick, 2008; Patrick & Mantzicopoulos, 2014; Perez-Granados & Callanan, 1997; Piaget, 1955; Przetacznik-Gierowska & Ligeza, 1990). Even before the onset of formal schooling, young children show remarkable sensitivity to the biological world and are capable of using "a variety of high-level causal and relational patterns" to reason about living things (National Research National Research Council, 2007, p. 69). This intense interest in the natural world is believed to be due to children's unique, innately controlled tendency to seek information and learn about nature in general (Chouinard, 2007; Lee, 2012; Piaget, 1955).

Children's Interest in Science Activities

In addition to the wealth of research from developmental psychologists, there are some studies that document children's motivation for science within formal educational settings. The latter information, however, must sometimes be extracted from larger studies about what children do in school, rather than being presented explicitly as evidence that addresses some aspect of young children's science motivation.

Science Books. Young children are interested in reading informational books about science topics, and enjoy them as much as or more than fictional stories (Caswell & Duke, 1998; Donovan, Smolkin, & Lomax, 2000; Mohr, 2006; Pappas, 1993; Price, Bradley, & Smith, 2012). For example, preschool teachers judged their students as being equally attentive, and showing comparable enjoyment, while reading a novel story book about dogs, pigs, cats, or bats compared to reading a new informational science book on the same subject (Price et al., 2012). Also showing the popularity of non-fiction science, first graders preferred overwhelmingly the one non-fiction science book from a selection that included diverse genres—realistic and fantasy fiction, informational books, humor, and poetry (Mohr, 2006). Specifically, children were individually shown nine picture books spanning different topics and genres (five fiction, four non-fiction), all of which were of high quality, had full-color illustrations, and were recommended by experts in children's literature. When students were told they could keep one book, almost half (46 %) of the 190 children chose the informational book *Animals that Nobody Loves*. No information was reported about why this book was the most popular.

As part of our research on young children's use of informational books we have found that kindergarteners enjoy reading expository books about a range of science topics, in addition to being able to understand their content (Mantzicopoulos & Patrick, 2010; Patrick & Mantzicopoulos, 2014). As one example, after we read excerpts from each of four science books, individually to children, we asked them whether or not they would like to read another book on the same topic. Two of the excerpts addressed biology—*Dolphins* (about a mother and baby dolphin) and *Fins, wings, and legs* (about structures that enable animals to move); one excerpt involved physical science—*What is a lever?* (about a seesaw or teeter-totter being a simple machine); and one involved Earth and space science—*Light* (about the sun and Earth). The length and complexity of the excerpts were comparable with each other and each was accompanied by a color photo also from the book. After we read each excerpt we asked each child, *"If I had a longer book like the one we just read, would you like to read it?"* Most children expressed clear interest in each of the books. Approximately two-thirds said they would like to read a longer book similar to the texts *Dolphins*, *Fins, wings, and legs*, and *Light* (70 %, 66 %, and 68 %, respectively). More than half of them (56 %) expressed interest in reading another book like *What is a lever?* Of additional interest, girls and boys were equally keen to read more about each of the science topics. Although this study was focused on informational texts, and therefore does not provide data on how children's informational book preferences compare to fictional book preferences, the evidence clearly highlights children's early interests in informational genres.

Science Centers. Young children also enjoy engaging in activities that involve science. Early childhood classrooms typically include a nature table or science center as one of the areas that children can choose to play at. In analyzing how children spent their free choice time in preschool—almost one-third (29 %) of total time—Early et al. (2010) found that science activities were popular. The children spent 15 % of their free time engaged in science activities—playing with mirrors, magnets, sand, or water, or reading science books. This is comparable with their time spent on other enjoyable activities: 16 % in art (music, painting, clay, playing instruments), 16 % in gross motor activities (e.g., running, playing ball, jumping), and 17 % on fine motor activities (e.g., cutting, stringing beads). The evidence is similar in kindergarten classrooms. Spending free time in science areas (water and sand table, science and nature area) is a popular choice for children, even though teachers use science materials infrequently during structured lessons (Saçkes, Trundle, Bell, & O'Connell, 2011).

Interest in science centers may require that children find the materials attractive, can recognize the materials or equipment and know how to use them, and view the contents as appropriate for them. Familiarity with the science materials as it relates to children's interest and use was examined by Nayfield and her colleagues (Nayfeld, Brenneman, & Gelman, 2011), after evidence that the science areas of six preschool classes were empty more than three-quarters of the time. After baseline measurements, the children in three of the classes participated in two lessons during which they were introduced to the balance scale that was present in each of the centers, and discussed how it can be used and why it is useful. The center attracted enormous interest, and children's use of the science area increased dramatically compared to pre-intervention levels. The science area was also used significantly more than in comparable classrooms, where the balance scale was also present but had not been targeted as a lesson topic.

The studies referred to in this section examined children's motivated behavior, but not their beliefs surrounding their behavior, therefore we can only speculate about reasons for their choices. Other research, however, has asked children directly about their motivation-related beliefs (e.g., enjoyment, perceived competence, and expectations).

Children's Motivational Beliefs About Learning Science

Children in kindergarten typically begin the year with positive, optimistic beliefs about the science they will learn during the year, and express comparable levels of confidence for learning about reading and math. Approximately 80 % of the children from different kindergarten classrooms told us that they expected to learn content pertaining to science (e.g., "In school we will learn about how living things grow," "…we will learn how to make observations")—a similar number to the approximately 90 % who expected to learn "about letters… numbers…shapes … [and] books" (Mantzicopoulos, Patrick, & Samarapungavan, 2013, p. 78).

Despite an expectation that they would learn science, kindergarteners reported at the end of the year learning very little, if any, science (we discuss this finding in a later section). This perception, though, may explain why the children reported, on average, low levels of competence in terms of knowing both science content and processes (e.g., "I know why living things camouflage," "I know how to use different tools to learn about science."). Their mean perceived competence (scored from 0 to 1) ranged from .28 to .37 across different samples (Mantzicopoulos et al., 2013; Samarapungavan, Patrick & Mantzicopoulos, 2011). At the end of kindergarten children expressed moderate enjoyment of science. Specifically, we asked different samples of kindergarteners whether or not they agree with statements such as "I have fun learning about the animals that live in the ocean," "I want to know more about living things," and "I like using different science tools." Their mean enjoyment ranged from .59 to .60 on a 0-1 scale (Mantzicopoulos et al., 2013; Samarapungavan, Patrick, & Mantzicopoulos, 2011).

Our study did not provide comparable data on children's perceived competence and enjoyment of reading and math. There is evidence, however, that children in kindergarten through 3rd grade believe, on average, that they are more competent in math than life science, and also more competent at math, reading, and life science than physical science (Andre, Whigham, Hendrickson, & Chambers, 1999). They also like life science as much as math and reading, but like physical science less than those subjects (Andre et al., 1999). Because these results were not reported separately by grade level, it is unknown whether there are differences in motivational beliefs about science between kindergarten and 3rd grade.

Changes in Science Motivation from the Early to Later Grades

There is ample evidence that by the middle- and high-school grades children have typically lost much of the zeal for science characteristic of young children (e.g., Gottfried, Fleming, & Gottfried, 2001; Watson, McEwen, & Dawson, 1994).

Intrinsic motivation for science declined longitudinally in a linear fashion from the time children were 9 years old to subsequent testing at 10, 13, and 16 years (Gottfried et al., 2001). This finding was replicated in a cross-sectional study of science motivation. Specifically, in comparing 3rd through 12th graders' attitudes towards science, the most positive were expressed by 3rd and 4th graders, whereas 9th–12th graders were least positive; 5th–8th graders' attitudes fell between the two. The younger children (i.e., grades 3-4) also reported a significantly greater science self-concept than did the older students (Greenfield, 1996).

The relative interest in different areas of science also changes between early childhood and adolescence. For example, questions asked about physical science constitute a small proportion of the total questions submitted by students to Ask-a-Scientist web sites (Baram-Tsabari & Yarden, 2005). Interest in physical science, relative to other areas of science and technology, was greatest for young children; 7 % of the questions that children 8 years and younger submitted to Ask-a-Scientist web sites were about physics, compared to approximately 3.5 % of the questions asked by children aged 9 and older. This sizable decline is surprising. It is unlikely that upper elementary children ask fewer questions because they understand most of their physical world; it is more likely that they just wonder about it less. Given that experiences within a content area affect motivation—a point we discuss in the next section—the lower curiosity about physical science is perhaps due to the relative emphasis on life science topics in the early grades curriculum (Weiss, Pasley, Smith, Banilower, & Heck, 2003).

There is so much more to learn about young children's science motivation than it being generally high at the beginning of their school careers, and much lower 5 or 6 years later. How does their science motivation unfold from year to year? What kinds of trajectories are typical throughout? How flexible, and how resilient, is children's science motivation during the early school years? Can a dip in first grade be made up by an exceptional, or even a solidly good, second grade experience? Can some instructional practices retain or sustain children's motivation, and if so, what are they? Of all the questions, though, arguably the most important at present is: Why does young children's motivation decline?

Experiences Shape Children's Motivation for Learning Science

Although considerably more research is needed, there is growing evidence that children's experiences with learning science are associated with their motivation in the subject, like it is in other academic areas such as reading and mathematics (Helmke & van Aken, 1995; Lerkkanen et al., 2012). Furthermore, evidence supports the argument that the typical decline in science motivation is not inevitable, but is related to the fact that young children have very few opportunities to engage in high-quality science activities. We discuss these two premises next.

The early experiences that children have with various school subjects influence the beliefs they hold about those subject areas and about themselves as learners of those subjects (Wigfield & Eccles, 2002). These beliefs, which contribute to motivation in important ways, include whether children view a subject as: being hard or easy for them, important for them to learn or not, appropriate for them to be learning (e.g., "It's not what girls do," "It's not for children my age"), interesting or boring, and, something they are or can be good at.

Children develop their liking for particular subjects, and their perceptions of being good at those subjects, when they have ongoing, meaningful opportunities to engage in them. For example, instruction that focuses on developmentally appropriate, child-centered (rather than didactic, teacher-directed) approaches fosters children's interest in reading and mathematics (e.g., Lerkkanen et al., 2012; Stipek, Feiler, Daniels, & Milburn, 1995). Also, positive early experiences with mathematics (e.g., success experiences) lead to children enjoying math and believing they are competent at it (Aunola, Leskinen, Onatsu-Arvilomni, & Nurmi, 2002; Chapman, Tunmer, & Pronchow, 2000; Helmke & van Aken, 1995).

Of interest, young children readily refer to their experiences when asked to reflect on their competence (i.e., beliefs that they are good at subjects such as reading, spelling, and writing). In their seminal study on the dimensionality of young children's competence beliefs, Harter and Pike (1984) cited evidence that supports children's understanding that experience is linked with motivation. Specifically, 96 % of the children's responses to questions such as "How do you know you are good at reading (spelling, writing)" were descriptive statements about their experiences with the content area they believed they were good at (e.g., "I can write words like 'cat' and 'dog'," or "I can spell because I read a lot," or "I read a lot at home," or "My mom and dad helped learn how," or "I do writing every day", p. 1977).

Children also draw inferences that an academic area is valued when the teacher provides frequent opportunities to engage with a variety of tasks in that area (Turner, 1995). Therefore, when a subject is absent from the curriculum, children may easily infer that it is unimportant, inappropriate (e.g., too difficult), or irrelevant, at least for them. In the absence of meaningful learning experiences in academic content areas, children may not (a) develop positive beliefs about these areas (i.e., that they are interesting and worth learning about); and (b) think of themselves as having the ability to do well in subject-specific tasks.

Findings from our research show that young children's competence beliefs and interest in science are dependent on their instructional experiences (Mantzicopoulos, Patrick, & Samarapungavan, 2008, 2013; Patrick, Mantzicopoulos, & Samarapungavan, 2009). Therefore, we have significant concerns about the effects that children's typical science experiences in the early school years have on their motivational trajectories. Concerns include that: young children have few opportunities to engage in meaningful science; lessons are usually not identified as science; and the boundaries between science and other disciplines are typically blurred. We expand on these points next and their implications for motivation.

Few Opportunities to Engage in Meaningful Science

For more than the last decade science has been virtually absent from the early grade curriculum (Blank, 2013; Marx & Harris, 2006). This is largely as a consequence of: (1) the national focus on early literacy, defined narrowly as reading competence (Marx & Harris, 2006; Rouge, Hansen, Muller, & Chien, 2008), and (2) schools' Adequate Yearly Progress being based only on English language arts (ELA) and math test scores (Judson, 2010). Other beliefs, such as that young children are concrete and unskilled thinkers who lack the readiness for engaging purposefully with science (Brown, Campione, Metz, & Ash, 1997), and that it is less important for children to learn science in the early grades than during the upper elementary grades (i.e., 4th–6th) (Andre et al., 1999), do not challenge the dominance of ELA. This situation may improve as states implement the Core Curriculum State Standards (CCSS), which integrate ELA with content areas, including science (National Governors Association [NGA] Center for Best Practices & Council of Chief State School Officers [CCSSO], 2010). However educators (e.g., International Reading Association, 2012) predict that it will take time for instructional practice to align with the CCSS.

There is substantial evidence that during preschool and the early grades, young children are afforded few opportunities for learning science. Science is taught infrequently (Fulp, 2002; National Institute of Child Health and Human Development, 2005; Saçkes et al., 2011; Tu, 2006; Weiss et al., 2003). Rather than involving practices that encourage children's rigorous and reflective science learning, instruction is usually infrequent, fragmented, and focused on decontextualized sets of skills (e.g., categorizing and classifying objects) that are thought to be foundational for science learning (Metz, 1995). However, the teaching of science as bits and pieces of discrete skills that are not integrated into a cohesive instructional framework is unlikely to promote learning about and understanding of the nature of science as a way of knowing about the world (Brown et al., 1997; Metz, 1995). Moreover, because meaningfully connected and sustained experiences with science are needed for children to develop both their knowledge and motivation in this subject (Mantziopoulos et al., 2013; Samarapungavan et al., 2011), piecemeal instructional approaches do not contribute to children developing positive motivational beliefs and behaviors about science.

Young children have the capacity to engage with science inquiry in meaningful ways (Zimmerman, 2007). Appropriate, contextualized, ongoing, and coherent science experiences promote children's science knowledge and their understanding of the process of inquiry (Samarapungavan et al., 2011); these experiences also nurture children's motivation. Rich and systematic science experiences promote the construction, organization, and maintenance of motivational belief systems about science, including science-specific self-perceptions (e.g., perceived competence, enjoyment) and perceptions about science (e.g., importance, difficulty). Therefore, when children do not have high-quality science-learning experiences their ability to maintain and develop motivation for science fades.

Low Disciplinary Integrity of Science Lessons

In addition to being infrequent and presented as discrete sets of skills, when science *is* taught in the early grades it is often not recognizable as a content area separate from others (Dickinson & Young, 1998; Furtak & Alonzo, 2010). In particular, science is usually taught through art activities, or reading fiction. For example, kindergarten teachers we have worked with, when explaining what they typically did for science, told us:

> We do it [i.e., science] mainly through literature. . . like different books about animals. Talking about the weather, different books about the weather. I know we did ‘Cloudy with a Chance of Meatballs.’
>
> When we did butterflies—I have a book called ‘Katrina.’ It’s about a butterfly, and it’s a song, so I would teach the kids the song and we would all make the butterfly paper.
>
> When we do fire safety, [another science theme] usually we make this HUGE cut-and-paste Sparky the Fire Dog with the rules. … And it’s one of THE highlights of the whole fire safety unit. They take this dog home that’s 3 feet tall.
>
> Now I would do [i.e., make] a bee, and they would too. And they could see the three body parts, and they would add the wings, and the six legs, and the antennae. So they actually do a little bee and then we hang ‘em up in the classroom. So [we do] artsy kinds of things (Mantzicopoulos & Patrick, 2013).

Observational data with two different cohorts of kindergarteners also bear out the typical practice of infusing art and fiction liberally into science instruction (for different descriptions of science lessons and excerpts of discourse see Mantzicopoulos, Samarapungavan, & Patrick, 2009; Mantzicopoulos et al., 2013; Samarapungavan et al., 2011). It is important to note that the science lessons we observed were comparable with other researchers’ accounts of typical science instruction in elementary school (Dickinson & Young, 1998; Furtak & Alonzo, 2010). Across the science lessons that teachers chose for us to observe, we watched, for example, children make: leaf rubbings; paper models of the pumpkin life cycle; books with pages representing each stage of the butterfly life cycle; spiders made from marshmallows, pretzels, and M&Ms (for head and body, legs, and eyes); snowflakes with crystals grown from saturated borax solutions; and a mouth of teeth by pasting mini marshmallows onto paper to represent two rows of teeth.

Throughout all of the science activities there were no instances of press for children’s understanding, elaboration, or model articulation. Teachers made efforts (albeit infrequently) to prompt recall of facts that lead children to give one-word responses (e.g., “What comes after the egg?”—“Caterpillars”). Beyond these closed, low-level questions, there were neither instances of science-related discourse, nor evidence of teachers intentionally engaging children with the language and processes of science. Even when instruction included opportunities for children to represent their understandings (e.g., make a butterfly book), it simultaneously constrained them (e.g., “Your butterfly book is going to look like this”) and focused their attention on neatness and appearances (e.g., “Do your very best to stay on the line,” “Don’t cut his antennas off,” “[The caterpillar page is] going to be this bright orange page”; Mantzicopoulos et al., 2013, p. 98).

In addition to science lessons typically not emphasizing core science concepts and language, the teachers we observed did not identify science lessons to their students, as is usual with other subjects (e.g., "It's time for math now," "Take out your reading book," or "When you get back from music it'll be lunch time."). Of the 22 science lessons that kindergarten teachers invited us to observe, the label "science" was used only by one teacher in two lessons. Instead, lessons were introduced by their topics, such as "learning about butterflies," "germs," "the ocean," or "sinking and floating."

Science Is Often Not Recognizable in Science Lessons

Kindergarteners find it difficult to recognize that they are learning science at school—or at least those in our study did—quite possibly because lessons were not identified by the teacher as 'science' and/or the content appeared fanciful or art-based, rather than 'scientific.' It does not seem unreasonable to suspect that many 1st and 2nd graders may share the same position. Consider that science in the U.S. does not appear as a separate subject on report cards or require reporting by teachers until 3rd grade. When children do not recognize they are learning science, they have no opportunities, at least at school, to construct coherent notions about science as a discipline with content, norms, and processes that are distinct from other subject areas such are language arts or art.

Not recognizing science lessons when they do occur may explain why, at the end of kindergarten, children typically stated that they had learned very little science content and process (Mantzicopoulos et al., 2013; Samarapungavan et al., 2011). Only about 40 % of the children confirmed that they learned about living things or butterflies, making predictions or talking about science, or other science content and processes. In contrast, nearly 80 % of the children reported that they learned about reading and math.

Further evidence that young children generally do not appreciate the scope of topics that fall within the domain of science comes from other interviews with kindergarten children (Mantzicopoulos et al., 2009; Patrick et al., 2009). We asked young children, individually, from regular kindergarten classes whether or not they learn science at school. Of 70 children, the majority (83 %) told us they did not learn science. Twelve children (17 %) reported learning science at school, however only five mentioned science-related activities. Activities they misidentified as science include art, music, language arts, or math, as illustrated in the following quotes:

> We color. We write our names. We write stuff.

> Bugs. We just color them in, that's all. (What do you learn?) About books. (What kinds of books?) "Sam I am" [i.e., a Dr. Seuss fictional book]. That's all.

> Learning to make stuff. (Like what?) Dolphins, whales, the boat, alligators, sharks. (What do you do in science?) We kind of make them with paper and we paint them. We sing the alphabet. We do math (Mantzicopoulos et al., 2009, p. 359).

We were also interested in what kindergarteners understand science to be. We asked those who reported learning science what they learn about, and those who claimed to not learn science, what they would learn if they were taught science. A large proportion (43 of 70) said they didn't know what science is. Of the 27 children who described some type of science learning, only 19 actually involved an aspect of science (e.g., "Being healthy" or "Rain, sun, and clouds"). Inaccurate construals of elementary school science included:

> You have to be big to do science. If you're little, you'd get hurt. Do stuff with chemicals, like mix them up together and they'd blow up.

> They can make stuff. Like people who are frozen. Or make little people, or make little monsters. Or they can make little bubble gum or rocks.

> It's not for kindergarten. It's for big people. I really hope I can make stuff out of science, like flowers (Patrick et al., 2009, p. 181).

Our findings indicate that most children did not recognize the discipline of the lessons that were viewed by teachers as being science. This is not surprising, considering that science instruction typically comprised superficial and unconnected content that was often more art than science, as we illustrated in the previous section. Consistent with their experiences, these children had a superficial understanding of science, at best; they tended to see it as content that didn't apply to them. When we asked these children to tell us about science, they referred to conceptions that perhaps were developed from out-of-school experiences. Certainly, science is often portrayed in children's television shows, movies, and books as a dangerous venture involving unusual people (usually men, often the villain) who mix potions or create dastardly inventions.

Does it matter that children don't have accurate ideas of science? Yes! People don't hold beliefs in a vacuum. Motivational beliefs are connected integrally to the meanings that people develop for a discipline. For example, interest in a topic or subject necessarily involves an understanding of what that topic is—its inherent meaning for the individual (Renninger, 2000). Furthermore, the way that students conceptualize what they are learning relates directly to how they view themselves as learners (Patrick et al., 2009). For example, I am more likely to view science as important or useful if I believe that science is the process of asking and answering questions about the world around us, than if I believe that science is about "do[ing] stuff with chemicals, like mix them together and they'd blow up" (Mantzicopoulos et al., 2009, p. 359). The development of competence beliefs (i.e., believing that oneself has the ability to do well or will be successful at a task) is based on frames of reference that include the individual as a participant in meaningfully linked activities and events. Therefore, children are more likely to construct realistic conceptions of their competence from participating in authentic activities (i.e., they can consider themselves as competent observers following a nature walk during which they observed and recorded different living things) than from viewing fantastical stories about scientists making frozen people. We expect that children's interest in biological growth would develop more within the process of systematically observing, recording, and learning about the transformation of a caterpillar to butterfly or of a tadpole to frog, than from a story about making potions that transform rabbits into people, or children to grown-ups, or vice versa.

Declines in Science Motivation and Misunderstanding the Nature of Science Are Not Inevitable

Our overview thus far of the course that children's trajectories of science motivation usually take is rather bleak. However, the good news is that this developmental course is not inevitable. Going back to the points at the beginning of this section, the development of motivation is contextually-situated (Mantzicopoulos & Patrick, 2013; Patrick & Mantzicopoulos, 2015), and therefore different approaches to science instruction are likely associated with different motivational patterns (see Vedder-Weiss & Fortus, 2011, for evidence from middle grades).

From our research we have shown that a year-long conceptually rich, personally meaningful, inquiry-based, and literacy-infused science program (i.e., Scientific Literacy Project, [SLP], 2009) results in significantly greater science motivation for kindergarteners, compared to the motivation of children not receiving this program of activities (Mantzicopoulos et al., 2009, 2013; Patrick et al., 2009; Samarapungavan et al., 2011). Furthermore, and relatedly, children develop a significantly more accurate understanding of what science involves, and recognize that they can and do learn science (Mantzicopoulos et al., 2009; Patrick et al., 2009). For example, after engaging in SLP for a year, 88 % of the SLP children gave an explanation of science that included content or processes relevant to the discipline (compared with 27 % of comparable students without SLP lessons). Examples of the SLP children's description of science include the following:

> People do science stuff to help them to know about things that lives [sic]—live in shells, like snails, crabs, and turtles (Patrick et al., 2009, p. 181).

> (What do you do in science?) Well, we see what's in our fish tank. We saw snails, anemone, rocks, and the temperature thing, I think it's called a thermometer. (What happens in science?) You learn all kinds of things. You learn more about things. Read science books and learn more. You can figure things out, like what goes faster and slower and see if something can go higher than another one (Mantzicopoulos et al., 2009, p. 251, 353).

> We learn how to predict and be a scientist. We predict what's going to happen, and if it happens, our prediction is right (Mantzicopoulos et al., 2009, p. 352).

Although the results from our SLP project are strong and have been replicated across different samples, it would be preferable to have concurring evidence from other researchers. However, we are not aware of other research that examines the effects that particular science instructional approaches have on young children's science motivation in the early grades.

Most science programs developed for children in preschool or the early elementary grades have investigated some aspects of children's learning (e.g., French, 2004; Gelman & Brenneman, 2004; Klein, Hammrich, Bloom, & Ragins, 2000;

Peterson & French, 2008; Shymansky, Yore, & Anderson, 2004; Varelas & Pappas, 2006; Vitale & Romance, 2012). We argue, though, that *children's motivation is every bit as important as their learning*. In fact, the present situation in the U.S. of too few people with sufficient ability choosing science careers fundamentally reflects a motivational problem! Therefore, we see an urgent need for more empirical research on motivational outcomes of young children's science instruction, and for evidence that new curricula benefit children's motivation as well as learning. We turn next to consider how researchers have measured young children's motivation to learn about science, and note methodological and analytic concerns we have about this line of research in general.

Measuring Young Children's Science Motivation

Methodological Approaches

Motivation to learn science is usually measured with self-report surveys for children in the upper elementary grades and beyond (e.g., Beghetto & Baxter, 2012; Denissen, Zarrett, & Eccles, 2007; Lamb, Annetta, Meldrum, & Vallett, 2012; Vedder-Weiss & Fortus, 2011; Wenner, 2003), however this method is rare during the early grades. More often, researchers infer motivation from children's behavior—whether observed live or deduced from physical records—or they ask teachers or parents to rate children's motivation. We describe and provide examples of each method next.

Observation. A prominent method for investigating young children's motivation for science involves using observational measures to document behavior, particularly the behavioral indicators of motivation we outlined at the beginning of this chapter. Motivation is inferred from children's *choice* of activities when they have different options available. For example, during live classroom observations Nayfield and her colleagues (2011) used time-sampling to record every 60 s how many children and teachers were at the science center and what they were doing. These data were used to calculate the proportion of available minutes that teachers and children spent in the science area, in addition to the "child minutes", or "the number of students present there during each minute that the area was occupied" (p. 980). Minutes per activity may be recorded separately for individual children, aggregated across groups (e.g., sex), or be a composite of the entire class, depending on the unit of interest. Similarly, *persistence*, or the amount of time children stay at any activity rather than moving on to another, can be calculated from observations. Although we did not find studies about young children's science motivation that used this method, it would involve differentiating among children and noting the time that each arrived at and left a science area generally, or began and stopped engaging in a specific activity.

Another way to measure young children's motivation is by observing their facial and verbal expressions during activities, in order to infer their motivation-related affect (e.g., interest, pride, shame). Examples, albeit not in the science domain, come from investigations of preschoolers' and kindergarteners' motivation and behavior while engaging in challenging puzzle and trivia tasks (Berhenke, Miller, Brown, Seifer, & Dickstein, 2011; Stipek et al., 1995). We are not aware of studies where this method was used to examine motivation for science. However, this method has the potential to provide additional, descriptive information about children's motivation and engagement during science.

Physical Records. Other times physical records of children's choices are collected at a later point and analyzed, such as investigating how many children choose to carry out an optional science fair project (Adamson, Foster, Roark, & Reed, 1998) or accessing library records to identify the most popular types of books. When all options involve science, researchers can differentiate among various specialties. Examples include noting whether a science project addresses a question relating to the biological or physical sciences (Adamson et al., 1998), or whether a question submitted to an Ask-A-Scientist website represents Biology, Physics, Chemistry, Earth sciences, Astrophysics, Nature of Science, or Technology (Baram-Tsabari & Yarden, 2005).

Teacher or Parent Reports. Researchers sometimes ask adults to rate young children's interest or motivation, based on the assumption that adults gain this knowledge from regular interactions with children. Additionally, secondary data analysis may be conducted using large, existing data sets, such as the Early Childhood Longitudinal Study (ECLS-K). Although this approach provides large and usually representative samples, with limited cost, a downside is that items may not match the construct of interest closely or be specific to science. For example, using the ECLS-K dataset, Saçkes et al (2011) created a measure of "children's motivation to benefit from instruction" (p. 223) using four content-independent items referring to children's "attentiveness, persistence, eagerness to learn, learning independence, flexibility, and organization" (p. 223).

We have developed the Teacher Rating Scale of Children's Motivation for Science (TRMS; Patrick & Mantzicopoulos, 2008) that, as indicated by factor analysis, consists of two sub-scales (Mantzicopoulos et al., 2013). The Interest in Learning Science subscale has seven items that assess teacher perceptions of how interested children are in science (e.g., "How excited or enthusiastic is he/she during science?" "How hard does he/she try in science?"). The Need for Support vs. Independence for Learning Science subscale, also with seven items, reflects teacher perceptions of children's independence versus their need for support during science learning (e.g., "How much support does he/she need from you in science?" "How much encouragement does he/she need from you in science?"). Teacher reports of kindergarteners have been internally consistent (alphas >.90) for both subscales.

Another group of adults sometimes asked to evaluate children's motivation for science are the children's parents. To measure children's interest in science Alexander and her colleagues documented parents' reports of the activities their children engaged in (Alexander, Johnson, & Kelly, 2012). This longitudinal study continued for 3 years, beginning when their children were 4 years old. Researchers contacted parents every 2 months during the first year of the project, then at 4 month intervals, and recorded parents' estimates of their children's science-related interests, preferred activities, and behaviors. These included children's favorite free-time play activities (including lists of favorite science-related TV shows), whether children had a focused interest in a science topic (e.g., dinosaurs, rocks, cars), the frequency of children's questions about science, and the apparent inspiration for those questions (e.g., book, TV program, a community activity). A less complex approach to measuring young children's science interest has been to ask parents to rate how much their child likes science (Andre et al., 1999).

Because parents' beliefs about their children's ability in different activities and subjects influence children's own perceived ability or competence (e.g., Frome & Eccles, 1998), parents may be asked to assess children's ability or about their expectations for their children. For example, Andre and his colleagues (1999) asked parents "How well do you expect your child to perform in [science]?" (p. 727).

Scales developed for teachers and parents to rate children's competence in different subject areas have been developed by Eccles, Wigfield, and their colleagues. These scales have referred to children in 1st grade onwards, and their scores exhibit good reliability (alphas >.80 across multiple samples) and validity (e.g., form independent factors). Although studies about children in early grades have asked adults to rate reading, sports, music, and arts competence (e.g., Fredricks & Eccles, 2002; Wigfield et al., 1997), the items could be easily used to address science. Items include "How good is your/this child in [domain]?" and "How well do you think your/this child will do in [domain] next year?" (Wigfield et al., 1997, p. 454).

Although they are useful for examining behavior, methods based on researchers', teachers', or parents' observations of children are not sufficient for understanding the perceptions and meaning systems that undergird children's behaviors. Recall that *perceptions* are central to social-cognitive theories; it is the beliefs that individuals hold, rather than an objective reality, that influences their motivation most.

Self-Reports. In addition to knowing *what* children do, it is important to understand *how* children view themselves, their interests and abilities. What thoughts and beliefs channel particular behaviors? Why choose to read a book about marsupials rather than one about Halloween? Why choose to play with the dress-ups instead of at the science table? What roles do such factors as interest, 'real' or perceived current competence, enjoyment of challenge, fear of not doing well, construals of gender norms, or friends' choices play in what children select, persist at, and expend energy on? These questions are best answered by the children directly.

Although self-report instruments are used often from the upper elementary grades onward (e.g., Gottfried at al., 2001), few researchers have used self-report instruments to measure young children's motivation for science. Measuring young children's self-beliefs is particularly difficult, given their limited verbal expression skills, short attention spans, and their need to have items read aloud to them. Consequently, self-report measures are necessarily administered to young children individually—not an efficient process. Despite this difficulty, some researchers have used single items to assess children's self-beliefs (e.g., self-competence) or views about science content or topics (we discuss concerns with single items in the next section). In measuring both types of perceptions Andre and his colleagues (1999) asked children in grades K-3 to identify "how good you feel you are" (p. 724) at physical science and at life science, using a 3-point scale of "good" (with a smiley face), "OK" (with a neutral face), and "not very good" (with a frowny face). Another two of their items asked "how much do you like" physical science and life science, using responses of "Yes, I like it!", "It is OK", and "No, I don't like it" paired with the same graphics. Particular science topics may be focused on explicitly, such as when children rated science programs about specific concepts (e.g., catapults and trajectories), after watching each program (e.g., Fay, 1998). Yet another approach is to ask children whether or not they would like to read a new book on the science topic they have just viewed (Fay) or read about (Mantzicopoulos & Patrick, 2010).

In contrast to using single items to measure children's motivation, we have constructed a set of items—the Puppet Interview Scales of Competence in and Enjoyment of Science (PISCES; Mantzicopoulos et al., 2008; Patrick et al., 2009). PISCES was constructed in line with developmental considerations, taking into account young children's limited verbal expression skills and evidence that young children (i.e., preschoolers and kindergarteners) are able to provide a wealth of psychological information about themselves when prompted with statements about their experiences (Eder, 1990; Harter & Pike, 1984; Measelle, Ablow, Cowan, & Cowan, 1998). Framed in expectancy-value theory (Eccles, 2005; Eccles et al., 1983), the items assess children's self-beliefs across different science content and processes.

PISCES is administered individually, with the administrator attributing two opposing statements, one positive and one negative (e.g., "I can't do science yet" vs. "I can do science") to each of two identical puppets. Children then indicate which puppet expresses what they themselves think. The puppets are the same sex as the children, who chose and name the puppet pair looking most like themselves (from five different configurations of skin, hair, and eye colors). The statements are fully counter-balanced in terms of order (which puppet speaks first), valence (which puppet makes positive or negative statements), and valence order (whether the first statement is positive or negative).

The PISCES items consistently factor into competence and liking scales. Specifically, they differentiate between children's perceptions of their knowledge of general and specific science content (e.g., I can do science, I know why living things camouflage), and science processes (e.g., I am good at making predictions, I know how to use different science tools). Other items identify children's liking of science (e.g., I want to know more about science). These scales are internally consistent with different samples of ethnically diverse kindergarteners; Cronbach's alpha were .82, .85, and .76 for competence in content, competence in process, and liking, respectively. The scales also correlate with other measures in expected ways (Mantzicopoulos et al., 2008, 2009, 2013; Patrick et al., 2009; Samarapungavan et al., 2011).

In contrast to addressing different subject areas separately, researchers sometimes ask children to make comparisons among subjects. For example, in an approach used by Freedman-Doan and her colleagues (2000), 1st, 2nd, and 4th graders were shown four pictures—of a same-sex child doing math, reading, spelling, and science—and asked which one of the activities he or she was best, and which not so good, at. The researchers then asked about the subject identified as the child's worst, in order to understand children's reasoning about their competence and improvement. Follow-up questions were (1) whether children thought they could become better at the subject, (2) if that subject could be their best, and, (3) depending on their previous answer, what it would take for them to be best at that subject or why they couldn't be best at it.

Methodological Concerns

In addition to the paucity of empirical research on young children's motivation for learning science, this field of research is hampered by concerns with methodological issues. We discuss some of these next.

Distinguishing Among Grade Levels. Young children exhibit considerable growth and development in their physical, emotional, and cognitive abilities, including memory, reasoning and judgment, and perspective-taking—all of which have implications for their motivational beliefs and behaviors. Therefore, we assume that just as there are changes in children's motivation for academic subjects such as reading and math (e.g., Jacobs et al., 2002), there are also age- or grade-related differences—quantitative and qualitative—in children's science motivation. Unfortunately, however, researchers frequently aggregate child data across a range of grade levels or ages, which obscures valuable developmental information. We believe that a better understanding of children's science motivation trajectories would result from examining the differentiation of children's beliefs across different grade levels over time (e.g., from kindergarten to 2nd grade). For example, because data for children in the early grades are reported in combination with upper elementary students (e.g., Adamson et al., 1998; Fay, 1998) it's not possible to discern whether there are significant differences among grade levels. Also, even when the participants come from a wide range of grade levels (e.g., Lamb et al., 2012), studies often don't report reliability data (e.g., Cronbach's alphas) by grade, making it difficult to assess the psychometric rigor of the scales when used with younger and older students.

Single Item Measures. As we have noted already, researchers sometimes assess young children's science motivation with single items. Single-item measures are appealing, because they are fast to administer and do not tax children's short attention span. However, there are significant drawbacks to this method. Single items: (a) correlate poorly with the constructs of interest; (b) may reflect skills or beliefs in domains (e.g., achievement) that are different from the domain (e.g., interest or liking of a subject) the research is intended to measure (e.g., a child may report that she likes dinosaurs because she just learned how to spell *dinosaurs* correctly); and (c) are notoriously unreliable (Nunnally & Bernstein, 1994). Because young children can sometimes be capricious in their responses, researchers need to be particularly attuned to the consistency of data collected from them.

Ecological Validity. As we noted earlier, young children—even by the end of kindergarten—may not have yet developed a coherent concept of science that can serve as an organizational scheme that accommodates their emerging knowledge and experiences with the natural world. This has implications for the ecological validity of questions that purport to measure children's liking, interest, or ability beliefs about science. Although children can supply answers to questions, researchers need to be confident that their study's participants understand the questions and constructs asked of them in the way the researcher intended. It is not always clear that this is the case in studies of young children's science motivation.

In order to interpret likert-scale data it is necessary to know what respondents understand the items they rate to mean; researchers cannot just assume that their understanding is the same as their study participants', especially when those participants are children. What do children mean by *science* when they answer questions about how much they like science, or how good they are at science? Do they know what science is? What if some think that science is "learn[ing] how to sing ABCs" (Patrick et al., 2009, p. 180), like one of the kindergarteners in our research project did? Might children's reports vary, depending on whether they view science in the same way as Arun, who told us "Sometimes we paper cut things with scissors and glue them together. We draw things and color things. And that's the only three things," or Malik, who responded to "What do you learn in science?" with "Measuring things, and water. Using a telescope, using trains to slide down ramps, using a microscope" (Mantzicopoulos et al., 2009, p. 348).

Even when researchers include differentiated questions about life science and physical science (e.g., Andre et al., 1999) we are concerned that without information about what children know about these two domains, these descriptors may not be meaningful. Therefore, given the contextualized development of science motivation, we wonder how useful it is to ask globally about "science," rather than about specific topics or activities (e.g., asking questions, observing, knowing why animals camouflage, recording data).

Asking children to report on activities they have not experienced undermines the validity of the study's findings, in our opinion. How can children know if they enjoy an activity or a subject if they are not aware of it? Nevertheless, researchers have investigated children's motivation to read science books this way. Some have asked how much children enjoy reading particular types of books in general, such as informational science or fairy tales (e.g., Fleener, Morrison, Linek, & Rasinski, 1997), and others have asked children to report how much they would like to read books representing different topics and genres, based only on fictitious titles and descriptions (e.g., Harkrader & Moore, 1997). If children have no experience reading informational books they may be unlikely to say they like this genre, even if it turns out they really would. Therefore, although children tend to say they prefer fiction (Harkrader & Moore, 1997), we argue it is because they have experienced fiction almost exclusively, not because they could not be equally (or more) interested in non-fiction. Without information about children's experiences these findings may simply be an artifact of familiarity and availability of resources rather than evidence of interest.

Differentiating Children's Motivation for Science from Motivation for Other Subjects. Sometimes teachers are asked to rate children on key, motivational qualities, such as interest, effort, or persistence, however there is no evidence about the validity of teachers' judgment of young children's motivation. Moreover, as used in research thus far, this type of measure is content-neutral; it does not refer to a specific content area, even though children's motivation does vary for different topics and they are aware of this (e.g., Eccles et al., 1993). For example, the measure created by Saçkes et al (2011), which came originally from a social skills rating system, is one of "children's motivation to benefit from instructional activities" (p. 223) and does not refer explicitly to science. The items do refer to indicators of motivation, but as general, rather than domain-specific, characteristics.

Although there is clear evidence that even young children identify differences in their motivation for various academic subjects, it is less certain that teachers make such differentiations when rating their students' motivation. Even when a measure refers to a specific domain, as in our teacher rating measure of children's science motivation, there is very little evidence that early elementary teachers make distinctions about children's motivation across different subjects. In our research, the correlations between PISCES child-reports and the Teacher Rating Scale of Children's Motivation for Science (TRMS) are statistically significant, however the magnitudes are nonetheless quite modest (rs = 0.18 between TRMS-Interest and PISCES science liking, –0.16 between TRMS-need for support and PISCES content competence, and -0.18 between TRMS-need for support and PISCES process competence) (Mantzicopoulos et al., 2013). However, although the constructs in the two measures are conceptually comparable, they are by no means identical, nor are we convinced that they should be. The items on the TRMS scale asked teachers to make more general judgments about children's science motivation whereas, as we noted earlier, for developmental reasons, the PISCES included many content-specific items. Together with frequently reported results on the modest agreement between young children's and teachers' reports (e.g., Mantzicopoulos & Neuharth-Pritchett, 2003; Measelle et al., 1998), our data also suggest that *children's reports are in no way a substitute for information contributed by teachers*.

There is evidence, nonetheless, that teachers are quite accurate in their judgments of young student's cognitive skills (Ready & Wright, 2011). Of note, the accuracy of teacher ratings increases with teacher experience and education (U.S. Department of Health and Human Services, 2002), and decreases as a function of the socioeconomic context of the school (i.e., teachers in schools that serve lower SES families under-estimate the cognitive abilities of their young students; Ready & Wright, 2011).

Methodological and Theoretical Advancements Needed for Research of Young Children's Science Motivation

We have already noted, in the previous section, our concerns with the way that many studies of young children have measured their motivation for learning science. Clearly, there is a need for ongoing advancements in instruments used to measure science motivation. These include: (1) distinguishing between different topics or spheres within science, (2) creating scales so that internal consistency reliability can be assessed, (3) reporting data about (e.g., alphas) and from (e.g., descriptive statistics) measures separately by grade level, (4) understanding what children mean by the questions they respond to, and (5) knowing more about the contexts within which children learn science.

Another area where advancement is needed is in aligning motivation research with the increasingly accepted premises of sociocultural theories. Motivation research has tended to be based in social-cognitive theories that focus on individuals and their own construals of themselves and their experiences. However, motivational researchers have come to acknowledge that the complexity of student's motivational development is best understood in terms of sociocultural theories that represent patterns of engagement across multiple contexts (e.g., Hickey, 1997; Järvelä & Volet, 2004; Kaplan & Maehr, 2002; Mantzicopoulos & Patrick, 2013; Nolen, 2001; Pressick-Kilborn & Walker, 2002; Turner, 2001; Turner & Patrick, 2008).

Studies that are aligned with sociocultural perspectives require researchers to not only attend to the people and activities, but to the systems of meaning the activities are embedded within. Generally, data should be multimethod, multiinformant, multilevel, overlapping (i.e., not independent), and longitudinal. However, most writing that portrays motivation socioculturally is theoretical and offers little guidance for how motivation research can be conducted to ensure it is methodologically compatible with the undergirding theory. Although not simple, aligning methods with sociocultural premises will prompt researchers to collect evidence of systems of contextualized meanings about science and learning science. We believe this is an essential step in the process of gaining insight to children's motivational beliefs.

Relevance of Science Motivation Research to Classroom Teaching Practices

At the risk of being repetitive, it is important to acknowledge that there is little research evidence about young children's science motivation on which to base suggestions for teaching. Nevertheless, we believe the following points, gleaned from that research, are relevant to teachers' practice:

- Motivation is inseparable from learning and the contexts in which they develop. Along with learning science, children learn whether they are or can be good at it, whether they enjoy it, and how important it is. Therefore, experiences doing (or not doing!) science have major implications for children's motivation.
- Young children need ongoing experience engaging in science, using the language, materials, and norms that are central to the discipline. They need to develop conceptually coherent and accurate notions of what science is and what scientists do, and lessons should be clearly identified as science (when science is being taught). Without explicit instruction, children are likely to construct their understanding of science from other sources, such as television and movies, which may undermine both the accuracy of their knowledge and their motivation.
- Although other subjects (e.g., art, writing) may be integrated with science lessons, the disciplinary boundaries of each should be clear. For example, drawing caterpillars within science lessons may involve close observation of a model and attempts to faithfully depict what is seen, using accurate colors and refraining from adding "extras" such as smiling faces or eyelashes.
- Interest increases as children develop skills and knowledge. Without competence there is just attraction, rather than an interest that sustains persistence, effort, and learning over time (Renninger, 2000). It takes some while for children to develop competencies, therefore central ideas need to be revisited and expanded on throughout a year, and across years. From both a motivational and knowledge acquisition stance there are few, if any, benefits from brief presentations of a potpourri of disconnected topics to children—an 'exposure' rather than an understanding approach to instruction.
- It is probably not helpful to ask children what they are interested in, in terms of science; they may not have the experience to know. It is preferable to assume that young children *will* enjoy learning about science concepts or reading informational books, and provide many opportunities for them to do so.
- Help children see that science is relevant, meaningful, and appropriate for *them*. If children believe that science is for other (e.g., older, smarter) people, they are unlikely to put forward effort and persistence to learn it, and possibly not choose to learn about it at all.

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