Science
Education

Children's Motivation Toward Science Across Contexts, Manner of Interaction, and Topic

MEGHAN E. BATHGATE, CHRISTIAN D. SCHUNN, RICHARD CORRENTI
Learning Research and Development Center, University of Pittsburgh, Pittsburgh, PA 15260, USA

Received 20 August 2013; accepted 29 October 2013
DOI 10.1002/sce.21095
Published online 31 December 2013 in Wiley Online Library (wileyonlinelibrary.com).

ABSTRACT: Understanding the features of science learning experiences that organize and motivate children at early ages can help educators and researchers find ways to ignite interest to support future passion and learning in the sciences at a time when children's motivation is declining. Using a sample of 252 fifth- and sixth-grade students, we systematically explore differences in children's motivations toward science experiences across context (formal, informal, neutral), manner of interaction (consuming new knowledge, analyzing, action), and topic (e.g., biology, earth science, physics). Motivations toward science were most influenced by topic. Responses were generally consistent across context and manner of interaction. Implications for science education, as well as measurement and assessment methodology, are discussed. © 2013 Wiley Periodicals, Inc. *Sci Ed* **98:**189–215, 2014

INTRODUCTION

Despite society's growth in scientific knowledge, research shows a gradual decline in children's motivation toward science as they approach adolescence (e.g., Osborne, Simon, & Collins, 2003; Simpson & Oliver, 1990; H. T. Zimmerman, 2012). Unfortunately, this decrease coincides with the sensitive timing of science choices and milestones that are influential to future science opportunities, such as science camps, advanced science courses, and calculus (Tyson, 2011; Tyson, Lee, Borman, & Hanson, 2007). As a result, a number of children will have made early experience choices that limit what they can later do based

Correspondence to: Meghan Bathgate; e-mail: meb139@pitt.edu

on premature evaluations of their fit with science (e.g., on the basis of stereotypes). Such early influences on career decision making could prevent the diversification of the pool of scientists and engineers that is currently being sought because obtaining a formal career in science depends upon the cumulative impact of all of these choices (Adams et al., 2011; Archer et al., 2012). Furthermore, reductions in openness and curiosity toward science experiences may prevent many children from fully developing scientific literacy, reducing what they can understand about technology, medical issues, and environment concerns as adults. Understanding why and in what ways children's motivation in science drops during early adolescence can help us learn how to mediate the decline in science across this age.

A number of efforts to increase individuals' science literacy and participation in science-related careers have focused on early exposure to science with the aim of generating long-term interest toward science. Hidi and Renninger (2006) suggest that general interest builds from interest in particular situations. Such a shift from particular to general seems intuitive at first blush, but actually hides a number of key complexities. Vis-à-vis a complex social construct like science, what is the character of those particular situations in the mind of the child? Science can be conceived of as a set of topics, a set of activities, and a set of places of engagement. For example, in developing a relationship to science, do children focus on the kind of tasks they are asked to do in that situation (e.g., hands- on science)? Or do they focus on the topic of inquiry (e.g., dinosaurs)? Or is the context the salient element (e.g., science camp or the class period called "science")? The ways in which children generalize early positive or negative experiences with science will likely be heavily influenced by the ways in which such situations are represented (Eshach & Fried, 2005). At the same time, the regularities in their environments will likely also shape the scope of interests and motivation that children have toward science (e.g., all the classroom-based experiences were dull or all the dinosaur experiences were exciting). We investigate how these aspects of science frame motivations in science.

Specifically, the goal of this paper is to investigate how students' early motivation varies across the dimensions through which science occurs. The literature suggests several frames for how a child's experience with science might be influenced, such as the context in which science is experienced (e.g., formal vs. informal spaces), the manner in which children interact with science materials or ideas (e.g., hands-on vs. worksheet activities), and the science content (e.g., physics vs. biology). These frames are our dimensions of interest. Each of these dimensions has been argued to be influential to children's science understanding and science motivation (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003; Jacobs, Finken, Griffen, & Wrightm, 1998; Mantzicopoulos, Samarapungavan, & Patrick, 2009).

Context

The simple "formal versus informal" distinction has existed in modern learning research for a number of years, yet what is encompassed by this distinction can be defined in multiple ways (Dierking et al., 2003; Hofstein & Rosenfeld, 1996). Formal science contexts are frequently defined as school-based science experiences, leaving informal learning to include a diverse set of out-of-school science experiences. However, there are a number of elements typically associated with the formal/informal distinction, such as by the relationships of participating individuals (e.g., teacher-guided classroom instruction, peer discussion), structure of a program (e.g., highly structured with clear expectations, unstructured with no expectation), or whether the child self-selected to participate in an activity (e.g., compulsory vs. free-choice) (Dierking & Falk, 2003; Dierking et al., 2003; Vadeboncoeur, 2006). The focus on performance assessments may also vary across contexts. Classroom science often has an evaluative component in which children are asked to demonstrate their knowledge and are given feedback often in the form of grades. Many informal experiences are less individually evaluative, although these activities are not free from competition and achievement, as can be seen often with sports teams or camp competitions (Ntoumanis, Taylor, & Thogersen-Ntoumani, 2012). These common formal versus informal experience characteristics imply that children will often explore science with different interactions, constraints, and expectations.

For our current purposes, we conceptualized context into the following categories: "formal" science, related to in-class experiences; "informal" science, representing those activities occurring outside of the classroom in an environment more likely to allow for free-choice, such as at a home, camp, or with friends outside of school; and a "neutral" category to explore whether adding a context shaped responses, which did not explicitly specify a context and could be relevant to both formal and informal contexts (e.g., "Understanding science is helpful for solving problems"). While we recognize that the boundaries of "formal" and "informal" are somewhat artificial and that a child's overall science experience is cumulative across a range of spaces (Dierking & Falk, 2003), our decision to dichotomize across formal/informal spaces was motivated by two reasons. First, our research question examines a child's sensitivity toward a number of dimensions of science, broadly constructed, and thus some simplification of each dimension, including formal/informal is required to make the study manageable and sufficiently powered. Second, although school-aged children generally have some in and out-of-school science experience, children vary in their exposure to particular subtypes of in and out-of-school science experiences (Sha, Schunn, & Bathgate, 2013). Using too fine a slice to differentiate between formal (e.g., text book vs. hands-on scripted vs. project based) or informal experiences (e.g., clubs vs. summer camps vs. science at home) is not possible for children with little experience or restricted in type of experience. As such, we attempted to gather a variety of examples of each category to adequately represent typical forms and features of these contexts.

In addition, to further allow for differences in children's specific experiences in particular activities, many items were phrased as modals (e.g., "If I . . . "). Since a key function of motivation is to drive choices, if children have a clear motivational preference based on choice characteristics (e.g., type, location, and topic of activity), these preferences are consequential even if these preferences are based on little prior experience.

Manner of Interaction

What does it mean to "do" science? Science has both a declarative domain knowledge (i.e., the content of a discipline), and processes and strategies within a given domain (C. Zimmerman, 2000). Furthermore, "science" itself covers a number of disciplines, and each discipline within science involves its own processes, discourses, analytic techniques, and ways of interpreting phenomena. The manner in which scientific processes are enacted, the speed with which these processes are done, the specific tools and techniques used, how findings are communicated, and how feedback is received varies across specific disciplines of science. For example, an astrophysicist spends a good deal of time working with mathematical models on a computer, never interacting with the physical substances being studied, whereas a marine biologist often works within the environment being studied, interacting with the living organisms being studied. Alternatively, an evolutionary biologist carefully studies and analyzes the past, but cannot alter and manipulate their artifacts in the way a chemist can through a series of experiments. Each domain has a concrete set of contextual expectations for knowledge and work that allows an individual to progress to expert levels within a narrow scope of the larger context of science. Yet, while the declarative and procedural knowledge differ across domains, there remain some shared foundational scientific processes.

How does appreciation of the scientific process, or of these distinctions within sciences, play out for children? Elementary-aged students often begin learning science domain knowledge via the classification and categorization of science content, but the more abstract science processes are not discussed until later in their education (Metz, 1995). This delay, whether a necessary step in developing scientific understanding or not, can affect a child's understanding of what science is and what it means to "do science" (Mantzicopoulos et al., 2009; Metz, 1995). This delayed appreciation of science processes may in part be attributable to the current education system in which curricula quickly cover a wide range of science content (Schmidt, McKnight, & Raizen, 1997) within a small amount of class time devoted to science. All of this is further complicated because teachers have limited knowledge of science processes (Fulp, 2002).

Furthermore, when children first begin to learn science, they are exposed to a variety of experiences that require a child to interact with science material in different ways that may or may not be authentic to the science being studied. The learning of science can rely on textbook reading, discussions, hand-on worksheet problems, inquiry investigations, or group work to explore science concepts across a range of science domains (Fulp, 2002). These modes of learning are substantially different from one another. Because children may have varying preferences with the way they interact with science material across these modes of learning, there may be large differences in the degree of engagement, interest, and understanding children have when interacting across these different experiences.

Although there is a common belief that hands-on activities are most engaging for children, research in this area shows conflicting results about the benefit of hands-on activities for learning outcomes and engagement, suggesting hands-on activities may not always be beneficial without structured, mindful guidance from instructors (Hofstein & Lunetta, 2004). Furthermore, the modes of learning can function together, moving between reading, experimentation, and discussions. Given the array of scientific activities in which a child participates of varying quality sometimes presented together and sometimes presented separately, it is an open question whether children show a preference for one type of science learning activity more strongly than another regardless of topic or context.

We divide manner of interacting into three categories, representing commonly discussed large divisions in subjective focus of the interaction type: *consuming new knowledge*, which involves the studying, reading, and going online for the learning of new science information (Hidi & Renninger, 2006); *analyzing*, which describes what may occur more within a child's mind and involves a child's thinking about information they have already learned (Mercier & Sperber, 2011; Vygotsky, 1978); and *action*, where a hands-on activity is specified (e.g., building things) (Wigfield, Guthrie, Tonks, & Perencevich, 2004). Although a given situation will often involve at least two if not all three of these categories, our distinctions here place emphasis on particular elements (the physical interaction or the acquisition of new information or the pondering of existing content) to understand how the subjective focus influences engagement.

Topics

Children are more likely to engage in learning experiences if they are interested and curious in the content (Hidi & Renninger, 2006). As science can be subdivided into different domains and is often taught in this partitioned way, researching "science" at the general level may not be nuanced enough to discover differences in children's motivation toward science. Even by kindergarten, children express some differences in their motivation toward different science disciplines (Mantzicopoulos, Patrick, & Samarapungavan, 2008); however, there are large differences in exposure to diverse science topics. By the time children are out of middle school, larger preferences can be found across a range of scientific areas (ByBee & McCrae, 2011; Trumper, 2006a, 2006b).

These developmental differences raise the question: at what level are these differences found in children? How specific are their interests at this age? Topic differentiation may occur at a very narrow level (e.g., dinosaurs), and interest may be found only in instances in which this topic is found. Alternatively, interest areas may be broader (e.g., biology) or even expansive (e.g., all science). Developmental process and new science experiences may affect these interests. Initial interest in a science topic may be triggered by a particularly engaging experience that initiates interest, and this interest may become a more personalized and self-driven interest that develops over time (Hidi & Renninger, 2006). However, the breadth of that interest may change as a child develops his or her understanding toward different components of science and his or her affective-cognitive reaction to them.

In conceptualizing the grain size of learner preferences, it is important to consider what kinds of distinctions children are likely to make. At older ages, children and adults have (potentially strong) associations with science disciplines per se, such as loving biology but hating physics. At younger ages, children may not know the labels or even meaning of typical science disciplines, like chemistry or earth sciences. But they may have already developed affinity for a range of topics within disciplines (e.g., various biology topics they have already encountered) (Crowley & Jacobs, 2002). By breaking down these larger domains into specific instances, it is possible to probe for disciplinary interests while avoiding complex terms unfamiliar to the child. Thus, we examine this topic dimension by including a range of science topics within five large domains of science (astronomy, biology, earth science, engineering, physical science[1]). In addition, however, it is useful to consider children's motivation at the general level of "science" to understand how children's general science motivation may differ from topic-specific motivation. Children may have idiosyncratic associations with the general term, yet the world is often labeled using that term and thus it is important. As a note about terminology, we asked children about "science," but we will use the term "general science" in our discussion here to help distinguish analyzing motivations about a general label from analyzing motivations across many topics.

Finally, the motivation literatures have identified a large number of constructs that influence student participation and engagement in science. For the purposes of the current study—understanding the contextualization of motivations in science—we sampled a subset of the motivational constructs (e.g., interest, appreciation, identity) to serve as the basis for our item structure that (1) have been previously associated with outcomes such as learning, achievement, and future activity choices; (2) come from a range of theoretical perspectives, and (3) are not mutually redundant (Archer et al., 2012; Bryan, Glynn, & Kittleson, 2011; Jacobs et al., 1998; Lent, Brown, & Larkin, 1984). Specifically, our measures included items relating to children's self-reported appreciation toward science, curiosity and interest toward science, identity with science, persistence in science activities, personal responsibility for learning science, and expectancy value in science. Table 1 provides a concrete conceptualization for these constructs and key references. However, our current purpose is not to formally test the differences among motivational constructs, but

[1]"Physical science" is the label given in the United States for physics and chemistry topics at the middle-school level.

TABLE 1
Conceptualization of Each Motivational Subscale, Examples, and Citation Sources

Construct	Conceptualization	Item Example	Citation Source Example
Appreciation	Appreciation items inquired about children's understanding of the value and nature of science in their lives.	Understanding science is helpful for solving problems.	Schreiner and Sjoberg (2004); Weinburgh and Steele (2000)
Curiosity	Curiosity items were designed to assess children's wondering, investigating, and excitement in learning more about science-related topics. Specifically, items asked about children's seeking understanding, opportunities to explore, and desire to investigate and question science phenomena.	I enjoy exploring new activities about [*favorite topic inserted*] in school.	Litman and Spielberger (2003); Engelhard and Monsaas (1988); Kashdan et al. (2004)
Identity	The formation and role of identity in a child's experience with science is multifaceted. Our identity items focused on children's recognition of their role in science pursuits and their thoughts about themselves related to science and scientific pursuits.	I think like a science type person.	Girod (2009); Fraser (1981); Moore and Foy (1997)
Interest	As a cognitive-emotional construct, interest relates to people's affect toward science and the "predisposition to re-engage" in science. Interest is often argued to be key factor in science learning in terms of both engagement and deeper learning processes (e.g., finding connections in science	I would like to do activities related to robots at home.	Hidi and Renninger (2006); Germann (1988); Dawson and Bennett (1981); Dawson (2000); Renninger, Ewen, and Lasher (2002); Girod (2009)

(Continued)

TABLE 1
Continued

Construct	Conceptualization	Item Example	Citation Source Example
	content to one's own life, question generation) Items were constructed to ask about children's fascination with science, whether they actively seek out information on a science topic, and if they have a positive affect toward science and science topics.		
Persistence	Persistence can be conceptualized as actions taken to remain engaged when facing a difficult obstacle (e.g., a bad teacher, a failed experiment), or maintaining engagement in science activities over extended periods.	I would keep studying science, even if my teacher tells me I'm not good at it.	Duckworth and Seligman (2006); Lufi and Cohen (1987)
Responsibility	Children's responsibility is conceived as children's perception of their ability to organize science information, take an active part in their science learning, as well as examine their perceived control over their science learning.	When it comes to learning about [*favorite topic inserted*], having a good instructor is more important than how hard you try.	Niemiec, Ryan, and Deci (2010); Nowicki and Strickland (1973)
Expectancy value	Expectancy value is the hypothesized powerful combination of expectancy and value. A number of studies have found that when one has both the confidence in one's ability to successfully complete a task in addition to intrinsically or extrinsically valuing that task/content, one has very high motivation levels as displayed in a variety of output measures.	If I started a class project on climate change, I think I could do a really good job.	Eccles and Wigfield (2002); Nagengast et al. (2011)

rather to use them as a platform for understanding a child's overall preferences and motivation toward science along the dimensions in which science experiences vary. Items from existing theories were used to embed the tested dimensions (context, manner of interaction, topic). Throughout this study, we use "motivation" to refer to a child's inclination or desire to engage or participate in science experiences, as reflected in this variety of motivational constructs.

THE CURRENT STUDY

To explore and disentangle the potentially important variation in motivations due to these dimensions, we examined the relationship between children's motivation toward science across a range of experiences, varying systematically the manner of interaction with science, using different science topics, and referring to a range of places. We are interested in answering the main research question: *Does children's motivation shift along the dimensions of context, manner of interaction, and topic?* We hypothesized that children's responses about their motivation toward various science activities may be heavily influenced by these factors.

While many studies have demonstrated the importance of student science motivation on science achievement, less is known about how concrete science experiences relate to children's motivation or how these experiences build toward a child's developing understanding of science. Among the particular dimensions examined within this study, topic interest is likely the most robustly studied. Large-scale measurements have been conducted to examine science interest across particular topics (ROSE: Relevance of Science Education, PISA: Program for International Student Assessment); however, our current work offers notable important additions to this prior research. First, our students are at a developmentally younger age (11–12 years old) than the students in the ROSE and PISA data (15 years old) (ByBee & McCrae, 2011; Jenkins & Pell, 2006; Schreiner & Sjoberg, 2004), and our students are much older than the studies showing topic preferences at the start of formal education (e.g., Mantzicopoulos et al., 2008). These large age differences between our focus and the focus of prior work involve large changes in self-reflective thought, independence from adult supervision inside and outside school, social interactions with peers, as well as exposure and opportunities for science-related experiences. The intentional sampling of early middle school also affords us an opportunity to measure students' science motivation close to the start of the gradual decline in children's interest in science as they approach adolescence (e.g., Osborne et al., 2003; Simpson & Oliver, 1990; H. T. Zimmerman, 2012).

In addition, while topic interest is one major focus of this article, we also explore other dimensions of science motivation that are much less studied at any age, including exploring topic across context and manner of interacting. In a child's common experiences, there may be strong natural correlations among the dimensions such that some learning spaces or specific science domains lend themselves more easily to a specific manner of interaction. For example, perhaps science classrooms typically have less of a hands-on component and more reading and listening than do informal experiences. This example shows the potential overlap that may occur between dimensions, in this case context and manner of interaction. To assess the independent influences of each dimension, we balanced across these dimensions using a factorial design to understand the unique contributions of each dimension. In other words, questions about more active (e.g., "hands-on") experiences occurred with equal frequency in different contexts and within different science domains. Using this approach, we mitigated the potential problem of imbalanced dimensions by structuring our survey to measure dimension combinations in a more controlled, equal way.

TABLE 2
Participant Information Across Locations

		Age (Years)		
State	Testing Location	*M*	*SD*	Gender
California	71% museum	11.2	0.5	60% female
Pennsylvania	All school	11.4	0.6	58% female
Overall	31% museum; 69% school	11.3	0.5	59% female

METHOD

Participants and Recruitment

Two hundred and fifty-two fifth- and sixth-grade students from Pittsburgh, Pennsylvania, and the Bay Area, California, participated in the study (see Table 2 for description). All children in the Pittsburgh region were recruited through their school science classrooms, whereas Bay Area students were recruited through their school science classrooms or through their class visit to a local museum. Although student-level socioeconomic status (SES), ethnicity, and were not assessed, schools in both regions drew students from a range of SES and were not particularly higher or lower performing schools. From open online school enrollment data, Pittsburgh students are primarily Caucasian and African American and Bay Area students are largely Caucasian, Hispanic, and Asian. All students who were present on the day of survey administration completed the survey.

Materials

Survey: Topic Checklist. At the start of the online survey, children were asked which science topics they were interested in learning about from a list of science topics. This checklist was used to obtain a measure of children's interest at the topic level. The topic checklist included items sampled from five broad science disciplines: astronomy, biology, earth science, engineering, and physical science (e.g., astronomy was represented with "planets," "space travel," "telescopes," "distant galaxies," "The Moon," "The Sun," "black holes"). This combination of five disciplines with seven instances yielded 35 topics for the item checklist.

To ensure some basic level of familiarity and interest for late elementary-aged children, these 35 topic items were initially gathered from pilot testing conducted with fifth-grade students. As elementary school curricula are not currently standardized in the United States, children in the pilot testing were given a large list of science topics commonly learned in elementary school and found on other topic checklists in the literature. Children were asked which topics they found interesting and would like to learn more about as well as asked to generate their own list of science topics if they liked something that was not presented. As such, an in-depth knowledge of each topic was not necessary to make motivational judgments. More popular items were selected within each of the five broad science disciplines to produce seven items per discipline.

When children selected these topics at the beginning of the survey, they were instructed to select as many of the topics that interested them, but to pick a minimum of two. This checklist then generated two measures of topic interest (number of science topics each child selects and popularity of science domains and topics). Next, to measure maximal preferences as driven by a favorite topic, a list of the individual's selected topics was presented and each child was asked to select his or her one favorite topic.

TABLE 3
Example Items Labeled with Their Respective Dimension Coding

Example Items	Context	Manner of Interaction	Topic
I would like to *do activities* related to **robots** at home. (Interest item)	Informal	*Action*	**Engineering**
If I started a class *project* on **climate change**, I think I could do a really good job. (Expectancy value item)	Formal	*Action*	**Earth science**
I would keep *studying* **science**, even if my teacher tells me I'm not good at it. (Persistence item)	Formal	*Consuming new knowledge*	**General science**

Note. Underlined words of the items indicate context, italicized words indicate manner of interaction, and bold words indicate topic. Items simultaneously count toward one of each of the four dimensions.

Survey: Item Adaptation Along Dimensions. The remaining survey items consisted of 89 survey items asking about children's motivation and behavioral preferences toward science across the dimensions of context, manner of interaction, and topic. Please see the Appendix for a full list of items.

The selection of the seven motivational scales came from a national panel of researchers from cognitive, developmental, social, and educational psychology and science education convened to discuss key potential motivational constructs of relevance to late elementary that would be most predictive of long-term engagement in science; a goal was to look across theories rather than endorse any particular theoretical framework (Dorph, Schunn, Crowley, & Shields, 2011). Based on discussion of evidence and overlap of relevant literatures, these seven constructs were deemed likely be relevant to science motivation in late childhood/early adolescent development and not mutually redundant. Following input from the panel of experts, we conducted a series of pilot studies with the various subcomponents of the survey with fifth- and sixth-grade students to make sure the constructs were being measured reliably at this age. Edits were made to the survey based on this pilot, and then further adaptions were made to meet the research goals.

The items were constructed by adapting and extending existing motivational scales that have been previously argued to influence learning and engagement with science in formal and informal settings. These adaptations included adding a particular context, manner of interaction, or topic, when necessary (see Table 3). For example, "Everywhere I go, I am looking for new things or experiences." (Kashdan et al., 2004) was changed to "Everywhere I go, I am looking for new things about animals" to gain insight into students' topic interests. Some scales also needed to be adapted to be appropriate for late elementary rather than normed for college or high school (e.g., "I actively seek as much information as I can ..." was changed to "I am often trying to find out more about ...").

Context. Context was divided into formal science experiences (relating to school, classes, teachers), informal science experiences (at home, at a museum, with friends, at a camp), and a neutral category that did not specify a context (see Table 4 for categories within each dimension). Some items needed to be adapted to ask specifically about science (both formal and informal) rather than their original focus on other topics (e.g., "I think that what I am learning in this class is useful for me to know." (Pintrich & de Groot, 1990)

TABLE 4
Dimensions With Subscales and Number of Items

Context	Manner of Interaction	Topic	Motivation
Formal (27)	Consuming new knowledge (30)	Astronomy (stars) (7)	Appreciation (12)
Informal (27)	Analyzing (29)	Biology (plants) (7)	Curiosity (8)
Neutral (35)	Action (30)	Earth science (hurricanes) (7)	Identity (14)
		Engineering (robots) (7)	Interest (11)
		Physical science (gravity) (7)	Expectancy value (10)
		General science (38)	Persistence (18)
		Favorite (16)	Responsibility (16)
Total: 89	Total: 89	Total: 89	Total: 89

Note. Number in parentheses represents number of items in each dimension subscale. There are a total of 89 items in the survey, excluding the topic checklist. Each item fell into one category of the four dimensions simultaneously.

was changed to "What I know about science will be useful outside of school"); some scale items needed to be adapted to have a balance of locations for scales entirely focused on school or out of school (e.g., "I have a good feeling toward science" (Girod, 2009) was changed to "I have a good feeling when I think about science in school").

Manner of Interaction. Manner-of-interaction questions were also divided into three categories: consuming new knowledge, referring to the studying, reading, and going online for the learning of new science information; analyzing, which described a child's thinking about information they had previously learned; and action, specifying a hands-on activity.

Topic. The topic dimension included the same 35 items from the five broad science categories presented in the topic checklist, described above. These topics were embedded in items throughout the survey while maintaining an even distribution across our other dimensions of interest (e.g., context, manner of interaction). The remaining items were split into two categories: items asking about "science" at the general level ($n = 38$) to serve as a comparison for the topic items or items that were completed with the child's selection of their favorite subtopic from the topic checklist ($n = 16$). The "favorite" topic each child selected from the topic checklist was automatically inserted into specific survey items across the various subscales to ask about children's motivation and behaviors regarding their self-identified favorite science subtopic. For example, the item "When I am confused about——, I try and figure out an answer" was completed with each child's individualized response to their favorite item from the checklist.

Motivational Constructs. General personality/disposition scale items were modified to make them more specific tests for effects of context, manner of interaction, and topic (see Table 3). Appreciation and identity items were also modified for context and manner of interaction, but were kept at the science general level (e.g., "I am a person who thinks like a scientist") due to the manner in which appreciation and identity have been typically conceptualized. For example, asking about children's value at the science level (e.g., "Science is important to my daily life") made more conceptual sense than asking at the topic level with our topic instances (e.g., "Fossils are important to my daily life"). Similarly, identity is also typically a science general subscale, examining the explicit knowledge of one's self related to science, and the items were more sensible when placed at the science general level (e.g., "I am a 'science' type person" vs. "I am a 'planet' type person"). Discipline-level terms are sensible (e.g., biologist or physicist), but we did not expect most children to be familiar with these terms.

Data Analysis Considerations Related to Our Measure

Previous research has shown that some of these scales tend to be correlated with each other, but measuring all these scales simultaneously is not common given that they originate from different motivational theories. We combine these measures to establish patterns across theoretical framings of motivation.

Rather than testing differences in means across motivational scales, the trends of children's positive or negative responses in response to context, topic, and manner of interaction were examined across motivational scales to understand children's preferences toward science. This decision was made because while it is mathematically possible to test potential mean differences between motivational scales in our survey (e.g., is interest higher than identity in this population?), the interpretation is difficult for a number of reasons. First, there is not necessarily a one-dimensional factor underlying each of the scales, as they contain meaningfully different dimensions that may be influencing answers. Second, two of the scales contained only general science items (appreciation and identity). Differences in means between motivational scales that varied across "general science" items and topic-based items may be driven by topic effects rather than true differences in levels across motivational constructs per se. Third, because the scale was not a full factorial across all dimensions, differences between motivational constructs could also vary on the popularity of the exemplars of each dimension (i.e., some science topics, such as "animals" were responded to more highly positive across topic list, favorite topic, and overall item mean).

Furthermore, because our survey has four orthogonal dimensions, traditional factor analysis at the raw item level cannot be used to extract (or confirm) any one dimension (e.g., motivation constructs). In addition, since we did not create items to represent the full factorial ($3 \times 3 \times 7 \times 7$) combinations of dimensions, it is also not possible to do factor analysis at intermediate aggregate levels because partial aggregates would be unbalanced (i.e., multiple dimensions were embedded within the same item, making it unclear which dimension was driving the factors). However, we do provide reliability indices for our measures of each dimension, which generally show high cohesiveness among items.

Procedure

All children completed the full 89-item survey in science class or during a class museum visit in a single sitting. The motivational scales (e.g., appreciation, persistence) were interspersed throughout the assessment to vary presentation of topic, manner of interaction, and context; but all children experienced the same order of questions. Children were asked to select the response that best represented how they felt about each item. Items were scored from –2 to 2 based on the following 5-point Likert scale: "YES!," "yes," "maybe," "no," NO!" and converted to *Z*-scores for analyses. The –2 to 2 scoring was used to make the numeric scale score meaningfully representative of the scale labeling. In other words, positive scale labels were coded with positive numbers (YES!, yes = 2, 1, respectively), and negative responses coded negative numbers (NO!, no = –2, –1, respectively; maybe = 0). All reversed items (e.g., "No matter how hard I try, I am confused by science") were reverse coded prior to analyses.

TABLE 5
Alphas, Means, and Intercorrelations of Motivational Subscales

Scale	*a*	*M*	*SD*	Curiosity	Identity	Interest	E-V	Persistence	Responsibility
Appreciation	.88	0.69	0.68	.70	.79	.75	.72	.76	.80
Curiosity	.74	0.56	0.71		.73	.77	.75	.78	.80
Identity	.91	0.39	0.78			.81	.77	.83	.84
Interest	.80	0.44	0.44				.80	.84	.84
Expectancy value	.77	0.56	0.56					.80	.81
Persistence	.88	0.47	0.47						.87
Responsibility	.83	0.36	0.36						

Note. $N = 252$. Mean scores range from –2 to 2. All correlations were significant at the $p < .001$ level. Column "E-V" represents the expectancy value.

RESULTS

Ruling Out Confounding Factors Between State and Testing Location

Comparative analyses on aggregate ratings were conducted to rule out potentially confounding effects of region (e.g., demographic differences associated with Pennsylvania vs. California) or testing context (within a museum vs. school) with the dimensions of focus here (i.e., formal/informal science preferences). No overall differences by region or testing context were found across any of the dimensions (e.g., children tested in the museum did not have higher informal question ratings than children tested in the school), and thus the testing location is not included within the analyses presented below.

Does Children's Motivation Shift Along the Dimensions of Context, Manner of Interaction, and Topic: Exploring Children's Sensitivity to Dimensions and Subscales

There are several important aspects to explore to effectively tease apart children's sensitivity and preferences to these various dimensions. Since the scale was a fractional factorial and not a full factorial through each of the dimensions (e.g., not every topic was placed in every context and in every manner of interaction), we examined these dimensions through correlation, main differences, and multidimensional scaling.

Motivational Subscales. Cronbach alphas for each of the seven scales ranged between $r = .74$ and .91, indicating that most of the scales could be adequately measured even with additional variance due to orthogonal manipulation of the other dimensions (as described below).

All the scales were highly correlated with one another ($r = .70$–.87, all significant at the $p < .001$; see Table 5). Paired-sample *t*-tests on these correlation coefficients revealed that responsibility and persistence subscales were most highly correlated with other motivational measures, curiosity was least correlated with other motivational measures, and the other measures correlating at intermediate levels.

Table 5 also displays the means for each subscale dimension, but as stated previously, formal testing between these means are neither inherently meaningful nor the goal of the current study. However, it is clear that children generally gave a modestly positive average response across all constructs, regardless of subscale, allowing for plenty of distance from scale end points to explore effects of context, topic, and manner of interaction.

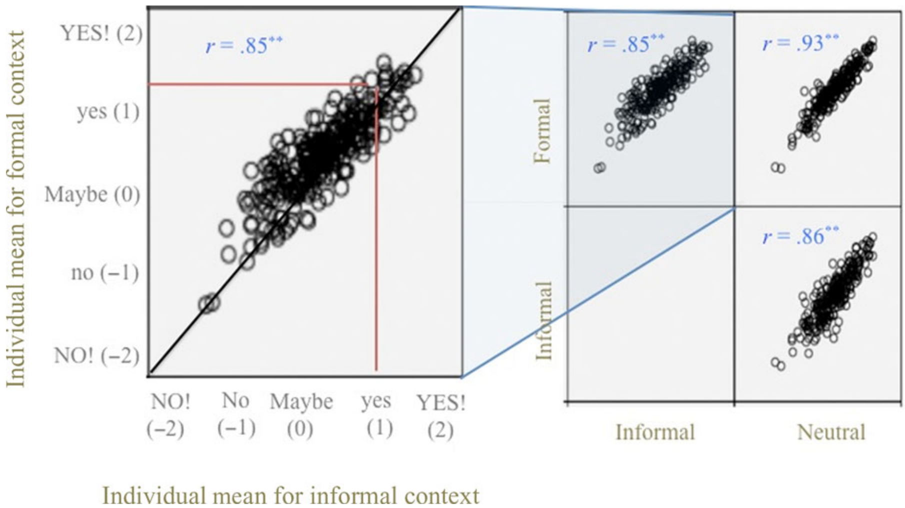

Figure 1. Correlations among context subscales.

Context. Items measuring context dimension (formal, informal, neutral) were used to generate a Crobach's alpha for each setting, respectively. In other words, the 27 items with formal context embedded in them were used to generate the reliability of formal items regardless of what motivational construct was being tested. With a large number of items per context, it was possible to produce high reliability in estimates of means for each context: The Cronbach alphas for each setting (formal, informal, and neutral) were very high (r = .91–.93). In contrast to the received wisdom that children should vary greatly in their responses to formal and informal science learning opportunities based on their highly individualized history of experiences in each context (e.g., a bad school experience or a lack of an informal learning experience), children's mean responses were remarkably consistent across context (r = .85–.93, all correlations significant at the $p < .001$ level). Figure 1 displays each of these correlations in more detail. Each dot represents the mean for a child plotted between two context subscales (e.g., mean responses for all informal context questions against the mean responses for all formal context questions). We can see that there are no large outlying cases (upper left corner or bottom right corner) in which a child responded consistently positively for one context and consistently negatively for another. Instead, we see that children tend to answer similarly on each (i.e., if they were strongly positive in their formal context responses; they were strongly positive in their informal context responses).

Since each context is roughly balanced across motivational constructs and the other dimensions of interest, comparisons across contexts are sensible. Examining the overall mean differences between subscales show that children tended to give more positive ratings to items related to the formal context or neutrally phrased items than to items related to the informal context ($t(251) = 11.72$, $p < .001$; $t(251) = 13.35$, $p < .001$, respectively; see Figure 2). This effect was moderate in size (Cohen's $d = 0.42$ between formal and informal and d = 0.44 between neutral and informal). Children's preference for formal context items is somewhat surprising given a common assumption discussed in the literature about the importance of informal science experiences for building a sense of fun versus formal science for building content knowledge (National Research Council, 2009). Conclusions drawn from such a finding should be interpreted carefully. For example, the differences may reflect aspiration rather than reality (e.g., I want to be interested in science experiences

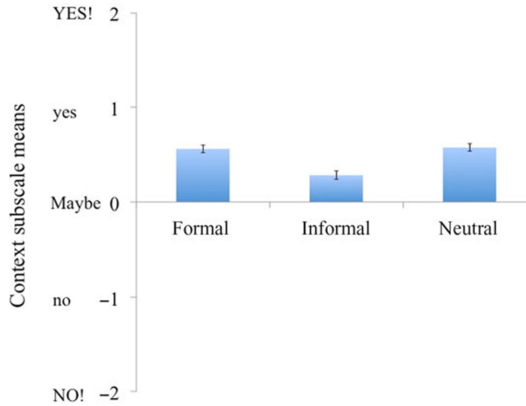

Figure 2. Average across context subscales.

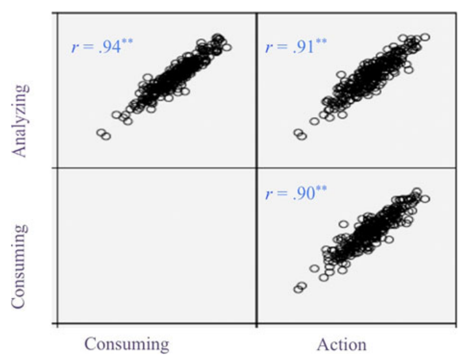

Figure 3. Correlations among manner-of-interaction subscales.

in school rather than I typically am interested in science experiences at school). Also, many children might have had relatively few prior informal science experiences, and the lack of experience might have driven down their agreement about motivational statements with respect to the informal context.

Manner of Interaction. As with the different contexts subscales, each manner-of-interaction subscale (consuming new knowledge, analyzing, action) had very high construct reliabilities ($r = .92$–$.93$). Correlations between each child's means for each manner of interaction were quite high ($r = .90$–$.94$, all correlations significant at the $p < .001$ level), showing that degree of preference for science is highly consistent across the manners of interaction (e.g., relative positivity toward analyzing items was very similar to relative positivity toward action). Figure 3 shows that no children had a very different relative response across the manners of interaction with science.

However, mean differences were observed across the manner-of-interaction items. A comparison of the subscale means showed that children responded less positively to items related to hands-on/action science activities, although this effect was small (analyzing and action: $t(251) = 6.77$, $p < .001$; consuming new knowledge and action $t(251) = 7.15$, $p < .001$; both differences had an effect size of $d = 0.19$; see Figure 4). There was no difference in responses between analyzing and consuming new knowledge ($t(251) = 0.53$, $p =$ n.s.). It is important to restate that each subscale was balanced across the other dimensions so that the difference found for action items is not due to confounds with

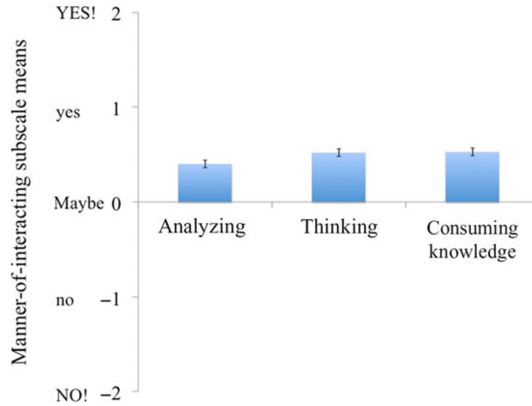

Figure 4. Correlations among manner-of-interacting categories.

TABLE 6
Intercorrelations of Topics

Topic Area	Item (*N*)	Biology	Earth Science	Engineering	Favorite	General Science	Physical Science
Astronomy	7	.53	.74	.60	.59	.72	.68
Biology	7		.65	.29	.51	.63	.53
Earth science	7			.55	.58	.76	.69
Engineering	7				.45	.58	.63
Favorite	16					.67	.61
General science	38						.79
Physical science	7						

Note. $N = 252$. All correlations were significant at the $p < .001$ level.

informal context items. The small preference against action items occurred for questions about the informal and for questions about the formal contexts.

Topic. In contrast to the small variation in preferences associated with the previous dimensions, children showed considerable differentiation by topic. There were fewer items per topic than per context or manner of interaction and the alphas for topics were somewhat lower, ranging from $r = .61$ to .80. In addition, there were significant, but smaller and more varied correlations between broad topic areas, ranging from $r = .29$ to .79 (see Table 6). Figure 5a presents the largest divergence by topic (biology against engineering). In this figure, we see many children's means plotted in the upper left and lower right quadrant, instances of a child responding positively toward one topic (e.g., biology), but negatively toward another (e.g., engineering). Thus, children did respond to topics with considerably more differentiation than they did to contexts and manner of interaction. Figure 5b also shows that children differentiated between topics (e.g., biology) and items asking about science at the general level.

Comparisons of the means across topic subscales shows us that children varied in their overall preferences across topics, with their favorite topic receiving the highest positive response. Biology, physical science, and engineering subscales received similar responses from children in that there were no significant mean differences between them. Astronomy and earth science were not different from each other, but were each, respectively, different

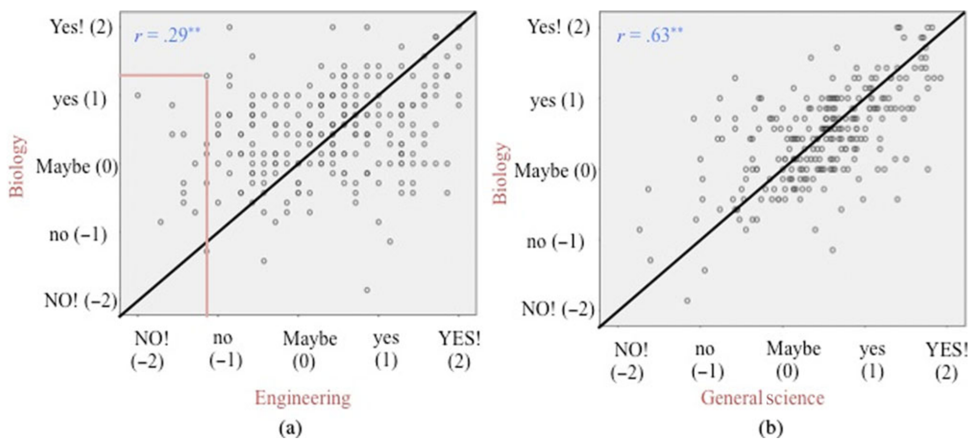

Figure 5. (a) Example of divergence between biology and engineering and (b) correlation between biology and general science topics.

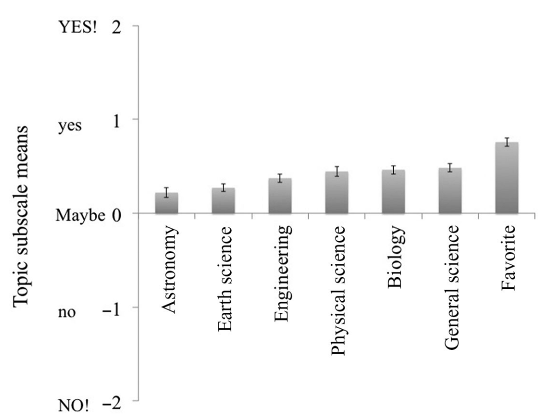

Figure 6. Averages across topic subscales.

from biology, physical science, and engineering (see Figure 6). That is, while engineering and biology are the most differentiated by individuals, the overall means are similar, suggesting that some kids strongly prefer engineering over biology whereas other kids strongly prefer biology over engineering.

Multidimensional scaling (MDS) was conducted and a three-dimensional scale provided a good to fair fit (Stress I = 0.09) and echoed the pattern above, with biology, physical science, and engineering clustering more closely together than astronomy and earth science (see Figure 7a).

Children's mean responses to the 32 items containing general science were similar to biology and physical science means, but varied from the engineering, astronomy, and earth science means. When placed into the MDS analysis, these general science items were more related to biology, physical science, and earth science more than astronomy and engineering, although the inclusion of general science did raise the Stress I slightly (Stress I = 0.12). Most critically, while there were generally moderately strong correlations between the general science means and the means on the other questions, assessments via questions about "science" are not synonymous with questions using more specific topics, like various biology topics (see Figure 7b).

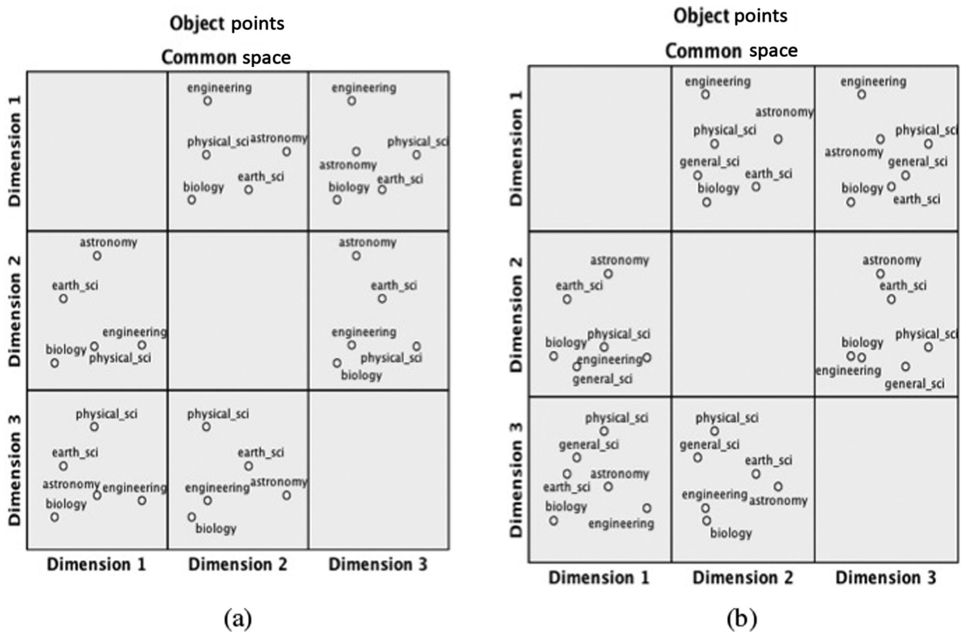

Figure 7. (a) MDS results with general science omitted and (b) MDS results with general science included.

Topic-Specific Preferences. Overall topic preferences can also be explored via the topic checklist data. Children chose an average of 10.1 items from the checklist ($SD = 7.8$), with a range of 1–35. Over 60% of children selected 10 items or less and roughly 80% selected 15 items or less, giving the distribution a rather positive skew. When examining which science domains (e.g., biology) were most popular, a similar pattern to the survey items was found, with biology items being most popular ($M = 0.32$, $SD = 0.26$), followed by physical science ($M = 0.32$, $SD = 0.27$), and engineering ($M = 0.29$, $SD = 0.30$). Earth science and astronomy again were slightly lower than other subscales ($M = 0.26$, $SD = 0.28$; $M = 0.26$, $SD = 0.29$), respectively. Within science domains, the most popular items did not represent a single domain, but were spread out across the different categories. Biology, earth science, physical science, and engineering were all represented in the five most popular items (animals, sea life, crystals, robots, oceans).

Children's favorite item selection also followed a similar subscale ranking. Thirty-eight percent of children selected a biology topic as their favorite followed by, physical science and engineering (each with 22%), astronomy (10%), and earth science (8%). The top 10 selected items were all chosen at least 10 times and resulted in the following most commonly favorite items: animals, sea life, optical illusions, robots, computers, DNA, crystals, body systems, technology, and chemicals. We see less astronomy and earth science preference, as was found throughout the Likert ratings.

DISCUSSION

The data presented here help increase our understanding of environmental features that shape children's motivation for science learning. We examined this motivation at a crucial time of development (the beginning of adolescence) when children's choice and autonomy generally increase (Wray-Lake, Crouter, & McHale, 2010). Gaining insight into the dimensions that ignite, support, and maintain children's science motivation during this time aids us in discovering ways to encourage such motivation. Most saliently, we find that specific science content has the largest effects. In addition, when means by context and manner of interaction did vary, they did so in surprising ways.

Context and Manner-of-Interaction Effects

Children's lower preference for informal activities and more active science opportunities is somewhat surprising considering many of these activities offer a higher degree of autonomy and freedom from graded assessments, and such freedom has been shown to increase intrinsic motivation (Black & Deci, 2000). However, the fact that an activity is "informal" or "hands on" may not be enough to motivate children effectively, as a number of prior studies have found (Areepattamannil, 2012; Klahr, Triona, & Williams, 2007). Since topic interest is intricately related to children's motivation, developing content-related activities that cross different manners of interaction may be beneficial. However, it seems that solely altering the context or the way a child interacts with material may not be enough to ignite their engagement. It could be that topic is such a large driver of interest and motivation that these other dimensions matter very little; for example, it could be that even a very didactic presentation on a highly interesting topic is more engaging to a child than a very rich task about a topic that is very uninteresting to that child.

Our scope of formal and informal contexts was broad to capture a wide range of common childhood science activities. There may be more fine-grained differences within these categories that may produce greater differentiation by context or manner of interaction. For example, formally testing whether social involvement with peers, learning at home versus at a museum, or children's participation in past science experiences (e.g., many vs. few science experiences; many hands-on experiences vs. few hands-on experiences) moderates preferences could be done with a survey instrument focused on these dimensional differences and the potential interactions among them. Yet, we should be careful to consider that these dimensions are somewhat blurry in real-world situations and children will engage in a wide range of science activities that vary dynamically and not always consistently (Dierking et al., 2003). We would lack full understanding of a child's science experience if we were to mistake these clear distinctions as the concrete ways in which children explicitly break up their perceptions of science. However, as we have seen in our data, children do hold different overall preferences toward contexts that can be useful to consider in design and implementation of science activities and challenge the assumption that informal activities are always more motivating.

Discipline and Topic Effects

Discipline Preferences. Children showed greatest sensitivity and preference to variations in science disciplines. Biology and physical science topics were most popular, and earth science and astronomy were least popular, as has been found in previous research with younger ages (Mantzicopoulos & Patrick, 2010). Our analyses show that some of these domains appear to be more closely associated than others, such as earth science with astronomy; however, how the children's motivation toward particular domains can be explored further in our data.

Topic Preferences. Our topic-based approach allowed us to examine popular topics within and across these larger domains. First, we find that children have specific interests at the individual topic level (e.g., robots) far beyond domain-level preferences (e.g., engineering). In other words, some topics were overall much more popular than others (e.g., animals, sea life, crystals, robots), irrespective of their larger domain category. For example, earth science was one of the least favored domains, yet "oceans" ranked as one of the most interesting topics for children. Second, even when asked at the individual topic level (i.e., the checklist), children reported a range of interest in various science topics, as is evidenced by their average selection of about 10 topics from the general checklist. By study design, the selection of 10 topics exceeds what may be found in one domain, showing many children held interests beyond one popular domain. How these topics and domains interrelate gives us insight into how children categorize and group their science interests at this age.

Alternative Topic Clustering. Our current grouping of science topics was based on common boundaries of what composes these larger science domains. As such, we placed topics such as "plants" in biology and "telescopes" in astronomy. However, at this early age, children's conceptualization of these domains is unlikely to be so well distinguished. Children are still familiarizing themselves with different sciences and science content as they progress in their learning and experience. Understanding the boundaries between domains may not be obvious or even clearly stated. Science experiences and curricula may not have clearly addressed "physics" as a distinct field, for example. We examined children's responses in a top-down approach, looking to see whether canonical categorizations of science categories emerged. If children were aware of their overall biology interest, they may be more likely to pick topics relating to this overall field. However, children likely considered each topic rather independently, given their age and experience with science material, especially given the random presentation of topics over the 89 items. While our data show Cronbach alphas for each science domain were moderately strong, children's interests may still pull from a variety of domains.

In fact, children's preferences may transcend the typical boundaries of science domains and even form different clusters. Perhaps, in their science experiences, some concepts are more associated than others. For example, a child may first learn about "gravity" in the context of a lesson on the planets. Although "gravity" is grouped as a physical science concept, perhaps it more closely aligns with "planets," "stars," and "the Moon" (*astronomy*) in the minds of children. Previous work has raised questions about the perception of science categories, positing that teenagers may express interest in topics for reasons other than their domain content (Jenkins & Pell, 2006). ByBee and McCrae (2011) found that adolescent males tended to express higher levels of interest in topics that have a technological component, even if the topic is not directly related to technology (e.g., pollution). This example shows one way in which science domains are not straightforward in children's minds, but can vary due to another dimension, such as procedural methods. Further work across different children's development would help us understand the composition of these dimensions at various ages, and how this structure may change through a child's experience with different kinds of science.

ByBee and McCrae's (2011) finding also raises an additional consideration: There are inherent procedural differences among science domains. While we attempted to constrain these differences as much as possible in our assessment, there are necessary variations in these disciplines beyond content that involve the way research is conducted, the distance from the object being studied, the speed of return of research, how this research is communicated, and how socially interactive the research field may be. For example, robots, chemical experiments, and electrical circuits all have a very physical and mechanical element. The result of such endeavors often yields a rather physical, occasionally immediate payoff (e.g., circuit works and a light comes on). Examining the habitat of an endangered animal requires a different set of tools and engagement resulting in outcomes that may seem differentially rewarding to various children (e.g., acidity values in water are lowered). Certainly there is overlap in the scientific thinking and inquiry between both, yet they seem qualitatively different in some of the processes. Perhaps some of the differences in science preference could be explained by the opportunities different sciences allow their scientists. Children at this age may not be fully aware of the details of such differences, but may be drawn to different science activities due to such variables. More exploratory studies focusing on children's perceptions of the relationships between sciences and their subtopics may provide further insight into children's science preferences.

Implications

Measurement. One goal of this research is to raise awareness of the value of measuring children's science perceptions at the topic level, in addition to research asking about science at a general level. While research has become increasingly domain specific (e.g., Eccles & Wigfield, 2002), domain specificity still allows for large degrees of unaccounted variation. A topic-based approach allows researchers to explore breadth of science interest (how many topics interest children?), the salient topics that are popular at various developmental ages (which topics interest children?), how these dimensions affect achievement and outcome variables, and how design implementation can improve children's interest and engagement. In addition, topic-level items allow researchers to probe children's motivations toward science more implicitly. Children vary in their preferences for science activities that they may not personally identify as science. Insightful qualitative work has shown this to be the case (Bell, Brickner, Lee, Reeve, & Zimmerman, 2006); larger scale assessments may miss cases of deep science interest if we skim the surface of children's preferences based on their interpretation of the word "science" itself.

Whether a scale examines motivation at the topic or at the general science level largely relies on the research question being asked. Our data show that responses at the general science level correlate with the aggregate using all the topic items at $r = .84$, demonstrating relatively good relationship between a child's overall awareness of their motivations toward "science" and their topic-based interests. However, there remains a trade-off between these two approaches that should be thoughtfully considered when selecting a method. For all the benefits of a topic-based approach, topic-specific surveys require more items to generate an approximation of children's motivation toward a domain within a specific theory. This raises questions about methodological constraints, such as length of test and the ordering presentation of items. It may also not answer questions about children's overall perception of science and their relationship to it; as much of the early learning environment comes with the label "science" (e.g., the Carnegie Science Center, sixth-grade science class, Sid the science kid), relationship with that label is important.

Alternatively, science general surveys are useful for answering a variety of questions and are an appropriate method for examining children's motivation in science, but their shortcomings should also be recognized and their application and generalizations should be carefully considered before administration. Asking science general questions forces ambiguity on the respondent when they like some aspects of science but not others. How individuals choose to handle that (some responding as if the question is asking about their favorite topic only vs. some asking about all topics) will inevitably be varied and thus lead to measurement error. Other differences occurring in subgroups, such as gender, vary greatly across science topics (Jones, Howe, & Rua, 2000; Tyson et al., 2007) and may be obscured at the science general level. Depending on a researcher's line of questioning, these may or not be highly influential to the question at hand, and researchers should decide what is most appropriate for their purposes, acknowledging these trade-offs.

Interventions. In alignment with the idea that science learning is cumulative throughout a child's life (Dierking et al., 2003), it is beneficial to help children connect their learning experiences across various contexts. These connections are not always spontaneously made or obvious to children (Stake & Mares, 2005). Helping them become more aware of ways to find, engage, and connect their curiosity and interest across different settings may help deepen their knowledge and persistence in science learning (Hofstein & Rosenfeld, 1996; Stake & Mares, 2005). There are many ways this could be enacted, and intervention and design-based research could help direct concrete future steps. Our purpose here was to examine children's sensitivity in motivation toward different science dimensions that could help inform this work.

With forthcoming work demonstrating a connection among items used in our survey and student engagement and choices in science learning (Sha et al., 2013), research exploring children's preferences toward the different dimensions of science may inform future development of early science activities (e.g., topical summer camp program), showing us where to focus to most effectively meet student interest and value toward science content and processes. It should be noted, however, that our work here focuses on how various situational aspects shape student motivation, but not which features shape learning outcomes. Consideration of student motivation, as well as learning outcomes, should be considered when developing science activities.

Research has shown that the importance of generating situation interest, regardless of topic, can help student engagement and learning (Hidi & Harackiewicz, 2000; Jarrett, 1999). As such, educators should feel encouraged to help scaffold students' potential interest in a topic they have yet to find motivating. However, in free-choice learning situations (camps, after school programs, elective courses), situational interest cannot be triggered if children choose not to come at all, and understanding children's topical interest can influence choices that will maximally recruit additional learners. For example, teaching and out-of-school science experiences could focus on specific topics that broadly appeal to children overall, or specifically at different developmental ages (Trumper, 2006a, 2006b). While children's differences in topic interest may appear to make topic selection more difficult for educators, clear trends emerge that can help direct content choices and development. Our data suggest that some combination of biology and engineering content may easily capture the interest of most children, specifically topics around animals, robots, and computers. Other, less inherently interesting topics would need to be introduced in a way that engages students to support the development of interest in those topics, for example, through consideration of important applications.

Considerations for Motivational Variables. Rarely are many motivational theories measured simultaneously and therefore not a great deal is known about their relationships among constructs across theories. The high correlation between these variables could mean a number of things. Perhaps some of these constructs co-occur within an individual (e.g., expectancy value and identity) and are part of an underlying latent factor that explains the relationship. Alternatively, some of the correlation among the variables may be due to lower metacognitive awareness in children at this age (Veenman, Van Hout-Wolters, & Afflerbach, 2006; Whitebread et al., 2010). Specific comparisons among motivational theories were not the focus of our current study, yet the considerably high correlation among them is worth noting. Do we know how these theories interact or relate to each other?

The high intercorrelations suggest that correlational findings in favor of one theory may also have produced correlational findings in favor of other theories as well. However, as we may have partially disrupted the typical relationships due to the embedding of other dimensions in these items, we cannot definitively say we are measuring each motivational construct distinctly, but rather are sampling a broad range of motivations. Future research should consider this positive manifold among these different theory-inspired motivational measures in more depth to clarify their coexistence within an individual (Pintrich, 2003).

APPENDIX: SURVEY ITEMS ORGANIZED BY CONSTRUCT

Appreciation
Thinking about science is important to my life.
All people should learn lots of science in school.
It's important to be good at doing science in order to get a good job.
Understanding science helps people make sense of today's world.
Scientists cause more good than bad in the world.
Scientists make our lives better.
Scientific theories change all the time.
Understanding science is helpful for solving problems.
Science can solve nearly all problems.
Most people should visit a museum to think about science.
What I know about science will be useful outside of school.
My science class will make me a better thinker.
Curiosity
Outside of science class, I often wonder about global warming.
I am curious to learn how the body works.
I like to mess around with new technology.
I enjoy exploring new activities about____in school.[a]
It is cool to learn new things about gravity in school.
Everywhere I go, I am looking for new activities about____.
Wherever I go, I am interested in discovering new facts about____.
I get excited about discussing space in school.
Interest
I would like to learn more about hurricanes in school.
I often watch TV shows and/or read about space travel.
I would like to look closely at fossils in a museum.
In school, thinking about topics like molecules makes me yawn.
Sometimes thinking about____is boring to me.
I have a good feeling when I do science activities in school.
I often think about science topics at home.
Thinking about DNA is interesting to me.
I feel good when I learn about optical illusions in school.
I use the internet to find information about____.
I would like to do activities related to robots at home.
Expectancy Value
I like to learn new facts about black holes by watching TV shows.
Learning about sea life is important to me.

When I'm confused about____, I try to figure out an answer.
If I started a class project on climate change, I think I could do a really good job.
I want to learn everything about____, even if it's complicated.
If I attend a science camp, I would expect that my project would be the best.
I would go to a summer camp to build a solar energy project.
It's important to me to be an expert using computers in school.
I am afraid I will do a bad job learning about____in school.
I know I can learn a lot about electricity.
Persistence
I would think about magnets in school over and over until I understood them.
I would use my free time at school to put extra effort into a volcano activity.
I am OK with thinking about____even if I don't understand it at first.
I'm ok with trying again if a model rocket activity doesn't work at first.
If I watched a TV show about the moon, I would keep thinking about it even after the show was over.
I would build a science project at camp, even if none of my friends are interested in science.
I would like to spend lots of time looking at stars through a telescope in my back yard.
In school, I would keep thinking about how crystals form, even if it was hard.
I would continue watching a TV show about science even if it gets confusing.
When I am thinking about a science problem, I keep going until I understand.
I will keep doing a class activity about the ocean, even if I have to keep at it for a long time.
I need people to cheer me on to keep working on activities about plants.
If I have started an activity about bugs and butterflies at home and it seems like it is going to take a long time, I will stop doing it.
I would keep reading a book about science even if it was hard or long.
I would never choose to do an activity about the sun that takes more than a few hours.
I would keep studying science, even if my teacher tells me I'm not good at it.
I would study science even if I have a bad teacher.
I would spend my free time learning about____even if my parents do not think it is important.
Responsibility
I can learn about ecosystems in school if I try hard enough.
If I'm having trouble thinking about science in school, working harder can make a big difference.
When it comes to learning about____, having a good instructor is more important than how hard you try.
I would take out a library book about science.
I would ask my parents to take me to the zoo to learn about animals.
I know who to ask if I want to know more about planets.
I often make time to think about____outside of school.
I'm able to get information on mixing chemicals from the web on my own.
I would ask my parents to let me attend a camp where we build and test structures.
I get science projects done without my teacher or parents telling me to.
To think like a scientist, you have to have a special talent.
With enough time, I could learn science in school.
I enjoy discussing what I know about____with other people.
I want to help people think scientifically.
I would try taking apart an old computer at home by myself.
I always look forward to talking to my friends about earthquakes.

Identity
I think like a science type person.
Other people think I'm good at doing science.
I am the type of person who could work as a scientist someday.
Learning about____would be very easy for me in school.
No matter how hard I try, I am confused by science. (R)
I often think, "I will fail" when a science activity seems hard. (R)
I am bad at doing science activities. (R)
When I think about the word "science," I have a bad feeling. (R)
I feel uncomfortable when other kids talk to me about science. (R)
I have a good feeling when I think about science in school.
It is important for me to learn about____over summer vacation.
I am a person who thinks like a scientist.
I often investigate____so that I can understand how things work.
I often investigate science in my free time so that I can learn more about it.

[a]A blank space ("____") indicates that a child's self-selected favorite topic item was inserted automatically into the item via the survey system.

REFERENCES

Adams, R., Evangelou, D., English, L., Dias de Figueiredo, A., Mousoulides, N., Pawley, A. L., et al. (2011). Multiple perspectives on engaging future engineers. Journal of Engineering Education, 100(1), 48–88.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., WIllis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. American Educational Research Journal, 49(5), 881–908.

Areepattamannil, S. (2012). Effects of inquiry-based science instruction on science achievement and interest in science: Evidence from Qatar. Journal of Educational Research, 105(2), 134–146.

Bell, P., Brickner, L. A., Lee, T. R., Reeve, S., & Zimmerman, H. T. (2006). Understanding the cultural foundations of children's biological knowledge: Insights from everyday cognition research. Presented at Proceedings of the Seventh International Conference of the Learning Sciences, Bloomington, IN.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. Science Education, 84, 740–756.

Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. Science Education, 95(6), 1049–1065.

ByBee, R., & McCrae, B. (2011). Scientific literacy and student attitudes: Perspectives from PISA 2006 science. International Journal of Science Education, 33(1), 7–26.

Crowley, K., & Jacobs, M. (2002). Building islands of expertise in everyday family activity. In K. Crowley & K. Knutson (Eds.), Learning conversations in museums (pp. 333–356). Mahwah, NJ: Erlbaum.

Dawson, C. J. (2000). Upper primary boys' and girls' interests in science: Have they changed since 1980? International Journal of Science Education, 22(6), 557–570.

Dawson, C. J., & Bennett, N. (1981). What do they say they want? Year 7 students' preferences in science. Research in Science Education, 11, 193–201.

Dierking, L. D., & Falk, J. H. (2003). Optimizing out-of-school time: The role of free-choice learning. New Directions for Youth Development, 97, 75–88.

Dierking, L. D., Falk, J. H., Rennie, L., Anderson, D., & Ellenbogen, K. (2003). Policy statement of the "informal science education" ad hoc committee. Journal of Research in Science Teaching, 40(2), 108–111.

Dorph, R., Schunn, C. D., Crowley, K., & Shields, P. (2011). An agenda for investigating and investing in effective science learning opportunities for young learners: The science learning activation lab. Paper presented at the American Educational Research Association Annual Meeting, New Orleans, LA.

Duckworth, A. L., & Seligman, M. E. P. (2006). Self-discipline gives girls the edge: Gender in self-discipline, grades, and achievement test scores. Journal of Educational Psychology, 98(1), 198–208.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. Annual Review of Psychology, 53, 109–132.

Engelhard, G., & Monsaas, J. A. (1988). Grade level, gender, and school-related curiosity in urban elementary schools. Journal of Educational Research, 82(1), 22–26.
Eshach, H., & Fried, M. N. (2005). Should science be taught in early childhood? Journal of Science Education and Technology, 14(3), 315–336.
Fraser, B. (1981). TORSA: Test of science related attitudes. Hawthorne, Victoria: Australian Council for Education Research.
Fulp, S. L. (2002). 2000 National survey of science and mathematics education: Status of electuary school science teaching. Retrieved June 27, 2012, from http://2000survey.horizon-research.com/reports/elem_science/elem_science.pdf.
Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. Journal of Research in Science Teaching, 25(8), 689–703.
Girod, M. (2009). Comparing the added value of blended science and literacy curricula to inquiry-based science curricula in two 2nd-grade classrooms. Journal of Elementary Science Education, 21(3), 13–32.
Hidi, S., & Harackiewicz, J. M. (2000). Motivating the academically unmotivated: A critical issue for 21st century. Review of Educational Research, 70(2), 151–179.
Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. Educational Psychologist, 41(2), 111–127.
Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. Science Education, 88(1), 28–54.
Hofstein, A., & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. Studies in Science Education, 28, 87–112.
Jacobs, J. E., Finken, L. L., Griffen, N. L., & Wrightm, J. D. (1998). The career plans of science-talented rural adolescent girls. American Educational Research Journal, 35(4), 681–704.
Jarrett, O. S. (1999). Science interest and confidence among preservice elementary teachers. Journal of Elementary Science Education, 11(1), 47–57.
Jenkins, E. W., & Pell, R. G. (2006). The relevance of science education project (ROSE) in England: A summary of findings. Leeds, England: Centre for Studies in Science and Mathematics Education, University of Leeds.
Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. Science Education, 84(2), 180–192.
Kashdan, T. B., Rose, P., & Fincham, F. D. (2004). Curiosity and exploration: Facilitating positive subjective experiences and personal growth opportunities. Journal of Personality Assessment, 82(3), 291–305.
Klahr, D., Triona, L. M., & Williams, C. (2007). Hands on what? The relative effectiveness of physical versus virtual materials in an engineering design project by middle school children. Journal of Research in Science Teaching, 44(1), 183–203.
Lent, R. W., Brown, S. D., & Larkin, K. C. (1984). Relation of self-efficacy expectations to academic achievement and persistence. Journal of Counseling Psychology, 31(3), 356–362.
Litman, J. A., & Spielberger, C. D. (2003). Measuring epistemic curiosity and its diversive and specific components. Journal of Personality Assessment, 80(1), 75–86.
Lufi, D., & Cohen, A. (1987). A scale for measuring persistence in children. Journal of Personality Assessment, 51(2), 178–185.
Mantzicopoulos, P., & Patrick, H. (2010). "The seesaw is a machine that goes up and down": Young children's narrative responses to science-related informational text. Early Education & Development, 21(3), 412–444.
Mantzicopoulos, P., Patrick, H., & Samarapungavan, A. (2008). Young children's motivational beliefs about learning science. Early Childhood Research Quarterly, 23(3), 378–394.
Mantzicopoulos, P., Samarapungavan, A., & Patrick, H. (2009). "We learn how to predict and be a scientist": Early science experiences and kindergarten children's social meanings about science. Cognition and Instruction, 27(4), 312–369.
Mercier, H., & Sperber, D. (2011). Why do humans reason? Arguments for an argumentative theory. Behavioral and Brain Sciences, 34(2), 57–111.
Metz, K. E. (1995). Reassessment of developmental constraints on children's science instruction. Review of Educational Research, 65(2), 93–127.
Moore, R. W., & Foy, R. L. H. (1997). The scientific attitude inventory: A revision (SAI II). Journal of Research in Science Teaching, 34(4), 327–336.
Nagengast, B., Marsh, H. W., Scalas, L. F., Xu, M. K., Hau, K. T., & Trautwein, U. (2011). Who took the "x" out of expectancy-value theory? A psychological mystery, a substantive-methodological synergy, and a cross-national generalization. Psychological Science, 22(8), 1058–1066.
National Research Council. (2009). Learning science in informal environments: People, places, and pursuits. P. Bell, B. Lewenstein, A. W. Shouse, & M. A. Feder (Eds.). Washington, DC: The National Academies Press.

Niemiec, C. P., Ryan, R. M., & Deci, E. L. (2010). Self-determination theory and the relation of autonomy to self-regulated processes and personality development. In R. H. Hoyle (Ed.), Handbook of personality and self-regulation. Oxford, England: Wiley-Blackwell.

Nowicki, S., & Strickland, B. R. (1973). A locus of control scale for children. Journal of Consulting and Clinical Psychology, 40(1), 148 – 154.

Ntoumanis, N., Taylor, I. M., & Thogersen-Ntoumani, C. (2012). A longitudinal examination of coach and peer motivational climates in youth sport: implications for moral attitudes, well-being, and behavioral investment. Developmental Psychology, 48(1), 213 – 223.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. International Journal of Science Education, 25(9), 1049 – 1079.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. Journal of Educational Psychology, 95(4), 667 – 686.

Pintrich, P. R., & de Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. Journal of Educational Psychology, 82(1), 33 – 40.

Renninger, K. A., Ewen, L., & Lasher, A. K. (2002). Individual interest as context in expository text and mathematical word problems. Learning and Instruction, 12, 467 – 491.

Schmidt, W. H., McKnight, C., & Raizen, S. (1997). A splintered vision: An investigation of U.S. science and mathematics education. Dordrecht, The Netherlands: Kluwer.

Schreiner, C., & Sjoberg, S. (2004). Sowing the seeds of ROSE. Background, rationale, questionnaire development and data collection for ROSE (The Relevance of Science Education)—A comparative study of students' views of science and science education. (4/2004), Oslo, Norway: Department of Teacher Education and School Development, University of Oslo.

Sha, L., Schunn, C. D., & Bathgate, M. E. (2013). The roles of self-efficacy, and effort regulation dispositions of self-regulated learning in predicting choice and engagement in science learning. Manuscript submitted for publication.

Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. Science Education, 74(1), 1 – 18.

Stake, J. E., & Mares, K. R. (2005). Evaluating the impact of science-enrichment programs on adolescents' science motivation and confidence: The splashdown effect. Journal of Research in Science Teaching, 42(4), 359 – 375.

Trumper, R. (2006a). Factors affecting junior high school students' interest in biology. Science Education International, 17(1), 31 – 48.

Trumper, R. (2006b). Factors affecting junior high school students' interest in physics. Journal of Science Education and Technology, 15(1), 47 – 58.

Tyson, W. (2011). Modeling engineering degree attainment using high school and college physics and calculus coursetaking and achievement. Journal of Engineering Education, 100(4), 760 – 777.

Tyson, W., Lee, R., Borman, K. M., & Hanson, M. A. (2007). Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment. Journal of Education for Students Placed at Risk, 12(3), 243 – 270.

Vadeboncoeur, J. A. (2006). Engaging young people: Learning in informal contexts. Review of Research in Education, 30(1), 239 – 278.

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. Metacognition and Learning, 1, 3 – 14.

Vygotsky, L. S. (1978). Mind and society: The development of higher mental processes. Cambridge, MA: Harvard University Press.

Weinburgh, M. H., & Steele, D. (2000). The modified attitudes toward science inventory: Developing an instrument to be used with fifth grade urban students. Journal of Women and Minorities in Science and Engineering, 6, 87 – 94.

Whitebread, D., Almeqdad, Q., Bryce, D., Demetriou, D., Grau, V., & Sangster, C. (2010). Metacognition in young children: Current methodological and theoretical developments. In A. Efklides & P. Misailidi (Eds.), Trends and prospects in metacognition research (pp. 233 – 258). Dordrecht, The Netherlands: Springer.

Wigfield, A., Guthrie, J. T., Tonks, S., & Perencevich, K. C. (2004). Children's motivation for reading: Domain specificity and instructional influences. Journal of Educational Research, 97(6), 299 – 309.

Wray-Lake, L., Crouter, A. C., & McHale, S. M. (2010). Developmental patterns in decision-making autonomy across middle childhood and adolescence: European American parents' perspectives. Child Development, 81(2), 636 – 651.

Zimmerman, C. (2000). The development of scientific reasoning skills. Developmental Review, 20(1), 99 – 149.

Zimmerman, H. T. (2012). Participating in science at home: Recognition work and learning in biology. Journal of Research in Science Teaching, 49(5), 597 – 630.