Journal of Childhood, Education & Society
Volume 2, Issue 3, 2021, 365-391
DOI: 10.37291/2717638X.202123122

ISSN: 2717-638X
Research Article

Are preschoolers expected to learn difficult science constructs? A content analysis of U.S. standards

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Abstract: In the current paper, we report on the recommendations for preschool science put forward in the educational standards of U.S. states. Our focus was specifically on whether educational standards recommend abstract science constructs—constructs that are difficult to learn. In Study 1, we focused on science constructs related to *inquiry* (i.e., activities geared towards the generation of scientific knowledge). And in Study 2, we focused on science constructs related to *facts* (i.e., established scientific knowledge). In each study, we developed a coding scheme to distinguish between concrete and abstract constructs and then determined the relative prevalence of each. Our findings show that preschoolers are indeed expected to learn abstract science constructs. At the same time, educational standards varied considerably across U.S. states. Implications for the field of early science learning are discussed.

Article History
Received: 21 August 2021
Accepted: 01 December 2021

Keywords
Early science learning; Readiness standards; Educational policy; Abstract reasoning; Content analysis

Introduction

With science education becoming increasingly popular in preschool classrooms (Educational Development Center, 2013; National Center for Educational Statistics [NCES], 2021), many have hailed this development as a positive move toward supporting science learning in later grades (Guo et al., 2016; Piasta et al., 2014). In the current paper, we seek to further contribute to this development by asking a simple question: What is actually meant by preschool science? Our research was motivated by perceived points of tension in the field of early science learning. In what follows, we describe these points of tension and illustrate why they might need to be resolved before preschool science education becomes commonplace.

Tensions in The Field of Early Science Learning

Research on early science learning has increased substantially over the last three decades. For example, a search for the keyword "early science learning" on Google Scholar shows a three-fold increase in scholarly work over the years from 2000 to 2013 (from 250,000 to 850,000 entries). The search term "preschool science" reveals an even more dramatic increase during that time frame (from about 8,000 to 40,000 entries). This increase in scholarly work has led to important insights in the field (for reviews, see Guo et al., 2016; Kloos et al., 2012). Yet, the amount of scholarly work has decreased visibly recently (e.g., from about 40,000 to 29,000 "preschool science" entries in the years from 2015 to 2020).

Upon surveying the literature about what might be the issue, one finding was striking: Preschool teachers often have reservations about teaching science to young children (Park et al., 2017). For example, many teachers report that they do not have enough mastery of science content (Blonder et al., 2014; Oppermann et al., 2021). In turn, they might feel underprepared when using science materials (Kloos et al., 2018). Many also report lacking the confidence to organize the preschool classroom in ways that support science activities (Gerde et al., 2018). Teachers also perceive barriers when it comes to evaluating students

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on science assignments, compared to other fields (Greenfield, 2015).

More generally, the question of whether early science learning has positive long-term effects is still open. On the one hand, some have argued that mere exposure is enough to give children an advantage for later learning (e.g., Kachergis et al., 2019; Kelemen et al., 2014; Saidi & Sigauke, 2017; Shtulman et al., 2016; Worth, 1999). This argument might explain the numerous online resources designed to make science learning fun (e.g., education.com, 2012). On the other hand, science in preschool does not consistently translate into later science proficiency: Exposure to early science education might not predict improved science performance in older children (Brenneman et al., 2009; Saçkes et al., 2010; Saçkes et al., 2013).

There is also ambiguity about the amount of effort needed to bring science to young children. On the one hand, there is the appealing notion of science learning requiring nothing more than play, for example in nature (Erickson & Ernst, 2011; Eshach & Fried, 2005). This notion might drive the relatively low requirements for preschool instructors to learn science ahead of placement (U.S. Bureau of Labor Statistics, 2021). On the other hand, there are concerns that preschool classrooms might not be set up in a way that is conducive for science learning (Gerde et al., 2018). This is especially evident when science materials or designated science areas are missing (Tu, 2006).

Even the debate about whether young children can learn science constructs remains unresolved. On the one hand, there is great excitement about the potential of early science learning, based on the idea that children are natural scientists (e.g., Gopnik et al., 1999; Metz, 1995). On the other hand, science is known to be notoriously difficult, eliciting misconceptions and exasperating students in higher grades (e.g., Chi & VanLehn, 2012; Sawyer, 2006; Vosniadou, 2009). Indeed, scholars have raised concerns about the fact that preschoolers and kindergarteners show little improvement in science achievement after participating in science readiness programs (Greenfield et al., 2009; Saçkes et al., 2010).

These points of tension—whether on learning readiness, long-term benefits of early science learning, or required resources for preschool science pedagogy—are likely to add uncertainty to the field. At the minimum, points of tension might undermine efforts to make science a central part of early learning. For example, open questions on whether young children are cognitively ready to comprehend science constructs hamper curriculum decisions. And open questions on how to best prepare preschoolers for science learning impede the development of teacher-training modules. Thus, to promote scholarly work in the field, points of tension need to be resolved first.

Understanding the Nature of Preschool Science

One way to respond to tensions in the field is to explore the underlying assumptions that sustain disagreements (Dahl, 2017). In the case of early science learning, one underlying assumption pertains to the nature of preschool science. Those who assume young children are ready for science might intuitively equate preschool science with constructs that can be learned easily at an early age. Vice versa, those who assume protracted learning might intuitively equate preschool science with constructs that are difficult to learn at a young age. Thus, there might be divergent views on what is meant with science at the preschool level. If we could provide data on the nature of preschool science, we could address the tension and therefore contribute to progress in the field.

For questions about the nature of subject matters, important insights can be gained from educational standards. Incidentally, all of the 50 U.S. states put forward recommendations about early science learning (Kloos et al., 2018). They are organized into content domains such as life science, physical science, and earth/space science (e.g., Larimore, 2020; Saçkes et al., 2009). For example, educational standards for preschool science recommend that preschoolers learn about the differences between plants and animals (life science), the properties of light (physical science), and the day-and-night cycle (earth/space science).

To what extent do educational standards recommend science constructs that are difficult for preschool children? The idea is that construct difficulty is central to the question of whether young children can benefit from exposure to science content. If educational standards recommend science constructs that young children can easily learn, we can assume that young children are ready to learn about science. If, on the other hand, educational standards recommend science constructs that are difficult for young children, then we can assume that young children are ill-equipped for science learning. Thus, construct difficulty is a relevant dimension by which to characterize the nature of science.

The idea of learning difficulty is fundamental to the field of cognitive development. Indeed, numerous measures have been proposed to capture the learning difficulty of concepts, including relational complexity (Andrews & Halford, 2002), feature density (Gentner & Kurtz, 2005; Kloos & Sloutsky, 2008), or hierarchical position (Kloos et al., 2019; Rosch, 1978). Most prominent is the distinction between concrete and abstract concepts (Crain, 2015; Flavell, 1982; Piaget & Inhelder, 1969). Concrete concepts can be learned easily because they represent the immediate here-and-now. Abstract concepts, on the other hand, require a cumbersome form of integrating otherwise separate pieces of information (Chambers, 1991; Dumontheil, 2014; Huitt & Hummel, 2003).

The distinction between concrete and abstract constructs fits well within the realm of science constructs. Learning about different body parts, for example, could be thought of as concrete: Students merely need to attend to obvious entities (e.g., "head," "shoulders"). Learning about the differences between plants and animals, on the other hand, could be thought of as abstract: Students have to attend to potentially hidden features (e.g., the ability of an entity to self-propel), while ignoring superficial but highly salient features (e.g., the color and size of an entity). Learning about constructs such as the properties of light or the day-and-night cycle could also be thought of as abstract: Students need to keep track of events over time and detect a common thread among them. Thus, the distinction between concrete and abstract constructs can be useful for examining the nature of preschool science.

Overview of The Current Research

The goal of the current study was to explore the difficulty of science constructs specified in educational standards. To do so, we carried out a content analysis of the educational standards put forward by the U.S. states. A content analysis is a systematic way of analyzing text in which the relative presence of target concepts can be determined (DeCuir-Gunby et al., 2011; Dinçer, 2018; Eğmir et al., 2017; Krippendorf, 1989; Larson & Rahn, 2015). In Study 1, we focused specifically on scientific *inquiry:* the process by which science knowledge is developed (e.g., "doing science"; Seefeldt & Galper, 2007). In Study 2, we focused on science *facts:* the established insights that make up the corpus of science knowledge (e.g., "content knowledge"; Guo et al., 2015). In each case, we asked whether young children are expected to learn about abstract (i.e., difficult) science constructs.

Study 1: Abstraction in Inquiry

Are preschool children expected to engage in the types of inquiry activities that require abstract thought? To answer this question, we first developed a coding system that could capture the abstraction level of different forms of inquiry. We then applied the identified codes to the U.S. educational standards.

Method

Preparation of content

The documents used in our content analysis were the publicly available U.S. readiness standards for science learning in preschool. These standards consist of bullet points in lists, charts, and diagrams, organized by headings and subheadings. Given the inconsistencies between headings across states, we opted to omit them, focusing instead on the bullet-point entries. To be included in the content analysis, a bullet-point entry had to be targeted for children between 36 to 60 months of age. The entry also had to be listed in a section labeled as science (or under similar headings, such as STEM).

Once bullet-point entries were isolated (N = 1060), we delineated them into individual *items*. Each item contains a separate science requirement for preschool science. In most cases, one bullet-point entry corresponded to one item. However, when a bullet-point entry contained multiple sentences that included separate requirements, the entry was split into multiple items. We split 17 bullet-point entries in this way.

Next, we identified the *inquiry terms* of each item. Inquiry terms are the phrases that capture an inquiry activity. This could pertain to single verbs (e.g., "observe"), or it could pertain to entire verb phrases (e.g., "make a prediction").

In the process of identifying inquiry terms in items, we encountered action terms that were only tangentially related to science. Such terms focused on engineering (e.g., building something), math (e.g., counting), or the like. We refer to these terms as *non-science* terms (see Appendix A.1 for detailed information about the codes for non-science terms). Items that consisted entirely of non-science terms, without any scientific inquiry terms, were excluded. The final number of items included in our content analysis was 959 (range per state: 4 to 38 items).

Coding Scheme

The coding scheme we developed for inquiry terms contained nine codes, ranging from lowest to highest level of abstraction (see Table 1 for a summary). Our scheme drew on two theoretical frameworks: The Scientific Method (i.e., the guide to the development of scientific theories; Gerde et al., 2013) and Bloom's Taxonomy (i.e., a list of activities, organized hierarchically to lead to increasingly deeper learning; Airasian et al., 2001; Hepburn & Andersen, 2021). Below, we explain each code and the rationale for its assigned level (see Appendix A.2 for additional details on how each inquiry term was coded).

Table 1. Levels of scientific inquiry

Level	Category	Description
1	Observe-without-tools	Uses senses to observe what is most salient
2	Observe-with-tools	Uses tools to enhance senses when noticing what is most salient
3	Communicate-without-tools	Communicates understanding, thoughts, etc. in verbal or nonverbal ways
4	Communicate-with-tools	Uses tools such as graphs to communicate thoughts
5	Ask-questions	Expresses confusion or interest about missing information
6	Compare-contrast	Recognizes similarities and differences between entities
7	Predict	Makes an informed guess based on previous experience or understanding
8	Test-a-prediction	Experiments with variables to test hypotheses
9	Explain	Generate explanations for why and how things happen

Low Abstraction

At the lowest degree of abstraction (Levels 1-2), inquiry codes pertain to observing the surroundings. Our thinking was that observations require very little abstraction, if any: Children merely have to look at what is most salient in front of them, without needing to imagine hidden connections. Here, we distinguished between the *observe-without-tools* code (Level 1) and the *observe-with-tools* code (Level 2). Example tools for observation include magnifying glasses, microscopes, or measuring cups. The idea was that observations with tools require children to bridge between what entities look like when perceived with tools versus without them, which increases the level of abstraction compared to mere observations.

Medium Abstraction

At a medium degree of abstraction (Levels 3-5), inquiry codes pertain to communicating about the surroundings. Here, we distinguished between communicating with or without tools, as well as asking questions. Specifically, the *communicate-without-tools* code (Level 3) pertains to activities such as identifying or recognizing entities (e.g., "know vocabulary"), describing or talking about events ("recall"), or responding to prompts (e.g., "answer questions," "give examples," "confirm"). This code also includes action phrases that refer to more specific forms of communication (e.g., "use evidence," "offer critiques," "interpret observed events") and non-verbal communication (e.g., "draw," "take pictures," "record data").

The *communicate-with-tools* code (Level 4) applies when specific tools are listed to enhance communication (e.g., "create graphs," "tally observations," "use models of what is observed," "create displays"). Our thinking was that the use of these tools requires children to organize information in ways that are more abstract than merely retelling unorganized information. The *ask-questions* code (Level 5) applies when the activity of communicating requires children to make connections between what they already know and what they do not yet know (e.g., "be curious," "show interest," "express wonder"). Here, our thinking was that the activity of asking questions requires an awareness of something that is missing, which makes it more abstract than merely talking about available information.

High Abstraction

Finally, at the highest degree of abstraction (Levels 6-9), inquiry codes pertain to identifying, integrating, or manipulating variables. Here, we distinguished between comparing and contrasting entities, making or testing predictions, and generating explanations. Specifically, the *compare-contrast* code (Level 6) applies to activities in which one or more variables have to be identified against the backdrop of irrelevant aspects (e.g., "analyze data," "sort"). Adding a layer of abstraction, the *predict* code (Level 7) involves anticipating events in the future by drawing inferences from current circumstances (e.g., "formulate a hypothesis," "make guesses").

Adding yet another layer of abstraction, the *test-a-prediction* code (Level 8) applies to activities in which a variable has to be manipulated to determine its relation to another (e.g., "test hypotheses," "verify predictions"). This requires not only identifying variables, but also creating a setting in which an otherwise hidden relation between variables can be uncovered. Finally, the *explain* code (Level 9) applies to activities in which the relation between variables is supplemented with a narrative that goes beyond the immediately available findings (e.g., "make conclusions," "generalize"). This activity is arguably the pinnacle of scientific inquiry: It requires the detection of an otherwise invisible causal chain among variables.

Unspecified Terms

In addition to the nine abstraction levels, we also identified action phrases that were too vague to apply to a unique abstraction level. An example of such a term is to "explore": This activity could refer to something as concrete as observing the surroundings (Level 1), or to something as abstract as designing an experiment to test a prediction (Level 8). Thus, this term could not be assigned a code unambiguously (consider also "become familiar," "develop an awareness," "learn"). Given this ambiguity, we established an *unspecified* code for these terms.

Coding Procedure

Coding of action phrases was carried out iteratively: It started with an initial definition of codes, which was given to two coders who reviewed the items independently from each other. Disagreements were then discussed, resulting in a revision of the code definitions to either adjust or clarify the codes. In the final iteration, three coders reviewed the database of coded items and checked each item's codes independently from the other coders. Disagreement was then discussed a final time, again resulting in adjustments to the coding scheme. Given the consensus approach taken to discussions at each iteration, all items yielded 100% agreement.

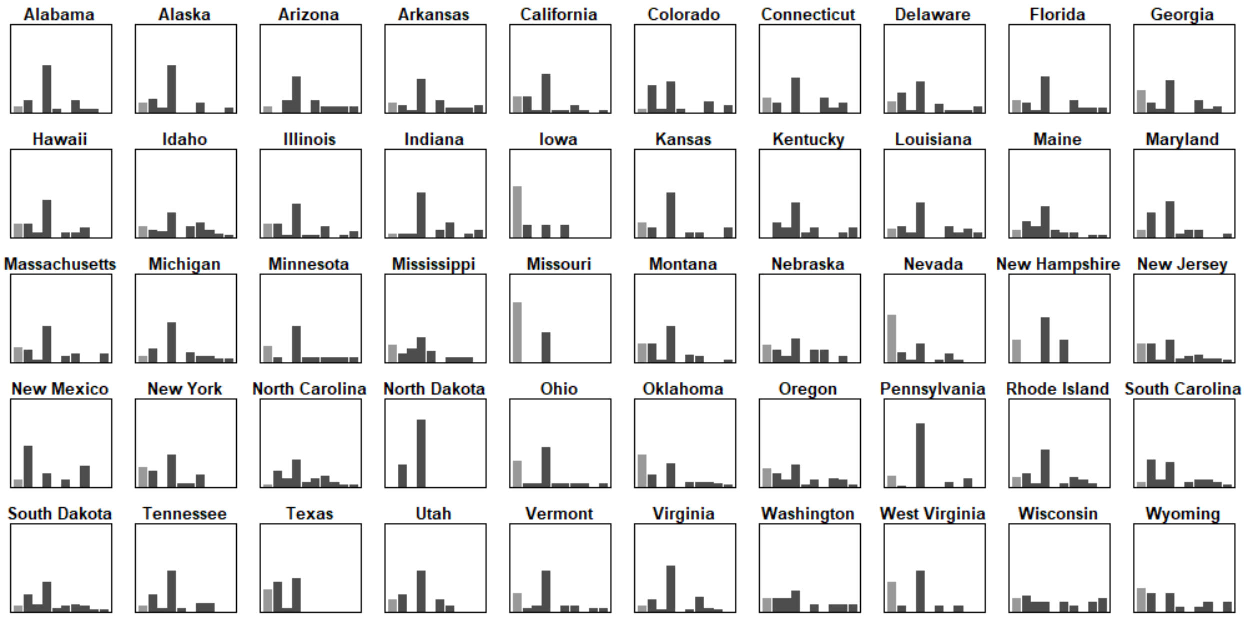
Results

Results are presented in three sections: The first section provides general information about how the educational standards differ among states. We then consider the broad distinction among the three degrees of abstraction (low, medium, high). Finally, we look more specifically at the prevalence of the four codes at the highest degree of abstraction.

Differences Among States

We found numerous ways in which state standards differed, starting with the number of items they listed: Some states had as few as 4 items, while others had over 20 items (see Appendix B.1 for the number of inquiry items and terms by state). Items also differed in their length: While some items consisted of just 2 words, others contained more than 20 words. The specificity of the content differed, too. While some items were vague (e.g., "use senses to experience something and make one or two comments to describe this"), others provided explicit examples (e.g., "observe processes and relationships, for example by using measuring cups to measure fish food, then observing fish and recording how much they eat").

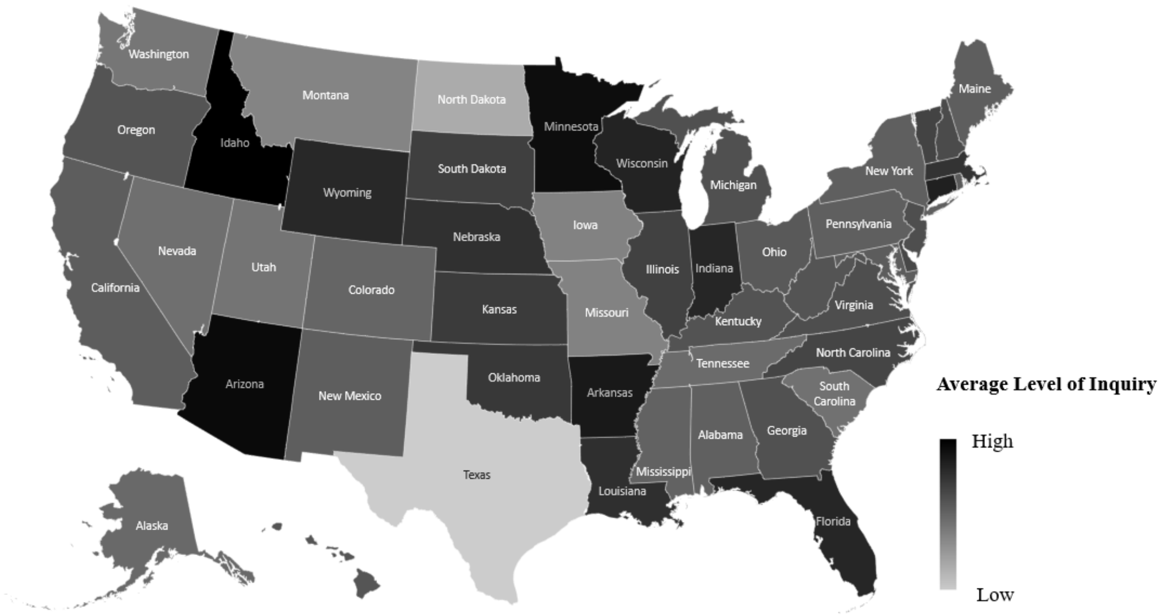
State standards also differed in what kind of inquiry they required of preschoolers. For example, while most standards used relatively few unspecified inquiry terms, some standards used primarily unspecified inquiry terms (6%). More to the point of abstraction levels, while some state standards covered every one of the nine abstraction levels (6%), other state standards restricted themselves to no more than three abstraction levels (10%). Figure 1 shows the prevalence of each abstraction code, separated by state.



Note. Light bars show the proportion of *unspecified* inquiry terms. Dark bars show the proportion of *specified* inquiry terms. The specified inquiry terms include: *observe-without-tools*, *observe-with-tools*, *communicate-without-tools*, *communicate-with-tools*, *ask-questions*, *compare-contrast*, *predict*, *test-a-prediction*, and *explain*. The specified inquiry terms are ordered from lowest to highest abstraction level.

Figure 1. Inquiry terms by state

We calculated an average abstraction level for each state, building on the idea that the nine levels of abstraction are ordered from lowest to highest. Specifically, we first calculated an average abstraction score for each item, and then we averaged across those scores for each state (excluding unspecified terms). Figure 2 shows the obtained results: While some state standards recommended inquiry at relatively high levels of abstraction (over 4.00, 20% of standards), the abstraction levels for inquiry recommended in other state standards was low (under 3.00, 4% of standards).



Note. The lowest possible score was 1 (*observe-without-tools*), and the highest possible score was 9 (*explain*). State averages range from 2.06 ("Low") to 4.65 ("High").

Figure 2. Map of average abstraction level

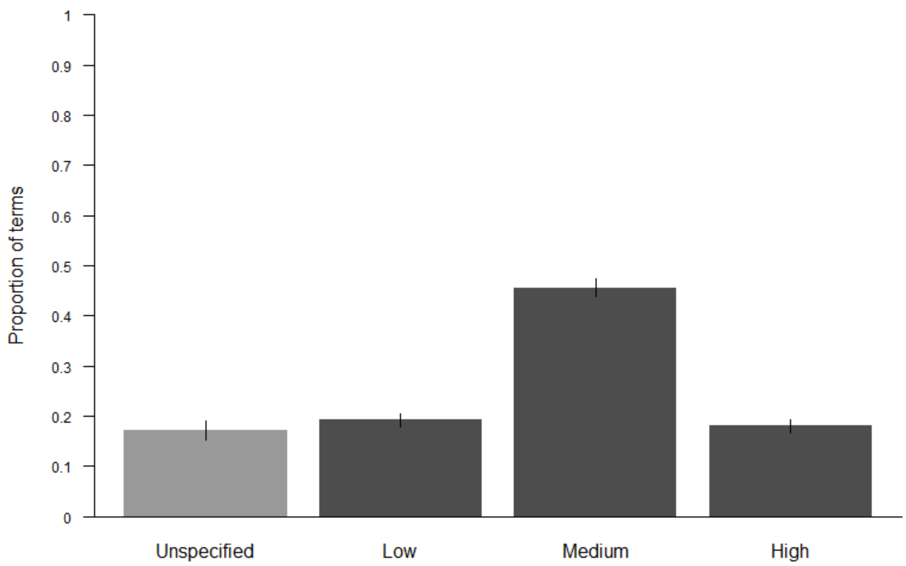
Broad Contrast Among Degrees of Abstraction

Next, we sought to capture broad trends across the U.S. standards. To do this, we calculated the proportion of inquiry terms that were of low (i.e., observing phenomena), medium (i.e., communicating about science), and high degrees of abstraction (i.e., attending to variables) and averaged them across states. Figure 3 presents the obtained results: The most common inquiry terms were at a medium degree of abstraction (M = 46%, SD = 12.16). Inquiry terms at the low degree of abstraction were less prevalent (M = 19%, SD = 9.76). They matched in prevalence with the high-abstraction inquiry terms (M = 18%, SD = 9.00).

Many state standards (44%) followed the overall pattern found across the U.S. states: Many featured a large number of medium-abstraction codes, and many featured approximately equal numbers of low- and high-abstraction codes. Thus, high-abstraction inquiry, while not the most prevalent, was nevertheless prominently featured in the educational standards—as prominent as low-abstraction inquiry. In fact, nearly all state standards (90%) required at least some high-abstraction inquiry. Considered together, high-abstraction codes accounted for 23% of the total specified inquiry terms.

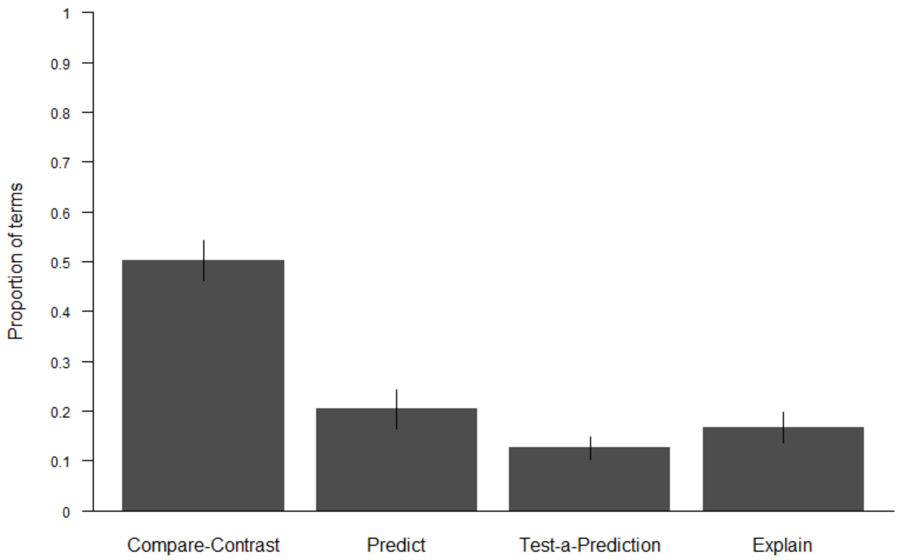
Specific Contrast Among High-Abstraction Codes

Finally, we sought to provide details on the type of inquiry required at the high end of the abstraction spectrum (*compare-contrast, predict, test-a-prediction, explain*). Figure 4 provides these data averaged across state standards. Of the four types of high-abstraction codes, the *compare-contrast* code was most prevalent (42%), occurring approximately twice as often as each of the other three types of high-abstraction codes. Indeed, this is the most prevalent of the high-abstraction codes for many states (54%), and most states feature at least one *compare-contrast* term (87%). The most common inquiry terms from this category were "differentiate" and "categorize."



Note. Proportions were averaged across states. The light bar shows the average proportion of *unspecified* terms. The dark bars show the average proportions of *specified* terms (low, medium, or high degree of abstraction). Error bars represent the standard error of the mean.

Figure 3. Average Proportion of Inquiry Terms



Note. Proportions were averaged across states. Error bars represent standard errors of the mean.

Figure 4. Proportion of high abstraction inquiry terms

The other three types of high-abstraction codes, though less prevalent than the *compare-contrast* code, were nevertheless represented in many state standards. For example, the *predict* code appeared at least once in 67% of the states. The most common terms of this type of abstraction were "hypothesize" and "anticipate". Likewise, the *test-a-prediction* code appeared at least once in 64% of the state standards. The most common terms of this type of abstraction were "test hypotheses" and "experiment." Even the highest level of abstraction, the *explain* code, appeared in many states at least once (67%). The most common terms of the *explain* code were "explain" and "generate conclusions."

Discussion

In Study 1, we sought to characterize the level of abstraction present in scientific inquiry. Our results show that abstract scientific inquiry is indeed expected in U.S. preschools, at least to some extent. We found that the most prevalent inquiry activity is that of communicating. On some level, this might be expected, given that children's communicative behavior allows teachers to gauge their students' understanding (Brenneman, 2011). At the same time, this type of inquiry—to recognize things, learn science vocabulary, and discuss observations—is far from trivial for young children. Further, state standards were largely consistent in requiring high degrees of abstraction in inquiry. In fact, many standards specified that young children should engage in all levels of high-abstraction inquiry, including to test predictions and formulate explanations.

Study 2: Abstraction in Science Facts

In Study 2, we sought to characterize the level of abstraction present in science facts. That is to say, we asked whether preschool children are expected to learn about abstract content in the corpus of established scientific knowledge. To answer this question, we developed a coding system to capture abstraction in science facts and then applied it to the educational standards that contained facts.

Method

Preparation of content

To prepare the content of this analysis, we started with the 959 science items used in Study 1. First, we identified the domain of science that each item belonged to. Our rationale was that scientific facts can be analyzed best if they are specific enough to fit within a domain of science. Or, put differently, if content cannot be attributed to a domain of science, then it is likely to be too vague to allow a designation of concrete versus abstract content. Domains of science pertained to topics such as *life science* (e.g., biology), *physical science* (e.g., physics), or *earth/space science* (e.g., astronomy). Some items were coded as *other science* (e.g., social science, environmentalism) or *multiple sciences* (e.g., a combination of domains). Appendix A.3 provides details on how the domains of science were defined.

We excluded a total of 271 items that either had no content at all (n = 188, e.g., "discuss predictions"), were too vague to attribute to a specific domain of science (n = 74, e.g., "collect data"), or were too general to determine their abstraction level (n = 9, e.g., "understand life science"). We conducted the content analysis with the remaining 688 items (range per state: 1 to 44 items).

Coding Scheme

To capture the abstraction level of science facts, we distinguished between concrete and abstract facts. Specifically, *concrete* facts were defined as those that are readily perceivable, without having to connect any pieces of information. Examples of concrete facts are visible physical properties (color, size, material) or obvious events (e.g., sinking). We also included facts that could be observed directly (e.g., sound, light, shadow), as long as there was no explicit requirement to understand the source of those phenomena. References to vocabulary, rules, or functions were also treated as concrete, since this information merely needs to be memorized.

Abstract facts, on the other hand, refer to information that is hidden and thus requires some mental effort to access. Consider, for example, the construct of "family." For a group to be family, there have to be unique relations among the members of the group. These relations cannot be reduced to a physical property or a salient event. Instead, individual pieces of information must be integrated into a coherent whole to arrive at the construct of "family."

For abstract facts, we distinguished between *relations, patterns, groups,* and *forces* (see Appendix A.4 for detailed information about these codes). The *relations* code captures connections between entities, whether the connection is causal ("effect," "impact," "control"), correlational ("interaction," "heredity"), or based on dependency (e.g., "protect," "preserve"). The *patterns* code captures events that unfold over time (e.g., "life cycle," "transformation," "motion"). The *groups* code captures distinctions between entities that are based on hidden characteristics or traits ("living vs. nonliving things"). And the *forces* code captures references to causal properties (e.g., "gravity," "magnetism," "buoyancy," "energy").

Note that the abstract categories of *relations, patterns, groups,* and *forces* are interrelated. For example, all relations are also patterns, and all forces are also relations. To distinguish codes consistently, we chose to base our coding scheme on individual words or phrases. For example, the item "describe the effects of forces in nature" received the code of *relations* (because of its reference to cause-effect relations) as well as the code of *forces* (because it invoked the term "force").

Note also that concrete terms were sometimes nested within abstract phrases. For example, the phrase "the effects of an action on an object" consists of both an abstract code (a causal relation) and a concrete code ("an object"). In cases like this, we coded both the abstract and the concrete part of the phrase. As a result, some items contained both concrete and abstract terms (vs. items that consisted entirely of concrete terms or items that consisted entirely of abstract terms).

Coding Procedure

Coding followed the same iterative process that was used in Study 1. We first drafted initial definitions of codes and then refined them through subsequent rounds of coding and discussion. Specifically, we identified all the fact phrases and determined whether each one was concrete or abstract (and, in the latter case, whether it falls into the category of *relations, patterns, groups,* or *forces*). In each round, two independent coders went through the items and coded them, then came together to discuss the disagreements and refine the definitions of the codes.

While all disagreements could be resolved during the aforementioned iterative process, one item provoked repeated discussion: "Recognize that everything is made of matter." Going by majority decision, this item was ultimately coded as *groups*, the argument being that the item was indicative of an underlying trait (i.e., everything has the hidden characteristic of matter).

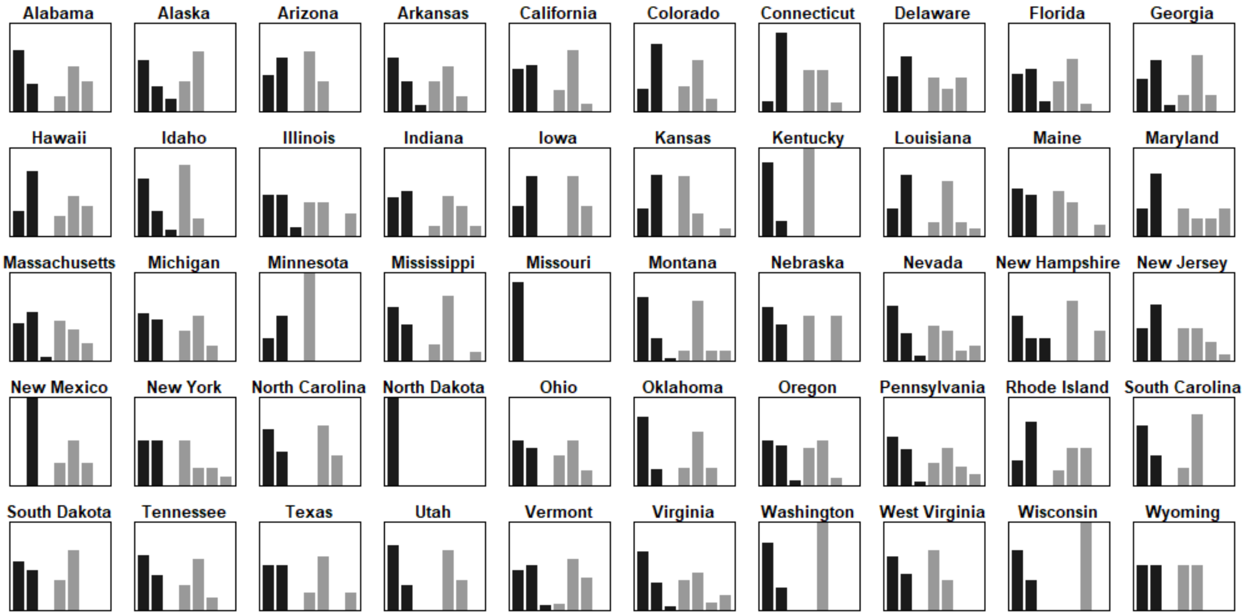
Results

Results are presented in three sections: The first section focuses on the variability among state standards. We then consider the broad contrast among items that contained only concrete terms, concrete and abstract terms, or only abstract terms. Of interest was the relative prevalence of each type of item (*concrete-only*, *concrete-and-abstract*, *abstract-only*) as a function of the domain of science. Finally, we look more specifically at the four types of abstract facts (*relations, patterns, groups, forces*) and explore their relative prevalence in each domain of science.

Differences Among States

Similar to Study 1, there were several differences across state standards (see Appendix B.2 for the number of fact items and terms by state). For example, while some standards included information about science facts for virtually all of their items (20%), others provided far fewer facts. There was even a difference in the number of facts per specified item, ranging from one to four facts per item. State standards also differed in the domain of science that was covered. For example, while some standards did not include any life-science items (16%), other standards featured them prominently. We found similar variability with physical science*:* While one state standard was comprised exclusively of physical-science items, two standards had none at all.

We also found differences in the degree to which the standards recommended abstract versus concrete facts (see Figure 5 for the profiles of each state standard, separated by types of items and types of facts). For example, two state standards consisted entirely of concrete items. And, while abstract content presumably builds upon concrete foundations, 38% of state standards nevertheless featured at least one exclusively abstract item. And, concerning the different types of abstract facts (*relations, patterns, groups,* *forces*), many standards featured at least three types of abstraction (46%). Eight standards listed all four types of abstraction, while four only had one primary abstraction code.



Note. The dark bars show the proportion of each type of item (*concrete-only, concrete-and-abstract, abstract-only*). The light bars show the proportion of each type of abstract fact term (*relations, patterns, groups, forces*).

Figure 5. Proportion of types of items and terms by state

Broad Contrast Among Different Items

Recall that an item could have concrete terms, abstract terms, or a combination of both (e.g., when concrete terms were nested within abstract terms). Table 2 displays the relative prevalence of each of these types of items. Results show that only 2% of the items had exclusively abstract content. This holds for the individual domains of science as well: The prevalence of abstract-only items ranged from 0% (multiple sciences) to 4% (earth/space science; other science).

At the same time, when considering whether items had at least some abstraction (i.e., abstract-only or concrete-and-abstract), the proportion of items with at least some abstract content is sizable (47% across domains). Using Generalized Linear Mixed-Effects Models (GLMMs) (Hox, 2010) to compare relative frequencies, we found that the presence of abstract content did not differ across science domains, $D(4) = 5.00$, $p = .287$. Almost half of the items in life science (45%), physical science (50%), and earth/space science (49%) featured abstract facts.

Specific contrast among abstract codes

Table 2 also shows the relative prevalence of the different types of abstract codes (*relations, patterns, groups, forces*). The *forces* code was the least common across the domains of science, found in only 6% of abstract fact phrases. Even within physical science, arguably the natural home of force-related concepts, only 14% of fact phrases referred to forces. The *groups* code was also relatively uncommon, occurring in only 16% of the abstract fact phrases. Here, we found a difference in proportion by domain, $D(4) = 32.35$, $p < .001$, with life science being the domain with the most *groups* codes, post-hoc Wald test $Ws(1) > 4.75$, $ps < .029$. A typical example of this code was to "categorize common living things as either plants or animals."

Table 2. Proportion of types of items and types of abstract terms within each science domain

Level of Abstraction	Domain of Science: Life	Physical	Earth/Space	Other	Multiple	Total
Types of Items						
Concrete Only	55%	50%	51%	62%	47%	52%
Concrete & Abstract	44%	46%	45%	32%	51%	44%

Abstract Only	<1%	3%	4%	4%	-	2%
Types of Abstract Terms						
Relations	25%	32%	13%	83%	33%	31%
Patterns	46%	46%	76%	14%	28%	47%
Groups	28%	8%	10%	3%	37%	16%
Forces	1%	14%	-	-	2%	6%

Note. Percentages were calculated within their respective domains. Deviations from totals of 100% stem from rounding errors.

The *patterns* code was more prevalent than that of *forces* and *groups*, found in 47% of the fact terms. Here too, we found a difference in proportion by domain, $D(4) = 42.02$, $p < .001$, with earth/space science being the domain with the most *patterns* codes (76%), Wald test $Ws(1) > 3.58$, $ps < .058$. One of the most common *patterns* constructs in this domain were cycles, such as the day/night and water cycles. Patterns were also common in the domains of life science and physical science, found in 47% of the abstract fact terms of each of these domains. Typical examples were growth over time (life science) and the motion of objects (physical science).

Finally, the *relations* code was of intermediate prevalence, found in 31% of the fact phrases across domains. Finding a difference by domain, $D(4) = 25.36$, $p < .001$, *relations* were most common in the physical-science domain (32%). For this domain, the most common *relations* construct was cause and effect (e.g., "cause and effect of pushing/pulling objects"). In contrast, *relations* were less common in the life-science domain (25%), $W(1) = 5.78$, $p = .016$, and even rarer in the earth/space science domain (13%), $W(1) = 10.45$, $p = .001$. Typical examples were interactions between living things and their environments (life science) and how weather relates to seasons (earth/space science).

Discussion

Are preschool children expected to attend to and learn about science facts that require abstract thought? Like with abstract inquiry in Study 1, we found that this is indeed the case: About half of the items assessed in the content analysis featured at least one abstract fact, regardless of science domain. Specifically, preschool children are expected to pay attention to patterns that unfold over time, most notably in the domain of earth/space science. They are also expected to pay attention to relations, for example when asked to think about humans and nature. They were even expected to pay attention to forces, though to a lesser degree than to relations or patterns.

General Discussion

Our work was motivated by a noticeable dip in the amount of scholarly work on early science learning. While we cannot claim to know the sources of this decline, there are several points of tension in the field that might hamper progress. In fact, there appear to be unresolved questions regarding whether young children are able to learn science constructs at all. Our paper was designed to address unresolved issues by looking more specifically at the difficulty level of the science constructs recommended for preschool.

Our results show that recommended science constructs vary widely in learning difficulty. Regarding inquiry, for example, most educational standards recommend something as simple as observing the surroundings with one's own senses. At the same time, they also recommend something as sophisticated as formulating and testing explicit hypotheses. Even the activity of generating explanations is common in the educational standards. A similar pattern emerges with science facts: While many standards recommend knowing something as obvious as the names of body parts, they also recommend knowing about patterns that evolve over time, such as the lifecycles of animals. Thus, preschool science is neither difficult nor easy: It is both.

Given the variability in learning difficulty of recommended science concepts, a conclusive "yes-or-no" answer to the question of whether young children can learn science is perhaps not sensible: Young children are cognitively ready to comprehend some, but not all, science constructs. That is to say, before an answer can be provided about classroom organization, teacher preparation, or pedagogy, more information about the difficulty level of the desired science construct is needed. When science constructs are concrete, young children can learn them spontaneously, merely via play (e.g., observing the surrounding). In contrast, when science constructs are abstract (e.g., making predictions; understanding the impact of gravity on objects), spontaneous play in the everyday surrounding is no longer enough to promote learning.

Still, learning about abstract science constructs is possible for young children. Research has shown that preschoolers can reason abstractly, such as when testing a hypothesis or reaching a conclusion (Bonawitz et al., 2011; French, 2004; Sobel & Legare, 2014; Sodian et al., 1991; Trundle & Smith, 2017). To be able to do this, however, children need exposure to a setting that highlights otherwise hidden links. For example, in order to formulate and test a hypothesis, the relevant variables need to be more salient than irrelevant variables (Kloos et al., 2019). In a typical preschool classroom, such order is unlikely to be present (e.g., Fisher et al., 2013; Kirschner et al., 2006). Thus, learning about abstract science constructs requires a change in the everyday preschool setting.

Research has indeed identified some strategies that might be helpful for acclimating young children to abstract science concepts. For example, prompting children to document their observations and talk about observed similarities and differences is a feasible and effective strategy to highlight what might otherwise remain hidden (e.g., Brenneman & Louro, 2008; Fleer, 1991; Fleer & Beasley, 1991). Similarly, the use of schematic representations such as concept maps or conceptual models can help young children see how entities or events are related (e.g., Gobert & Buckley, 2000; Hunter et al., 2008; Kenyon et al., 2008; Novak, 2010; Wiser & Smith, 2008). Incidentally, we found that the educational standards only rarely recommended the use of tools to visualize otherwise hidden relations.

Regarding preschool teachers' apprehension about incorporating science into the general curriculum, our findings highlight the importance of specifying the degree of difficulty of the chosen science constructs. Vaguely phrased science items could give practitioners some leeway in their curriculum choices. For example, teachers who are unsure about science pedagogy could focus on science constructs that can be learned spontaneously during children's play (i.e., concrete science constructs). At the same time, the lack of specificity is likely to put a heavy burden on teachers to come up with ways of organizing their science curricula. The solution is to work out a clear definition of science and recommend a sensible ordering from lower- to higher-abstraction constructs—which is currently missing from the educational standards.

Conclusion

Even though the field of early science learning has enjoyed increased attention over the decades, fundamental disagreements remain, such as about whether young children are capable of learning science. Our findings put important constraints in place to address this disagreement. Specifically, we found that scientific inquiry and scientific facts recommended at the preschool level vary considerably in difficulty. This suggests that the question of whether children can learn science depends on how difficult the particular science construct is. Young children might be able to easily learn salient science constructs from exposure alone. For more hidden science constructs, however, a more intentional effort might be needed to support preschoolers' learning.

Our findings also highlight an important gap in the field of early science learning: that there is no universally accepted definition of science at the preschool level. For example, while state recommendations largely agree on including both concrete and abstract science constructs, there are numerous differences among the existing recommendations. Without a clear definition of early science, research on science learning is necessarily confined to the idiosyncratic definitions adopted by each research team. In turn, this curtails transferability to the preschool classroom and, thus, has only limited practical relevance for those who operate under a different definition of science. Before early science education can be successful, then, it might first be necessary to adopt a consistent definition of science.

Declarations

Acknowledgments: Not applicable

Authors' note: Part of the research presented in this paper was derived from a master's thesis completed by A.O.

Authors' contributions: A.O. and H.K. contributed to all aspects of the work reported here, including the design and implementation of the research, the data analyses and visualization, and the writing and editing of the manuscript. T.W. contributed to the development of the methodology and its implementation, data analysis and visualization, inferential statistics, and some writing and editing of the manuscript. C.C. contributed primarily to the development of the methodology and some data analysis.

Data Availability: The data used in this research, as well as additional supplementary information, are publicly available on the Open Science Framework: https://osf.io/geqnb/

Competing interests: The authors declare that they have no competing interests.

Funding: Not applicable.

Adherence to ethical concerns

The research reported here does not involve human subjects. The basis for the research was the analysis of records that are publicly available (educational standards).

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Appendix A: Coding Schemes

Appendix A.1 Explanation of Codes for Non-Science Items

Codes	Words and Phrases	Example
Engineering	Broadly: finding solutions, fixing something broken, creating a non-scientific model Specifically: solves problems, builds a structure, use tools in play, develop procedures, invent	"Construct a device to protect from the sun" "Solve problems by designing or using tools"
Math	Broadly: counting, using numbers, doing math without connection to science Specifically: use numbers, use quantities, uses mathematical thinking, counts	"Uses number to represent quantity" "When counting, assigns number to each item"
Language Arts	Broadly: reading, writing, or speaking with a focus on the process of language proficiency rather than science Specifically: makes signs, uses letter-like symbols, writes messages, listens to stories, tells stories, repeats words	"Talk about ways to be safe" "Repeat new words"
Personal Growth	Broadly: following the rules, learning norms, showing respect, developing traits Specifically: showing respect, follows rules, asks for help, invites peers, develops personal interest, shows surprise	"Demonstrate respect" "Follows directions"
Caring for Others	Broadly: referred to volunteering time, assisting, helping Specifically: Take care of, participate in care, express concern, is considerate	"Care for plants and animals in the classroom" "Participate in activities that help to care for the environment"

Appendix A.2 *Explanation of Codes for Inquiry Terms (Study 1)*

Codes	Words and Phrases	Examples
Unspecified		
	become familiar; determine; develop a sense; develop an awareness; engage in activities; explore; find out; inquiry; interact with; investigate; know; learn; look for answers; manipulate; pursue questions; reason; reflect; seek information; think about; try things out; understand	"Explores what a variety of living organisms need to live and grow (e.g., water, nutrients, environment)" "Investigates concepts of structures."
Low Degree of Abstraction (Levels 1, 2)		
Level 1: Observe-without-Tools	collect data; collect information; discover; examine; gather information; make observations; manipulate; notice; observe; sensory exploration; use senses	"Observes the characteristics and movement of the sun, moon, stars, and clouds" "Makes simple observations of the characteristics, movement, and seasonal changes of the sun, moon, stars, and clouds."
Level 2: Observe-with-Tools	explore with tools; gather information with tools; investigate with tools; measure; use books	"Use tools to explore the properties and characteristics of objects" "Uses simple tools for exploration and investigation."
Medium Degree of Abstraction (Levels 3, 4, 5)		
Level 3: Communicate-without-Tools	answer questions; confirm (observations); count; define; demonstrate (awareness, knowledge); describe; discuss; display data; document observations; draw; evaluate; give examples; identify; indicate (awareness, knowledge); infer; interpret; know vocabulary; label; name; offer critique; present; recall; recognize; record (data, information); represent; retell; share (explanations, findings, ideas); show understanding; summarize observations; take pictures; talk; use evidence	"Begins to use scientific vocabulary" "Observes and describes characteristics, basic needs, and simple life cycles of living things."
Level 4: Communicate-with-Tools	create maps; graph; use charts; use models; use tally sheets	"Collect, describe, and record information through discussions, drawings, maps, and charts." "Record observations using simple visual tools."
Level 5: Ask-Questions	be curious; demonstrate interest; express wonder; generate questions; show curiosity; show interest	"Exhibits curiosity about objects, living things, and other natural events in the environment." "Asks and responds to questions about relationships of objects, living things, and events in the natural environment."
High Degree of Abstraction (Level 6, 7, 8, 9)		
Level 6: Compare-Contrast	analyze data; categorize; classify; differentiate; discriminate; distinguish; match something with something else; order; organize; sort	"Compares and categorizes solids and liquids based on their physical properties" "Compares baby and adult animals and recognizes similarities (e.g., matches adult stuffed animals with their baby in a play setting)"
Level 7: Predict	anticipate; formulate hypothesis; make guesses; make predictions; predict changes	"Make predictions about changes in materials or objects based on past experience." "Describe and anticipate weather changes."

Level 8: Test-a-Prediction	check predictions; experimentation (engage in, explore through); participate in experiments; test hypotheses; verify predictions	"Test a variety of materials and configurations to design an end product." "Adjusts their approach if results are different than expected and continues testing."
Level 9: Explain	conclude (draw, formulate, make conclusions); explain; form explanations; generalize; generate explanations	"Constructs theories to explain their investigations." "Develops increasingly detailed explanations of their ideas and reasons"

Appendix A.3 Explanation of Codes for Domains of Science (Study 2)

Codes	Words and Phrases	Examples
Life Science		
	Broadly: biology, organism(s), life Specifically: plants, animals, growth, senses, living objects, effect on living things (e.g., of the weather, habitats, environment, seasons)	"Uses senses to observe and describe the properties of familiar plants and animals" "Ask and answer questions about changes in the appearance, behavior, and habitats of living things."
Physical Science		
	Broadly: physics, chemistry. Specifically: objects, motion, sound, light, vibrations, forces, magnetism, materials, matter, circumstances, physical models, physical structures, speed, fast/slow, heating/cooling, melting/freezing, light as energy, light variations, shadows, sinking, floating, temperature, things, states of matter	"Investigates and describes different types or speeds of motion" "Use objects to effect motion (e.g. build a ramp with blocks so the car goes faster)"
Earth/Space Science		
	Broadly: astronomy, meteorology, geology Specifically: earth materials, objects in the sky, sun, moon, stars, water cycle, rock cycle, day/night (cycles), natural objects, natural resources, materials in the environment, changes in the environment, non-living things in the environment (e.g., rocks, minerals, water), seasons, weather, impact of weather on the environment	"Describe how the Earth's surface is made up of different materials" "Observe, describe, and discuss the characteristics of the sun, moon, stars, and sky"
Other Science		
	Broadly: technology, social science, methodology, complex systems, environmentalism. Specifically: effects on daily life (e.g., of the weather), effect of own actions, family, culture, digital media/devices, tools, scientific principles/process, caring for the planet, conservation, recycle/reuse, climate change, environmental concerns, pollution, human impact on earth/weather/seasons, uses of water, complex concepts, guidelines, day/night activities, human use of materials/resources/etc.	"Explains why a simple machine is appropriate for a particular task" "Explore and use simple tools and machines."
Multiple Sciences		
	Combinations (2 or more) of the above categories (Life, Physical, Earth/Space, or Other)	"Explore concepts and information about the physical, earth, and life sciences" "Discriminate between living organisms and non-living objects"
Unclear domain of science		
	World, data, information, environment, nature, events	"Ask questions to find out more about the natural world." "Displays and interprets data."

Appendix A.4 Explanation of Codes for Facts (Study 2)

Codes	Words and Phrases	Examples
Concrete		
	items; objects; materials; activities; resources; events; actions; characteristics; properties; features accessible via senses (visual, auditory, etc.); need; function; purpose; rules; vocabulary; tools (e.g., microscope, computer); reuse/recycle; weather; seasons; habitat; light/shadow; sink/float; ramps; speed (fast, slow); pushing/pulling	L: "Identify and describe common animals and insects." P: "Identify materials that make up objects." E/S: "Identify common earth materials and landforms." O: "Describe typical day and night activities." M: "Describes objects and living things in increasing detail."
Abstract		
Relations	affect; impact; interact; influence; control; cause/effect; why X happens; result of; respond to; generate; depend on; provide for; take care of; protect; preserve; system; family; heredity; offspring; density	L: "Asks questions about the relationship between two things (e.g., Why do you think some animals sleep in the day?)." P: "Investigate different sounds made by different objects and different materials." E/S: "Demonstrates, through observation and investigation, an understanding that human action impacts the earth" O: "Identify how weather affects daily life." M: "Asks and responds to questions about relationships of objects, living things, and events in the natural environment."
Patterns	patterns; changes; cycles (e.g., rock, water); stages; sequence; routine; growth; moving/motion; stability; transformation (e.g., solids to liquids); melting/freezing; heating/cooling; dissolving; polluting	L: "Demonstrates an understanding that living things change over time in size and other capacities as they grow". P: "Explore and describe in greater detail changes in objects and materials." E/S: "Uses senses and tools (including technology) to observe, describe, discuss and generate questions about changes in weather over time" O: "Understands how actions people take may change the environment" M: "Show an awareness of changes that occur in oneself and the environment."
Groups	groups; categories; kinds of; types of; similarities/differences among groups (e.g., mammals; species; age group; living/nonliving); X as Y (e.g., "wetland as an ecosystem"); X vs. Y; X to Y (young to old); X from Y; models.	L: "Compares baby and adult animals and recognizes similarities." P: "Explore different kinds of matter and describe by observing properties." E/S: "Identify various types of moving water" O: "Describe the types of clothing needed for different seasons." M: "Begins to describe the similarities, differences and relationships between objects, living things and natural events."
Forces	force; inertia; friction; buoyancy; magnetism; electricity; gravity; falling without support; vibrations making a sound; energy; light (when a source of energy); heat (when a source of energy)	P: "Explore the effect of force on objects in and outside the early childhood environment." P: "Describes and compares the effects of common forces on objects and the impact of gravity, magnetism and mechanical

		forces.”
General Science		
	general statements about a domain of science; scientific principle; scientific process	L: “Ask questions and conduct investigations to understand life science.” E/S: “The child investigates and observes the basic concepts of the Earth” O: “With prompting and support, use scientific vocabulary words to describe steps in the scientific process” M: “Pose questions about the physical and natural environment.”

Note. The acronyms pertain to the various domains of science (L: life science, P: physical science, E/S: earth/space science, O: other science, M: multiple sciences).

Appendix B: Number of Items and Terms per State

Appendix B.1 Number of Inquiry Items and Terms (Study 1)

	Non-Science Items						Inquiry Terms	
State (Publication Year)	E	M	LA	PG	CfO	Science Items	Unspecified Items	Specified Terms
Alabama (2012)	1			1		17	2	26
Alaska (2007)					1	14	2	17
Arizona (2018)				1		14	1	14
Arkansas (2016)	1			2		24	4	31
California (2012)						25	7	32
Colorado (2011)						11	1	22
Connecticut (2014)						15	3	15
Delaware (2010)				1		20	4	27
Florida (2019)	2			1		26	5	30
Georgia (2019)	1					17	7	21
Hawaii (2014)						11	3	16
Idaho (2014)	1	5	12	15		31	6	41
Illinois (2013)		1		2		18	5	27
Indiana (2014)		2				20	1	23
Iowa (2017)						6	4	3
Kansas (2014)						13	3	15
Kentucky (2010)						14	0	18
Louisiana (2013)				1	1	21	3	30
Maine (2015)	6		1			19	3	31
Maryland (2010)	1		1			13	2	23
Massachusetts (2010)						30	7	35
Michigan (2013)						17	2	25
Minnesota (2014)	3			2		15	3	14
Mississippi (2018)	3					28	8	32
Missouri (2013)	3					9	6	3
Montana (2014)	3			3		37	10	39
Nebraska (2018)						13	3	12
Nevada (2010)			1			46	28	25
New Hampshire (2011)						4	1	3

New Jersey (2014)				1		21	10	37
New Mexico (2017)						10	1	12
New York (2019)		1				18	5	17
North Carolina (2013)					2	19	1	32
North Dakota (2018)			1			4		4
Ohio (2019)						21	8	19
Oklahoma (2016)	1		1		3	38	19	33
Oregon (2016)					1	27	8	31
Pennsylvania (2014)				4		44	7	52
Rhode Island (2013)						19	3	23
South Carolina (2017)	1			1	3	19	2	37
South Dakota (2019)	3		1		4	30	3	42
Tennessee (2019)						17	2	28
Texas (2015)					1	10	6	18
Utah (2013)	1					14	2	13
Vermont (2015)	6				1	22	6	22
Virginia (2013)						34	3	40
Washington (2012)			1		2	9	2	11
West Virginia (2019)						11	5	10
Wisconsin (2013)	2			1		15	4	23
Wyoming (2009)						9	5	14
Total	40	6	19	34	19	959	236	1168

Note. Items differed in whether they pertain to science (*science items*) or not (*non-science items*). Non-science items could be about engineering (E), math (M), language arts (LA), personal growth (PG), or caring for others (CfO). Appendix A.1 provides detailed information about the non-science items were defined. For science items, the abstraction level of their inquiry terms was coded. Inquiry terms could be *unspecified* (i.e., too vague to fit a single abstraction code), or they could be *specified* (i.e., precise enough for an abstract code). Items with only unspecified inquiry terms were referred to as unspecified items.

Appendix B.2 Number of Fact Items and Terms (Study 2)

State	Items without Domain	Items with Domains					Fact Terms				
		L	P	E/S	M	O	Co	R	P	G	F
Alabama	4	3	5	4		1	9	1	3	2	
Alaska	7	2	2	3			4	1	2		
Arizona	9				5		2	2	1		
Arkansas	9	5	3	1		6	9	2	3	1	
California	4	6	8	3	2	2	10	3	9	1	
Colorado	3	3	4	1			2	2	4	1	
Connecticut	6	3	4		1	1	1	5	5	1	
Delaware	7	4	2	3	2	2	5	3	2	3	
Florida	7	6	5	4	2	2	8	4	7	1	
Georgia	3	3	5	4	1	1	5	2	7	2	
Hawaii		2	5	2	1	1	3	2	4	3	
Idaho	17		7	2	2*	2	8	4	1		
Illinois	7	2	4	2	1	2	5	3	3		2
Indiana	4	2*	6	4	1	2	7	1	4	3	1
Iowa	3		1		2		1		2	1	
Kansas		3	2	1	2	5	4	8	3		1
Kentucky	8		6				5	1			
Louisiana	5	5	3	3	2	2*	4	2	8	2	1
Maine	4	5	5	3		2	8	4	3		1
Maryland	3	2	7	1			3	3	2	2	3
Massachusetts	1	9	9	4	4	3	12	9	7	4	
Michigan	4	4	2	4	3		7	2	3	1	
Minnesota	11		1			2*	1	2			
Mississippi	3	11	7	3	4		15	2	8		1
Missouri		3	2*	3			8				
Montana	5	7	11	12	2	*	22	1	6	1	1
Nebraska	8	1	2		2		3	1		1	
Nevada	7	15	13	6	2	2*	24	7	6	2	3
New Hampshire		1	1	1		1	2		2		1

New Jersey	2	5	7	1	6		7	5	5	3	1
New Mexico	6			4				1	2	1	
New York		4	7	3	3	1	9	5	2	2	1
North Carolina	11	1	5	1		1	5		2	1	
North Dakota	3				1		1				
Ohio	9	5	3	3	*		6	2	3	1	
Oklahoma	11	5	11	6*	1	3	21	1	3	1	
Oregon	7	6	8	3	2	1	10	5	6	1	
Pennsylvania		12	7	9	4	12	24	6	10	5	3
Rhode Island	5	6	5		2	1	4	2	5	5	
South Carolina	7	2	7	2	1		8	1	4		
South Dakota	10	4	9	3	2	2	11	4	8		
Tennessee	4	3	4	2	2	2	8	2	4	1	
Texas		3	4	3			5	1	3		1
Utah	3	4	3	3	1		8		2	1	
Vermont	2	6	8	5	1		9	1	8	5	
Virginia	5	4	10	5	2	8	19	4	5	1	2
Washington	5	1	1	2			3		1		
West Virginia	6	1	1	1	1	2	3	2	1		
Wisconsin	12		1		2		2			1	
Wyoming	5	1	3				2	1	1		
Total	262	181	237	129	74	76	362	120	180	61	23

Note. Items differed in whether they could be attributed to a domain of science (*items with domains*) or not (*items without domains*). Domains refer to life science (L), physical science (P), earth/space science (E/S), other science (O), and multiple sciences (M). Appendix A.3 provides detailed information about how the domains of science were defined. The fact terms differ in whether they were concrete only (Co), a relation (R), a pattern (P), a group (G), or a force (F).
*reflects the presence of any additional items not included in the count that were too broad to receive a code for their abstraction level (e.g., "life science").