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Elementary Preservice Teachers' Perceptions of Assessment Tasks that Measure Content Knowledge for Teaching about Matter

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ABSTRACT

Developing knowledge about science instruction is critical for preservice teachers. This study explores how 79 elementary preservice teachers perceive the relevance and importance of assessment task scenarios designed to elicit information about content knowledge for teaching (CKT) about matter and its interactions—a foundational topic for teaching physical science. Participants completed practice-based assessment tasks that described teaching scenarios about elementary science teaching and that addressed five matter topics: properties of matter, changes in matter, the model of matter, materials, and conservation of matter. We aimed to explore how relevant preservice teachers felt these task scenarios were to their teaching experience and how important knowing how to answer these tasks was for the work of elementary teachers. Findings suggest that preservice teachers tended to recognize the centrality of these task scenarios for the work typically done in elementary classrooms, even if they do not report having firsthand experience with the content and practices represented in the scenarios. Moreover, participants tended to provide a general rationale about why these scenarios were important for the work of teaching science, but a limited number of responses made explicit connections between a task scenario and the specific instructional practice related to elementary teachers' work. This study poses implications for the use of CKT tasks in elementary education programs.

KEYWORDS

Elementary preservice teachers; content knowledge for teaching; assessment tasks; work of teaching science

Developing specialized knowledge about teaching science is essential for elementary teachers who enter the profession, as this specialized knowledge is required when they plan for, engage in, and reflect on the work of teaching science (Etkina et al., 2018; Gess-Newsome, 2015; Hanuscin et al., 2018; Hill et al., 2008; Loughran et al., 2012). This specialized knowledge, or what some refer to as content knowledge for teaching (CKT), is paramount for elementary pre service teachers (PSTs), who tend to have limited opportunities to learn science content and pedagogy and face competing demands to teach multiple subjects (Brobst et al., 2017). Content knowledge for teaching (CKT) includes both subject matter knowledge and pedagogical content knowledge (PCK) (Ball et al., 2008) and is an important mediator in teachers' abilities to engage in critical teaching practices, such as selecting instructional resources for planning and enacting an activity (Baumert et al., 2010; Schneider & Plasman, 2011).

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The use of practice-based assessment tasks has the potential to elicit PSTs' ideas about CKT in the context of authentic and teaching-based scenarios. By practice-based assessment tasks, we mean the ones that require test takers—in this case, PSTs—to leverage their subject matter knowledge and pedagogical content knowledge as they engage in a particular aspect of the work of teaching science, such as making decisions about which probing questions to use to elicit student thinking about a specific science phenomenon or concept or which student-generated explanation uses sufficient evidence and reasoning to justify a claim. These practice-based tasks include scenarios such as figuring out how to best interpret students' thinking and deciding how to explore students' specific science ideas and misconceptions (Coffey et al., 2011; Forbes et al., 2015), evaluating the instructional strategies that would be most beneficial to address specific instructional goals (Davis, 2006; Davis & Smithey, 2009), and evaluating the strengths and weaknesses of multiple instructional activities for developing coherent content storylines (Hanuscin et al., 2016; Roth et al., 2011). For PSTs, the use of these CKT task scenarios has the potential of increasing their familiarity with content and practices associated with science teachers' work and opportunities to learn to teach science (Yung et al., 2013).

This study explores how elementary PSTs perceive the relevance and importance of a set of assessment tasks scenarios designed to measure CKT about the Next Generation Science Standards' (NGSS') disciplinary core idea of "matter and its interactions" (PS.1), which is foundational for K-12 science education. A better understanding of PST perceptions about science teaching, represented in task scenarios, can help teacher educators to enhance the areas that PSTs initially identify as important and support them in recognizing the value of those areas they identify less often or do not see as valuable—especially when PSTs have limited experience with some aspects of CKT for matter and its interactions. PST conceptions of teaching science tend to reflect their experiences as learners and, often, these conceptions are resistant to change, which can shape their future classroom practice, and influence decisions about content, activities and strategies to be used (Fives & Buehl, 2016; Koballa et al., 2005). This study can provide insight to teacher educators and researchers about how PSTs perceive the ways in which teaching topics about matter and its interactions is relevant to their conceptions of teaching and important to the work that they will face as elementary science teachers. The research questions for this study are: (1) To what extent and in what ways do elementary PSTs perceive the scenarios represented in CKT assessment tasks as relevant for the work of teaching matter and its interactions?, (2) To what extent and in what ways do elementary PSTs perceive these CKT assessment tasks as important to the work of teaching matter and its interactions?

Conceptual framework

This study explores elementary PST perceptions about the relevance and importance of assessment tasks focused on CKT for matter and its interactions. These assessment tasks were designed as part of the process to develop a new assessment for elementary PSTs to measure CKT for matter and its interactions to be administered in teacher education settings (details on the assessment development process can be found in Mikeska et al., 2020). These assessment tasks focus on authentic and practice-based teaching scenarios with content related to matter and its interactions and contextualized in instructional practices that are critical for the work of beginning elementary science teachers.

Content knowledge for teaching (CKT)

Grounded in Shulman's seminal work (Shulman, 1986) about knowledge bases for teaching, CKT includes both the subject knowledge about a topic—such as matter and its interactions—and the specific knowledge to teach that topic (Ball et al., 2008; Etkina et al., 2018; Hill et al., 2008; Kersting, 2008; Krauss et al., 2008; Phelps et al., 2014). CKT is a key mediator in teachers' abilities to engage successfully in critical teaching practices such as interpreting students' ideas, supporting students' work on content representations, constructing explanations, and selecting and modifying resources for instruction (e.g., Baumert et al., 2010; Hill et al., 2008; Schneider & Plasman, 2011). As such, CKT is part of the professional knowledge base for teaching that transcends the subject matter and includes types of professional knowledge that inform the activities teachers select, the challenges that teachers face, and the decisions that teachers make daily about instruction as part of their practice. There have been several efforts to define and operationalize CKT in different disciplines such as mathematics (e.g., Hill et al., 2004), reading (e.g., Gitomer & Bell, 2013), and science (Etkina et al., 2018) to orient the design of assessments and curricular materials. Aligned with this work, we decided to focus on CKT related to the NGSS' disciplinary core idea (DCI) of "matter and its interactions" (PS.1) to design assessment tasks to measure elementary teachers' CKT. We purposely focused on the broader construct of CKT, rather than a narrower focus on either PSTs' subject matter knowledge or pedagogical content knowledge alone, because we were interested in the ways PSTs bring to bear both CKT knowledge components to address perennial challenges elementary science teachers face as they prepare for, engage in, and reflect on science instruction. By doing so, we were able to target the CKT assessment design on the intersection of these components by developing assessment task scenarios that situate the PSTs in responding to challenges that elementary science teachers face when teaching about matter and its interactions. This approach allows targeting more closely the CKT that elementary teachers use in the work of teaching science.

Each task scenario was aligned with key content categories about matter and its interactions, such as properties of matter and their measurements, properties of materials, the particle model of matter, changes in matter, and conservation of matter. We created operational definitions for these five content categories (see details in Appendix 1), by considering the content specifications for the NGSS' DCI about matter and its interactions (PS.1), research on student ideas about matter (e.g., Krajcik & Merritt, 2012; Mikeska et al., 2018; Nakhleh & Samarapungavan, 1999; Talanquer, 2009), curriculum materials focused on matter (e.g., Kessler & Galvan, 2007), and resources about matter for teachers (e.g., Keeley, 2016).

"Work of teaching science" (WOTS) framework

The WOTS framework describes the science-specific teaching practices that are most critical for beginning elementary science teachers (Mikeska et al., 2018). The framework is based on the review of teacher standards (e.g., the Interstate New Teacher Assessment and Support Consortium Standards, Council of Chief State Schools Officers, 2011) and relevant research literature in science education such as the one focused on critical science teaching practices (e.g., Windschitl et al., 2012). The WOTS framework specifies the content challenges that novice elementary science teachers face in their professional work and is

Table 1. *Instructional Categories for the Work of Teaching Science Framework (WOTS)* (Mikeska et al., 2018).

WOTS Categories	Examples of Science Teaching Practices (Two per Category)
1. Scientific Instructional Goals, Big Ideas, and Topics	- Identifying the big idea or instructional goal of an instructional activity - Choosing which science ideas or instructional activities are most closely related to a particular instructional goal
2. Scientific Resources (texts, curriculum materials, etc.)	- Evaluating instructional materials for their ability to address scientific concepts; engage students with relevant phenomena; promote students' scientific thinking; and assess student progress - Choosing resources that support the selection of accurate, valid, and age appropriate goals for science learning
3. Scientific Models and Representations	- Evaluating or selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals - Evaluating student ideas about what makes for good scientific models and representations
4. Student Ideas	- Analyzing student ideas for common misconceptions regarding intended scientific learning - Developing or selecting instructional moves, approaches, or representations that provide evidence about common student misconceptions and help students move toward a better understanding of the idea, concept, or practice
5. Scientific Language, Discourse, and Vocabulary	- Anticipating scientific language and vocabulary that may be difficult for students - Modeling the use of appropriate verbal and written scientific language in critiquing arguments or explanations, in describing observations, or in using evidence to support a claim
6. Scientific Explanations	- Critiquing student-generated explanations or descriptions for their accuracy, precision, or consistency with scientific evidence - Selecting explanations of scientific phenomena that are accurate and accessible to students
7. Scientific Investigations and Demonstrations	- Selecting investigations or demonstrations that facilitate understanding of disciplinary core ideas, scientific practices, or cross-cutting concepts - Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question

Note. The WOTS framework includes 27 science teaching practices.

organized by various instructional categories that elementary science teachers use as they plan for, engage in, and reflect on teaching science. These WOTS categories can be used to characterize and organize CKT when recognizing, understanding, and responding to the practices that they engage in to teach science. For example, when teachers plan for instruction, they need to select and sequence learning goals that are appropriate for the grade level and aligned with science key ideas or relevant phenomena. As teachers select learning goals, they also need to connect science ideas to particular activities, models, and content representations that are closely related to that learning goal. Based on the outcomes from a nationally convened panel of elementary teacher educators and teachers, Hanuscin et al. (2018) suggested or hypothesized seven categories as critical for the work of novice elementary science teachers (see Table 1). Each category is broken down into specific science teaching practices.

Assessment tasks

Practice-based assessment tasks contextualized in the content of teaching scenarios can be used to elicit PSTs' ideas about CKT. As part of the CKT assessment design, we followed the guidance of earlier work (Ektina et al., 2018; Hanuscin et al., 2018; Phelps et al., 2014) to situate the PST within a specific aspect of the work of teaching science through the use of an opening scenario. The opening scenario is carefully designed to set up the assessment task so that PSTs activate and access the CKT that is relevant to addressing the specific teaching challenge described in that scenario. In other words, the opening scenario serves to situate and contextualize the PSTs' use of their CKT in actual teaching challenges that elementary science teachers face when preparing for, engaging in, or reflecting on their instructional choices in this content topic (i.e., matter and its interactions). The CKT assessment task development process used two key design principles. First, each CKT assessment task is purposefully designed to address the CKT that elementary science teachers need to leverage at the intersection of one matter content category (e.g., conservation of matter) and one science teaching practice from the WOTS framework (e.g., selecting investigations or demonstrations that facilitate understanding of disciplinary core ideas, scientific practices, or crosscutting concepts). By doing so, the CKT matter assessment tasks situate the PSTs' use of CKT within an aspect of the work of teaching science. Second, each CKT assessment task is designed to address a specific teaching challenge that elementary science teachers face when preparing for, engaging in, or reflecting on science instruction in this content topic. This design principle meant that one of the first steps in the CKT matter assessment development process was identifying these specific teaching challenges within each of the five matter topics across the K-5 grade levels and linking those challenges to the various science teaching practices identified in the WOTS framework.

In this study, we asked a group of elementary PSTs to explain the relevance and importance of a group of assessment tasks focused on CKT for matter and its interactions, given its foundational role in science learning and physical science courses in high school and college. The task scenarios were used as a contextual tool to help us elucidate how PSTs connected the tasks scenarios to their experiences as teachers and learners and perceived their importance for the specific aspects of the work of teaching science. Therefore, we hypothesize that PSTs can notice and recognize connections between the instructional context of these task scenarios, the knowledge that is embedded in the task scenarios, and their prior experiences as teachers or learners of science. By contrast, if PSTs are unable to recognize the relevance and importance of the knowledge embedded in teaching scenarios (or believe that irrelevant topics are the important ones), they may not develop awareness of the relevance of the content and practices needed to teach science at the elementary level.

Methods

The purpose of this study is to explore PST perceptions about the relevance and importance of a set of assessment tasks scenarios focused on CKT about matter and its interactions. The tasks were created and designed as part of the process to develop a new assessment for elementary PSTs to measure their CKT for Matter and its Interactions to be administered in teacher education settings. A pool of 130 assessment tasks were created and refined by collaborative teams of experts in elementary science education, physical science content, teacher education, and assessment development (Mikeska et al., 2020). The assessment tasks were developed to target the seven science categories contemplated in the WOTS framework and the five content categories related to matter and its interactions. As part of the assessment development work and before testing the assessment task scenarios with PSTs, a team of teacher educators, assessment developers, and the project's external Advisory Board reviewed them to ensure their alignment with the target content categories for matter and its interactions, the WOTS categories, and the NGSS performance expectations. We explicitly asked our advisory board to confirm whether the task scenarios and questions described realistic classroom situations and reflected the types of thinking elementary PSTs engage in the tasks.

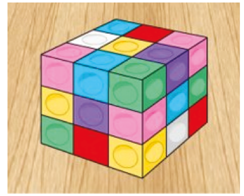
CKT matter assessment task example

Each CKT assessment task is aligned with a specific content category about matter and its interactions and one WOTS category and includes a teaching scenario that describes an instructional situation and provides relevant information, such as descriptions about students' ideas, learning goals, or classroom discussions. In addition, stimuli such as copies of students' written work or images of science instructional materials are included in the tasks. Figure 1 shows an example of a CKT assessment task named s*napblocks*, aligned with the content category of *model of matter* and the WOTS category about *scientific instructional goals, big ideas, and topics*. This assessment task asks PSTs to identify the big idea of an instructional activity, in which elementary students explore that an object can be assembled and disassembled in smaller pieces. This assessment task is also aligned with the NGSS Performance Expectation 2-PS1-3, "Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object," as it introduces students to a model of matter from a macroscopic perspective. When PST select the correct response, "matter is made of small particles that can be arranged in multiple ways," they acknowledge that this activity supports students' understanding of a model of matter composed of small units, because in this activity students recombine small blocks to form something new, which connects to the activity learning goal.

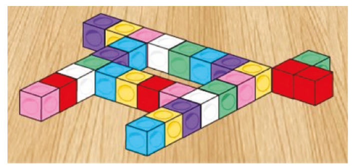
Participants

We recruited 79 PSTs to participate in cognitive interviews with the goal of having each PST answer between six to eight assessment tasks. We asked our network of preservice teacher educators to disseminate a recruitment flyer for elementary PSTs and through their professional networks. PSTs who responded to the recruitment flyer completed a brief survey that helped us select those PSTs that matched the two selection criteria: (1) currently enrolled in a teacher preparation program to teach elementary students and (2) working to be certified to teach science in the elementary grades (K-5). PSTs from different U.S. geographical locations and settings (urban, suburban and rural) and types of higher education institutions (state universities, private universities, and liberal arts colleges) agreed to participate in the study and provided consent for participation. Based on the selection criteria, we selected the 79 participants across multiple institutions. Table 2 describes participant PSTs' demographic information. Although all participants were enrolled in a program to be certified as elementary teachers, only 61% of participants were majoring in elementary education (other participants' majors were special education, general science, early childhood education and psychology, liberal arts, among others). Participants were mainly in their junior or senior year

During a unit on matter, Ms. Johnson asks her second-grade students to take apart a cube made of snap block pieces (see the image below) and examine the number and color of the pieces.



Students are then asked to use all the pieces to make something new. After all students create their own object, they look at one another's objects (see example in the image below). Ms. Johnson guides students to recognize that the number and color of the pieces in the new object remain the same as they try to identify what the object is. Finally, the class has a whole-group discussion that focuses on the potential of a new object being created from the original cube and the wide variety of objects created from the same starting cube.



Which of the following concepts about matter does this lesson best support at a second-grade level of understanding?

A) Matter can undergo changes that are reversible.
B) Matter can be described by observable properties.
C) Materials have properties that make them suitable for different purposes.
D) Matter is made of small particles that can be arranged in different ways.

Figure 1. Assessment Task "Snapblocks."

Table 2. PSTs Demographic Information.

Variables	Frequency (n = 79)	Percent (%)
Gender		
Female	76	96
Male	3	4
Race/Ethnicity		
White	61	76
Hispanic or Latino/a	6	8
Asian	3	4
More than one race [a]	3	4
Not Reported	6	8
Year in the Teacher Education Program		
Freshman/Sophomore	3	4
Junior/Senior	60	76
Graduate	11	14
Not Reported	5	6
Program Type		
Elementary Education	52	66
Early Childhood Education	9	11
Special Education	3	4
Science Major	3	4
Others (e.g., psychology, liberal arts)	10	13
Not Reported	2	2
Science College Courses Completed		
Yes—At least one science course	76	96
No—Science teaching methods only	3	4
Additional Science Experiences as Learner or Instructor (e.g., summer camp, tutoring, volunteer, etc.)		
Yes	22	28
No	57	72

[a]Refers to PSTs who self-identified as "White and Latino/a" (2 PSTs) and "African-American, White, and American Indian and Alaskan Native" (1 PST)

(76%) of their programs and had completed at least one science-focused college course (96%). Most of the participants self-identified as female (96%) and White (76%), which is similar to the population of elementary teachers in the United States (Banilower et al., 2018).

Interviews

We recruited and engaged elementary PSTs in cognitive interviews using concurrent think aloud methodology (Ericsson & Simon, 1984) to elicit PSTs' knowledge and reasoning as they responded to the CKT assessment tasks. We created an interview protocol and interview forms that included six to eight CKT tasks per form. Typically the assessment tasks included in each form included two or three content categories for matter and its interactions. We also made sure that each assessment task was answered by at least four PSTs. For each CKT assessment task, we had participants provide their response choice and explain their knowledge and reasoning. This approach allowed us to learn about the decision processes that the PSTs made and the knowledge that they leveraged as they worked through each assessment task. Then we asked follow-up probing questions to explore whether PSTs thought that the task scenarios were connected to the work of elementary science teaching and whether knowing how to respond to the task was important for the work of elementary science teachers. In this study, we are only focusing on the follow-up probing questions of the interview because these are directly related to the research questions. These questions were:

(For Research Question 1) *Did the scenario presented remind you of something you've experienced in your teaching?* If the participant answered affirmatively, a follow-up question was asked: *Explain what it reminds you of*. However, if the participant response was negative, the interviewer prompted: *Do you think this is a scenario that other teachers might encounter? Why or why not?*

(For Research Question 2) *Do you think it is important for elementary teachers to know how to answer this question? Why or why not?*

The authors of the manuscript were trained in the interview protocol and conducted the interviews. PSTs were contacted via phone for the interview and their responses were recorded and transcribed. Interview time usually ranged from 105 to 120 minutes as participants responded to six to eight CKT assessment tasks. Participants provided consent for participation and were compensated for the time devoted to the interview ($75).

Coding procedures

We first used an existing coding scheme designed to identify the types of responses elicited by PSTs in a previous CKT interview study (Mikeska et al., 2018). Interview transcripts were segmented and then entered in an online software for coding and analysis. Research team members were trained in using the coding procedure and successive rounds of calibration were conducted in the use of the coding. We also organized three sessions in which the research team members coded the same assessment tasks and PST responses (six assessment tasks and 18 responses in total). The agreement among scorers tended to be high (over 85% of exact agreement) and, when discrepancies occurred, we discussed and solved them according to the coding descriptions.

After completing the preliminary coding, we used thematic analysis (Clarke & Braun, 2014) to review PSTs' interview responses and reorganize the coding categories. Based on the review of the preliminary coding and PST responses, we identified a set of preliminary themes and subthemes (see Table 3). Broadly, the themes were related to the relevance and importance of addressing the WOTS framework, the work of elementary teachers, ideas about elementary students' learning, and the types of content embedded in the scenario—either related to matter and its interactions or other topics. Then, we created a matrix that listed themes and subthemes, response frequencies, and

Table 3. List of Preliminary Themes that Guided the Development of the Coding Rounds about Perceptions of Relevance of the Task Scenario and Importance for the Work of Elementary Teachers.

Theme	Theme Foci
Work of Teaching Science	Science teaching practices specifically related to the task scenario
	Science teaching practices not directly connected to the task scenario
Elementary teachers' work	Critical knowledge for elementary teachers
	General ideas or contexts reflected in the task scenario
	Content standards or a particular curriculum
	Generic lessons or activities typically used in elementary classrooms
Elementary students	Task scenario is critical or foundational for science learning
	Task scenario supports student interest
	Task scenario reflects areas of difficulty for elementary students
Content	Specific content related to matter and its interactions
	Science content, but not related to matter and its interactions
	Content related to other subject areas

representative examples that helped reorganize and refine the codes. Thus, through our team discussions, we noticed some patterns across themes and subthemes. For example, we noted that several PST responses recognized the importance of the content described in the scenario, but the ways PSTs described the content tended to be general—and not very different of those responses that paid attention to the lesson activity outlined in the task scenario. Therefore, we decided to group responses that referred to content and activities into one single code focused on contexts of teaching. As an illustration, for the CKT task *snapblocks* presented in Figure 1, PST 60 said the task scenario reminded her of "my second-grade internship placement. One day my teacher was teaching balancing equations by using the natural balance. And she put cubes in like, on different sizes of balance to show like how to balance the equation." PST 57 said the *snapblocks* task scenario reminded her of a mathematics activity ("we use these manipulative blocks a lot for learning math in the lower grades, and we learned about it in one of my math courses in the program as well.") Thus, responses from PSTs 57 and 60 were coded in the same code about contexts of teaching for the first research question.

Likewise, we found that some PST responses were very explicit to recognize the relevance and importance of WOTS practices intended in the task scenario, while other responses referenced other science contexts such as the content described in the scenario. For example, in the case of the CKT task *snapblocks* presented in Figure 1, PST 58 was explicit to include the WOTS practice in her response (" … it's important to also have learning goals … to create lessons but are relevant to your learning goals and that when you have a lesson, you have a learning goal in mind") and PST 65 described that the task was important for elementary teachers because they need to accurately illustrate the content to students ("no matter what I do to this, I'm still going to have this many blocks … They need to be able to prove to the students that I still have so and so many pieces.") Thus, we considered that keeping this distinction was important for the second research question. After completing and discussing our revised codes, we grouped and revised their definitions and computed frequencies for each code.

Coding round 1: perception of relevance of the task scenario

This coding round was developed to understand the extent to which the task scenario reminds the participant of a teaching experience, either in relationship to their own teaching or if the participant believes other teachers might encounter a similar scenario as part of the work of elementary science teaching. Responses were also coded for the nature of how or why the teaching scenario reminds the participant of teaching (see code descriptions and examples in Table 4). Because PSTs often have limited teaching experience prior to entering the classroom, this coding was applied broadly, indicating that the teacher made a connection to something that they have taught themselves, something that they have observed another teacher teaching, or something that they have learned in their K-12 or teacher education. For this coding round, we analyzed 688 PST responses about recognizing relevant connections and 648 PST responses that provided a justification for those connections.

Table 4. Codes Used for Perception of Relevance of the Task Scenario.

Code	Description	Task Scenario	Example of response
Science teaching practice (STP)	Indicates that the PST mentioned the specific science teaching practice evident in the teaching scenario provided in the task, focusing on the teacher's role.	Task: *Liquid definition* A teacher selects two materials to challenge one incorrect student claim that states all substances that take the shape of the container are liquids.	"It's very important for teachers to be able to look at a claim that a student makes and to be able to know evidence to be able to verify whether that claim is correct or incorrect, or to be able to challenge student claims, even if the student makes the claim that is correct." [*PST 17*]
Teaching contexts	Indicates that the PST mentioned the classroom content or context in a way that does not highlight the specific science teaching practice evident in the teaching scenario provided in the task.	Task: *Snapblocks* A teacher asks students to take apart a cube made of snap blocks and resemble the blocks to form a new object. The teacher guides students to recognize that the number and color of the pieces in the new object remain the same.	"Yeah, it does sort of remind me of, in my second-grade internship placement. One day my teacher was teaching balancing equations by using the natural balance. And she put cubes in like, on different sizes of balance to show like how to balance the equation." [*PST 60*]
Ideas students struggle with	Indicates that the PST explicitly referenced specific ideas or concepts that students often find difficult.	Task: *Liquid definition* A teacher selects two materials to challenge one incorrect student claim that states all substances that take the shape of the container are liquid.	"My students did have troubles in asking the difference between solid and liquid based off of their shape. It's for a matter unit when you're supposed to introduce solids generally keep their shape and liquids don't. I have students feel like, oh, but you can fold your clothes into like a smaller space, so as to keep its shape. So, it's a very challenging subject to teach. [*PST 14*]

Coding round 2: perception of importance for elementary science teaching

This coding round was developed to explore whether the participant considered it was important for elementary teachers to know how to respond to the task scenario. Participants were encouraged to provide the reason why they felt it was, or was not, important. Table 5 describes the codes used to explain the rationale for the perceived importance of this task scenario for the work of elementary science teaching and provides examples of task scenarios and PST responses. We coded 673 PST responses about recognizing the importance of the task scenario and 690 PST responses that provided a justification.

After establishing the final codes, crosstabs were used to analyze the frequencies of responses by code, according to the seven WOTS categories and the five content categories for matter and interactions. For example, we computed the frequencies and percent of responses for the content category about model of matter (out of 79 PST responses) that fit each code. We also examined similarities and differences in frequencies for PST responses according to the WOTS and content categories for matter and its interactions (e.g., more than 10% for a particular category). This helped us note trends, for the first research question, in the categories that PSTs perceived more related to the specific science teaching practices intended in the scenario and general descriptions of instructional contexts. Likewise, for the second research question, we noticed trends across categories in which PSTs recognized as more important to know for the specific work of elementary science teaching versus other categories that were considered important but discussed in general terms (e.g.,

Table 5. Codes for Perception of Importance of the Task Scenario for the Work of Elementary Science Teaching.

Code	Description	Task Scenario	Example
Important for doing the work required in science teaching	Indicates that the PST mentioned how teachers must know the content in order to engage in specific science teaching practices.	Task: *Snapblocks* A teacher asks students to take apart a cube made of snap blocks and resemble the blocks to form a new object. The teacher guides students to recognize that the number and color of the pieces in the new object remain the same.	"I think that it's important to also have learning goals that are . . . are relevant to your learning goals and that when you have a lesson, you have a learning goal in mind." *[PST 58]*
Critical or foundational science knowledge	Indicates that the PST mentioned how a scientific concept, fact, or idea is critical or foundational knowledge for them to have as a teacher to help students learn, or to the discipline itself.	Task: *Snapblocks* A teacher asks students to take apart a cube made of snap blocks and resemble the blocks to form a new object. The teacher guides students to recognize that the number and color of the pieces in the new object remain the same.	"Just so that they can show their students that no matter what I do to this, I'm still going to have this many blocks, it's just not in this shape anymore. They need to be able to prove to the students that I still have so and so many pieces; it just looks like this now." *[PST 60*]
Related to science curriculum or assessment	Indicates that the PST mentioned how this scientific concept, fact, idea is part of the curriculum that is taught at a particular grade level or content that is part of the assessments they use for students.	Task: *Class demo* A teacher asks students to use evidence from a video that shows mixing vinegar and baking soda to draw conclusions about the formation of a new substance.	"With the new Next Generation Science Standards, this is probably part of the elementary school curriculum now so I think it's important for teachers to know." *[PST 79*]

responses that referred to the scenario context only.) We also focused on identifying task scenarios that PSTs found noteworthy, critical, or irrelevant to the work of science teachers and compared interview responses in which PSTs felt the scenario was very familiar to their prior experiences and those scenarios that they felt they were more distant. This resulted in our selection of a pool of ten assessment tasks, five per research question, that were used to illustrate the differences and trends in PST responses.

Findings

For each research question, we present and describe frequencies for response codes, including the breakdown by content categories for matter and its interactions and WOTS. Then, we show examples of PSTs' responses to one selected assessment task to illustrate trends in the ways PSTs perceived the task scenarios and highlight PST perceptions of relevance and importance for elementary science teaching.

RQ1: To what extent and in what ways do elementary PSTs perceive the scenarios represented in these CKT assessment tasks as relevant for the work of teaching matter and its interactions?

All PSTs recognized connections between the CKT task scenario and a teaching experience (either personal or that other elementary teachers may encounter). Seventy-five out of 79 PSTs made this type of connections in more than 75% of the assessment tasks they reviewed. Regarding responses to the individual assessment tasks, in about half (50.7%) of the responses (N = 668), the scenario reminded them of something they have experienced in their teaching and in 46.9% of the responses the participants mentioned the task scenario reminded them of a situation that other teachers may encounter. Participants did not recognize a teaching connection of the task scenario or expressed uncertainty in 2.4% of the responses.

Perception of relevance of the task scenario

Table 6 summarizes the codes for the relevant connections that participants made between the assessment scenarios and their own or others' teaching experience. Among the 648 responses that were coded as the participant making a connection between the assessment task scenarios and their teaching experience, and that provided a justification for their choice, only 30.4% of the responses referenced the specific aspect of science teaching intended in the assessment task scenario. The majority of the responses (65.1%) of the connections made were related to the teaching context of the scenario but not related to the specific teaching practice. A few responses (3.4%) made connections to the assessment task scenario and specific ideas about matter that elementary students struggle with. These results suggest that the majority of PSTs, although recognizing the task as part of a plausible teaching scenario, tended to make connections that are general or broader, and less focused on science-specific teaching practices.

Table 6. Codes Used for Perception of Relevance of the Task Scenario (Only Participant Tasks Responses that Recognized a Connection and Provided a Justification).

Code	Task Responses [a] (N = 648) *N* (%)
Science teaching practice[b]	197 (30.4%)
Teaching contexts	422 (65.1%)
Ideas students struggle with	22 (3.4%)
Other reasons[c]	7 (1.1%)

[a]The *N* represents the number of participant task responses that met each code. Each participant response could receive one or more "perception of relevance of the task scenario" codes.
[b]PST mentioned the specific WOTS teaching practice associated with the task scenario.
[c]Examples of "other reasons": (1) task scenario was irrelevant for elementary science but relevant at higher grade levels (2) resources described in the scenario were not available in school placement so a connection cannot be made (3) relevance, is described in terms of ensuring safety in inquiry, activities.

Perception of relevance of the task scenario by WOTS categories

Table 7 compares frequencies for reasons for teaching connection, according to the WOTS categories. PSTs referred in their explanation to the specific science teaching practice intended in the assessment scenario, more frequently, in the case of WOTS category 6, *scientific explanations* (37%) and WOTS category 7, *scientific investigations and demonstrations* (33%). By contrast, for WOTS category 1 *scientific instructional goals, big ideas, and topics* and WOTS category 4, *scientific models*, fewer PSTs' responses recognized connections between the assessment scenario and the work of science teaching.

Table 7. Task Responses that Recognized a Type of Connection to the Task Scenario, for Each Category of the WOTS Framework and Code (N = 648 Responses in Which PSTs Recognized a Connection and Provided a Justification).

	Science teaching practice[a]	Teaching contexts	Ideas students struggle with	Other reasons
	N (%)	*N* (%)	*N* (%)	*N* (%)
WOTS 1 Scientific instructional goals, big ideas, and topics (18 assessment tasks; 87 PSTs' responses)	22 (25)	63 (73)	2 (2)	0 (0)
WOTS 2 Scientific resources (13 assessment tasks; 56 PSTs' responses)	15 (27)	39 (69)	1 (2)	1 (2)
WOTS 3 Scientific models and representations (14 assessment tasks; 71 PSTs' responses)	18 (25)	49 (69)	3 (4)	1 (1)
WOTS 4 Student ideas (26 assessment tasks; 138 PSTs' responses)	43 (31)	88 (64)	7 (5)	0 (0)
WOTS 5 Scientific language, discourse, vocabulary and definitions (14 assessment tasks; 72 PSTs' responses)	23 (32)	42 (58)	5 (7)	2 (3)
WOTS 6 Scientific explanations (22 assessment tasks; 108 PSTs' responses)	41 (38)	62 (57)	3 (3)	2 (2)
WOTS 7 Scientific investigations and demonstrations (23 assessment tasks; 116 PSTs' responses)	38 (33)	74 (64)	2 (2)	1 (1)

[a]PST mentioned the specific WOTS teaching practice associated with the task scenario.
Note: Each participant response could receive one or more "reasons for teaching connection" codes.

Table 8. Task Responses that Recognized a Type of Connection to the Task Scenario, for Each Category of Matter and its Interactions and Code (N = 648 responses in which PSTs Recognized a connection and Provided a Justification).

	Science teaching practice[a]	Teaching contexts	Ideas students struggle with	Other reasons
	N (%)	*N* (%)	*N* (%)	*N* (%)
Changes in matter (42 assessment tasks; 206 PSTs' responses)	74 (36)	126 (61)	4 (2)	2 (1)
Conservation of matter (17 assessment tasks; 80 PSTs' responses)	29 (36)	49 (62)	2 (2)	0 (0)
Materials (10 assessment tasks; 48 PSTs' responses)	11 (23)	37 (77)	0 (0)	0 (0)
Model of matter (16 assessment tasks; 79 PSTs' responses)	18 (23)	59 (75)	1 (1)	1 (1)
Properties of matter and its measurements (45 assessment tasks; 235 PSTs' responses)	63 (27)	153 (65)	14 (6)	5 (2)

[a]PST mentioned the specific WOTS teaching practice associated with the task scenario.
Note. Each participant response could receive one or more "reasons for teaching connection" codes.

Perception of relevance of the task scenario by matter and its interactions content categories

Table 8 presents the percent distribution of PSTs' reasons for teaching connection, based on the five content categories for matter and its interactions. Although the percent of PSTs that referred in their explanations to the specific science teaching practice of the assessment task tended to be lower than responses focused on teaching contexts, we found some differences between content categories. *Materials* and *model of matter* were the content categories in which PSTs recognized the specific teaching practice of the assessment task less (about 23% of the responses). Likewise, for these two content categories, PSTs tended to provide more responses related to the teaching contexts described in the scenarios. In the case of the code about ideas that students struggle with, the majority of the responses were related to the content category of *properties of matter and its measurements*.

Evidence of assessment tasks

In this section, we present response examples to one selected CKT assessment task to illustrate the nuances in PST responses for teaching connection. The assessment task presented in Figure 2, named *selecting objects*, asks PSTs to choose investigations that facilitate students' understanding that solids tend to retain their shape, while liquids tend to take the shape of their container. PSTs who correctly respond to this item, and select the bead and the cup of water are the objects that best help students understand specific properties of solids and liquids, are able to leverage the idea that a single bead will not change its shape when placed in a container but the water will take the shape of its container. The task scenario is aligned with the WOTS category 7 about *scientific investigations and demonstrations* and the content category of *properties of matter and its measurements*. PST responses to this assessment task demonstrate the different types of connections they made between the teaching scenario and either their own teaching experiences or teaching experiences they believe other teachers might encounter.

Ms. Feliciano prepares a set of stations to help her second-grade students investigate different types of solids and liquids. Each station has several objects sorted by similar characteristics.

Station 1	Station 2
Piece of aluminum foil, rubber bands, pipe cleaners. 	Sand, granulated sugar, beads 
Station 3	Station 4
Water, vegetable oil, and molasses 	Cotton balls, felt, wool yarns 

As students rotate through the stations and write down observations about the objects and their properties, they discuss their observations with their classmates, explain how the objects were sorted in each station, and identify each object's state of matter.
The first activity that students do at each station is to transfer each object from their container to separate clear plastic cups. Ms. Feliciano selects this activity to help students develop an understanding that solids tend to retain their shape while liquids tend to take the shape of their container.

Which of the following combinations of objects will best help students develop this understanding?

A) A bead and a cup of water
B) A pipe cleaner and a cotton ball
C) A cup of granulated sugar and a cup of water
D) A piece of felt and a piece of aluminum foil

Figure 2. Assessment Task "Selecting Objects."

For example, PST 66 described how this assessment task was somewhat similar to a phases of matter lesson that this PST had taught to first graders in which students identified objects based on their state of matter. She described, "it's like out of nine objects: which three were liquids?, which three were gas?, and which three were solid? And it was fairly simple … " PST 72 made a connection to her own teaching experiences and the WOTS science teaching practice of the task. She said,

> It's not a lesson that I've taught or participated in yet, but I think as many of the questions have asked, being intentional about your resources and thinking how to stage and set it up so that students get the idea, and then maybe extending on that idea, is something that I thought a lot about in my lesson planning so far.

While PST 72 had not taught a lesson like the one included in the task, she was able to see a connection to the science teaching practice of intentionally selecting resources and activities as part of the lesson planning process she has engaged in. Out of the respondents who were not able to make a connection between the task and their own teaching experiences, PSTs were able to see the scenario in the task as one that other teachers might encounter. For example, PST 74 saw the content of this lesson as being something that teachers would teach and described how "trying to isolate this one idea is something that teachers, I'm sure, see often." In addition to the content being something other teachers would teach, other PSTs considered the science teaching practice included in the task as a teaching practice that teachers would often engage in. For example, PST 73 said that the scenario is something other teachers might encounter "because it's important to show students the difference between a shape, a solid retaining its state, and a liquid changing, and taking the shape of the container. And it's important that they show and know how to show students." Not only is content about solids and liquids something teachers would teach, this PST believes that teachers need to know how to demonstrate this idea effectively to their students. These findings show that while some PSTs had direct experiences with a scenario similar to the one presented in the task and some did not, four out of five PSTs who reviewed this assessment task were able to identify this task as describing a plausible science teaching scenario and therefore, relevant to the work of teachers. However, a few PSTs were able to include in their answer the specific teaching practice this assessment task was designed to engage the PST in when responding to it.

RQ2: To what extent and in what ways do elementary PSTs perceive CKT assessment tasks as important to the work of teaching about matter and its interactions?

In 644 out of 673 assessment task responses (95.7%), PSTs considered that knowing to respond to the task was important for elementary teachers in at least one of the six to eight assessment tasks they reviewed. By contrast, in only 3% of the responses (20 out of 673), PSTs did not perceive that knowing how to respond the specific task was important for the work of elementary teachers. In only nine responses, PSTs expressed uncertainty about the importance of the CKT task.

Perceived importance of the task scenario for elementary teachers' work

Figure 3 presents the number of responses to the codes for perceived importance. Among the 690 PSTs' responses that perceived that knowing how to answer the assessment tasks was important for the work of elementary teachers and provided a justification, 69% of PSTs' responses were coded as it was important for elementary teachers because they needed to address the science teaching practices of the WOTS framework (and referred to them.) Thirty-five percent of the PSTs' responses were coded to reflect that knowing how to respond to these assessment tasks was important and critical for elementary teachers,

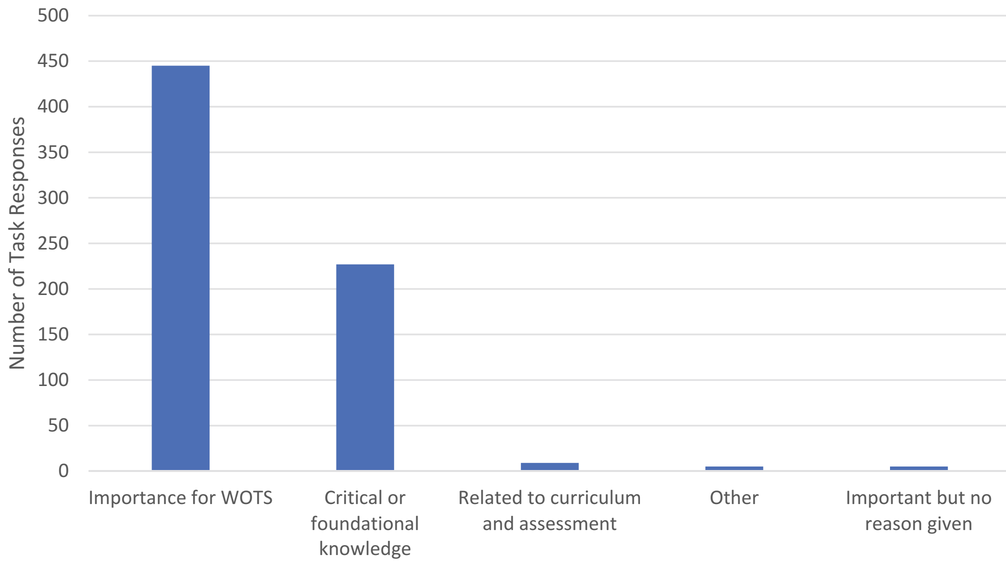


Figure 3. Codes for Perception of Importance of the Task Scenario for the Work of Elementary Science Teaching (N = 695, which includes five responses that did not provide a justification for their perceived importance.).
Note. Examples of "other" responses about importance of the task scenario for elementary teachers' work were the task scenario promotes student curiosity or interest, is more appropriate for middle school teachers, or considered important for teachers' work but uncommon.

because they were connected to foundational knowledge of the elementary science curriculum. Responses associated with the codes about "curriculum and assessment" and "other reasons" had fewer mentions.

Perceived importance of the task scenario for the work of elementary teachers by WOTS categories

Table 9 shows the percent of PST responses according to the reasons for perceived importance for the work of elementary teachers and the categories of the WOTS framework and code. Although the majority of the teachers attributed the importance of responding to the task to the need of knowing about science teaching practices, we found some trends that suggest differences among WOTS categories. Regarding the code about importance for the work required in science teaching, the responses that fit this code range from 56% to 68% with larger percentages for the WOTS categories 4 (student ideas), 5 (scientific language, discourse, vocabulary and definitions), and 6 (scientific explanations). For the code about critical or foundational knowledge, the proportion of responses ranges from 28% to 40% with the largest frequency for the WOTS category 2 (scientific resources).

Table 9. % of Task Responses that Recognized the Importance of the Assessment Task for the Work of Elementary Teachers, for Each Category of the WOTS Framework and Code (N = 690 responses).

	Importance for WOTS	Critical or foundational knowledge	Related to curriculum or assessment	Other reasons
	N (%)	*N* (%)	*N* (%)	*N* (%)
WOTS 1 Scientific instructional goals, big ideas, and topics (18 assessment tasks; 91 PSTs' responses)	57 (63)	32 (35)	1 (1)	1 (1)
WOTS 2 Scientific resources (13 assessment tasks; 67 PSTs' responses)	38 (57)	27 (40)	2 (3)	0 (0)
WOTS 3 Scientific models and representations (14 assessment tasks; 73 PSTs' responses)	45 (62)	28 (38)	0 (0)	0 (0)
WOTS 4 Student ideas (26 assessment tasks; 140 PSTs' responses)	96 (69)	40 (29)	2 (1)	2 (1)
WOTS 5 Scientific language, discourse, vocabulary and definitions (14 assessment tasks; 81 PSTs' responses)	55 (68)	25 (31)	0 (0)	1 (1)
WOTS 6 Scientific explanations (22 assessment tasks; 117 PSTs' responses)	79 (67)	35 (30)	2 (2)	1 (1)
WOTS 7 Scientific investigations and demonstrations (23 assessment tasks; 121 PSTs' responses)	75 (62)	40 (33)	2 (2)	4 (3)

Each participant response could receive one or more “importance for the work of elementary teachers” codes.

Perceived importance of the task scenario for the work of elementary teachers by matter and its interactions content categories

Table 10 presents the proportion of PST responses, according to the reasons for the importance attributed to responding to the assessment tasks and assessed content categories for matter and its interactions and code. Regarding the code about importance for doing the work required in science teaching, the proportion of responses ranged from 60% for model of matter to 69% for the category about materials. For the code about critical or foundational knowledge, the proportion of responses ranged from 28% (materials) to 37% (model of matter). In all content categories, the percentage of responses that fit the code about importance for the work required in science teaching was higher than the percentage for the code of critical or foundational knowledge.

Table 10. % of Task Responses that Recognized the Importance of the Assessment Task for the Work of Elementary Teachers, for Each Category for Matter and its Interactions and Code (N = 690 responses).

	Importance for WOTS	Critical or foundational knowledge	Related to curriculum or assessment	Other reasons
	N (%)	*N* (%)	*N* (%)	*N* (%)
Changes in matter (42 assessment tasks; 226 PSTs' responses)	144 (64)	75 (33)	2 (1)	5 (2)
Conservation of matter (17 assessment tasks; 89 PSTs' responses)	56 (63)	33 (37)	0 (0)	0 (0)
Materials (10 assessment tasks; 49 PSTs' responses)	34 (69)	14 (29)	1 (2)	0 (0)
Model of matter (16 assessment tasks; 80 PSTs' responses)	48 (60)	30 (38)	2 (2)	0 (0)
Properties of matter and its measurements (45 assessment tasks; 246 PSTs' responses)	162 (66)	77 (31)	2 (1)	5 (2)

Each participant response could receive one or more “importance for the work of elementary teachers” codes.

Evidence of assessment tasks

In this section, we present examples of PST responses to one CKT assessment task to illustrate the nuances in their perception of importance for elementary teachers. Figure 4 presents the assessment task named *extending the models*, aligned with the content category of *conservation of matter* and the WOTS category 3 about *scientific models*. Specifically, it focused on selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals. Responses to this assessment task, shown in Figure 4, illustrate differences among PST perceptions of the importance of elementary teachers' ability to answer the task.

As part of a unit on the conservation of matter, Mr. Jones guides his fifth-grade students to make models of a body of water in plastic containers with tight-fitting plastic lids. They add rocks, sand, and water to their models, weighing each individual component, and then the completed system.
They set their models on a sunny window ledge. The following day the students notice that some water droplets have formed on the inside of the lids.
Mr. Jones asks the students to make analogies between their models and other systems that they have observed.

Carl says: "The model is like my aquarium at home. The water filter helps move the water around the tank. Sometimes the filter makes the water splash up onto the sides of the tank so I see little water droplets. I haven't ever weighed my aquarium, but I don't think that matters."

Mary says: "I think the model is like the terrarium I have on my dresser. The water travels from the bottom where the little pond is to the top and so I see water droplets hanging off the inside of the lid. My terrarium has plants inside, though. I don't think I have ever weighed it, either."

Based on their analogies, which student demonstrates a better understanding of the model?

A) Carl demonstrated a better understanding of the classroom model.
B) Mary demonstrated a better understanding of the classroom model.
C) Both students demonstrated equal understanding of the classroom model.
D) Neither student demonstrated any understanding of the classroom model.

Figure 4. Assessment Task "Extending the models."

PSTs considered this assessment task as being important for elementary teachers to know how to answer it for different reasons, such as important for the WOTS framework or as foundational science knowledge for teachers. For example, PST 45 made a connection to the WOTS and said, “I think it would be very important for them to answer the question, because you want to make sure that if a student is giving you an example, they’re choosing one that actually relates to the content, so they don’t get confused.” PST 45 saw the importance of teachers knowing how to analyze students’ analogies and models for their correlation to the phenomenon so that they do not generate misconceptions.

PST 52 also believed that it is important for elementary teachers to know how to answer the task, but this PST saw it as emphasizing critical or foundational knowledge for teachers. This task is relevant for her because it includes developmentally appropriate ideas for upper elementary students that upper elementary teachers should have the scientific understanding necessary to answer this task. She explained,

> I think specifically, like upper elementary, like fourth or fifth. This is a good idea to have the students think about. I think if you ask any younger [children], they would kind of not really understand enough to go out and be able to explain the water in my fish tank . . . it would kind of be like, ‘My fish splashed up some water in his tank so now it’s evaporated.’ I don’t think they would get the idea of what we’re asking them, so, I’d say definitely a fourth and a fifth-grade elementary school teacher should definitely know.

On the other hand, PST 55 did not recognize the importance of knowing how to answer this task at all. PST 55 described how this task is not important for elementary teachers to know how to answer because, “I think that they don’t really need to think about other student’s own experiences, like how it can apply to the model because again, this model doesn’t really demonstrate experiences. It’s just an example that they use in class.” This suggests PST 55 is struggling to not only see the value in bringing students’ personal experiences into the classroom, but also fails to recognize the value of using models in science instruction—an aspect that we saw consistently across several assessment tasks.

Discussion

In this study, we examined 79 elementary PST responses to a set of assessment tasks focused on CKT for matter and its interactions. We explored how PSTs perceived the relevance and importance of these task scenarios for the work of elementary science teachers. This study is grounded in the research work on CKT (e.g., Ball et al., 2008; Baumert et al., 2010; Schneider & Plasman, 2011) and the framework for categorizing elementary science teachers’ work (Hanuscin et al., 2018). The study also addresses prior research on the importance of considering elementary science teachers’ conceptions of teaching (e.g., Fives & Buehl, 2016; Koballa et al., 2005; Yung et al., 2013). Our findings suggest that, across assessment tasks, PSTs tended to recognize the teaching scenarios presented in the assessment tasks as relevant for elementary teachers and important for elementary teachers’ work. We found nuances in their perceptions of the assessment task scenarios, especially in recognizing the science-specific content and science teaching practices involved in the tasks.

First, we learned participant PSTs were mostly able to recognize the relevance of the task scenarios, even when they did not have firsthand experience. Interview responses show that PSTs were able to draw on multiple and varied teaching connections, as learners or as teachers of science and of other subjects, to find relevance in the assessment scenarios. The analysis of interview responses describes a broad spectrum of experiences that PSTs use to leverage their prior knowledge and experiences to identify why the task scenario is related to elementary teachers' work. For example, some PSTs referred to their experiences learning science in middle and high school and in science college courses. Others recalled experiences in the methods courses and field experiences—not only in science, but also in other content areas such as mathematics. Overall, it is important to note the diversity of experiences that PSTs bring into their understanding of what elementary science teachers' work looks like and the recognition of task scenarios that are important for teachers. We also learned that PSTs can envision other teachers encountering specific teaching scenarios, even if they have not had direct experience with them. This suggests that PSTs who have opportunities to learn with authentic teaching scenarios can become familiar with a set of knowledge and resources that can be enacted in the classroom and recognize the content and teaching practices they will teach as beginner teachers (Yung et al., 2013). Therefore, this type of practice-based scenario can be used to support elementary PSTs by developing instructional resources and formative assessment opportunities about learning to teach matter and its interactions. Working in teacher education settings, Yung et al. (2013) suggested that the analysis of teaching scenarios has the potential of eliciting, modifying, or reinforcing PST conceptions of good science teaching and can potentially impact their preparedness to teach science. Furthermore, those PSTs who are not able to make any type of connection may need more support in learning how to bridge these prior experiences to particular teaching scenarios. In the process of helping PSTs develop the knowledge and practices necessary to teach science effectively, leveraging PSTs' prior experiences appears to be a good starting point in teacher education courses.

Second, we found that many PSTs struggled to identify the specific disciplinary knowledge and teaching practices that are embedded in the task scenarios. PSTs tended to recognize that the task scenarios were relevant for the work of elementary teachers from a more generic standpoint (i.e., referring to the content or instructional context) instead of identifying the specific content topic and WOTS categories each assessment task was aligned to. This suggests that many PSTs tend to recognize the assessment task scenarios are related to the general domain of *matter and its interactions* and to the work of teaching science—but in a broader fashion. Within this general pattern, we found some differences across content and WOTS categories. PSTs tended to identify more frequently the importance (although slightly) of tasks related to working with student ideas, such as addressing student misconceptions, and those related to selecting and using scientific investigations and demonstrations, in comparison to other WOTS practices. Similarly, in the case of content categories about properties of matter and their measurements and changes in matter, PST responses tended to be slightly more specific to identify the importance of the task to prior experiences and their relevance. By contrast, the CKT assessment tasks aligned with the WOTS category 4, *scientific models* and the content category about *model of matter*, tended to reflect a more general recognition of their importance and relevance for elementary science teaching. Overall, these findings suggest that PSTs need a more refined and nuanced understanding of the specific teaching practices they have trouble recognizing. Thus, teacher educators would need to provide practice-based learning opportunities in teacher education so PSTs can learn to recognize how CKT is leveraged in the components of the work of teaching science more directly. Developing CKT for PSTs requires the interplay of different types and categories of knowledge, related to specific content ideas, with specific teaching practices, and with specific students (Carlson et al., 2019). Therefore, PSTs would need a more specific understanding of the key ideas of the disciplinary core ideas for matter and its interactions, especially to identify how these ideas are distinctive from one another.

Limitations of the study

We recognize the limitations of the study. First, our PST sample was not randomly selected, and participants' findings cannot be generalized to the national population of elementary science teachers. Amidst the diverse characteristics and modalities for teacher preparation programs for elementary education, we cannot assume that PST responses are applicable to the context of each program structure and curricula. Future studies can explore how PST perceptions of relevance and importance vary across demographic variables, such as participation in field experiences or teaching experience. Second, our data source relied on cognitive interviews that, although they provide rich and descriptive information about PSTs' thoughts and perception, do not capture evidence about what PSTs can do in the context of their field placements or classrooms. Third, we did not collect complementary evidence for this study for other measures of PST learning. Future research would aim to integrate a more comprehensive set of measures about elementary PST work about science CKT.

Contribution of the study

The findings of the study are important for preservice teacher education, assessment developers, and researchers in teacher education. Given that elementary PSTs have limited opportunities to teach science in their teacher education programs, developing assessment tasks that are closely related to PSTs' teaching experiences and relevant to their teaching practice is essential in teacher education settings. Research posits that PST conceptions of teaching science tend to reflect their experiences as learners and can be resistant to change (Fives & Buehl, 2016; Koballa et al., 2005); therefore, the use of task scenarios can help PSTs increase and diversify their knowledge of classroom contexts in which content and practices interplay. In this effort, PSTs could be provided with learning opportunities to help them analyze and interpret these task scenarios to develop a more fine-grained understanding of the specific content, either science disciplinary content or knowledge for teaching science. Potentially, PSTs can broaden their awareness of different teaching scenarios, recognize connections between the work of elementary teachers and their prior experiences, and increase their knowledge of instructional strategies, content representations, and activities (Yung et al., 2013). As PSTs develop knowledge about quality assessment scenarios, they can also make connections with other topics that are relevant to elementary science education.

This analysis also provides evidence to support the validity of the assessment tasks designed for CKT about matter and its interactions. The interviews conducted on elementary PSTs suggest the widespread relevance of the assessment scenarios. The results of this study can be also used for task revisions to make the assessment tasks more relevant to PSTs' experiences. Other researchers in preservice teacher education can develop similar task scenarios (for instructional and assessment purposes) that are relevant to the elementary pre service teacher population and help them to increase their knowledge of the work of teaching science.

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Appendix

Definition of content categories for Matter and its Interactions used in assessment scenarios

Content Category	Definition
Materials	This sub-area focuses on materials' descriptions based on their properties. According to their properties, different materials can be related to specific purposes; for example, to explain the uses of a material based on evidence or design a solution. This sub-area is typically explored in an engineering context in grades K-2. Tests of different materials, or objects or tools made of these materials, are conducted to produce data. The collected evidence is generally qualitative (e.g., relative hardness). The data can be analyzed to determine the relationships between certain properties of materials and their suitability for their intended uses. The data can also be used as evidence to support or refute claims about the suitability of a particular material relative to other materials for its intended purpose (e.g., a rock is harder than a piece of wood, so the rock would be more suitable for breaking a nut.). The properties of some materials may be changed when heated or cooled, which may affects it suitability for use.
Properties of Matter and its Measurements	This sub-area focuses on descriptive properties that characterize matter such as texture and hardness, as well as the quantitative properties such as mass and volume. Behaviors of different types of matter can be explained by their properties. This area also addresses the description of solids, liquids, and gases based on properties of matter. Measurements of weight and volume of different materials are included in this characterization. (Boundary: In grades K-5, mass and weight are not distinguished.) This sub-area is typically explored in the context of planning and carrying out investigations involving observations and measurements of properties of different kinds of materials. The investigation plan may involve observing materials at different temperatures. This sub-area also includes using tools and methods to collect the data. In grades K-2, the focus is on recognizing patterns in the observable properties of materials and describing and classifying objects or materials based on shared properties. For example, solids have definite shapes and liquids take the shape of their container. In grades 3–5, some properties may be measured, such as weight and volume, in standard metric units (grams and liters), while others are observed qualitatively, such as conductivity and reflectivity. The collected data can serve as evidence for identifying materials. For example, a metal spoon and a plastic spoon made to look like metal can be distinguished by how they conduct heat, the sound they make when dropped, and relative mass.
Model of Matter	This sub-area focuses on developing a particle model of matter and using this model to explain some properties of solids, liquids, and gases. The model is developed from the observation and description of macroscopic matter properties, for example, the particle model can be used to explain the behaviors of gases. In grades K-2, matter is modeled using macroscopic particles, such as building blocks. Objects made of pieces can be disassembled and reassembled into new objects with different characteristics (e.g., size, shape, arrangement of pieces). However, the properties of the pieces themselves remain the same. In grades 3–5, particle models are used to describe and explain the behavior of bulk matter. Observable phenomena, such as the effects of wind on objects, inflating a balloon, or sugar dissolving in water, provide evidence that matter is made of particles that are too small to be seen. At this grade level, the sub-area does not include creating and using models to explain atomic-scale mechanisms of evaporation and condensation, or defining the invisible particles (i.e., atoms, molecules, or ions).
Changes in Matter	This sub-area focuses on physical and chemical changes in matter. During a physical change, a substance changes form but not its chemical composition. During a chemical change, a new substance with a different composition and properties is formed. Matter can change when heated or cooled. Chemical changes also may occur when two or more substances are mixed. Some changes in matter are reversible, while others are irreversible. Observations of the quantitative properties (e.g., mass, density) and qualitative properties (e.g., state of matter, color, texture, and odor) of the substances are used to determine what type of change occurred. In grades K-2, this sub-area is typically explored through observing the effects on matter by heating or cooling. Changes caused by heating and cooling may be reversible or irreversible. As an example of a reversible change, ice can be melted into liquid water by heating and then refrozen into ice. The cooking of an egg is an example of an irreversible change; upon cooling, the egg does not revert to its original form. In grades 3–5, this sub-area is typically explored in the context of planning and carrying out investigations to produce data that will serve as evidence that mixing two or more substances may have resulted in a chemical change. An investigational plan will include observations and measurements of quantitative and qualitative properties of the substances before and after they are mixed. Also included in the plan can be methods, such as controlling the variables and running multiple trials, to ensure reliable data. Examples of reactions that produce observable changes include baking soda and vinegar (gas production) and milk and vinegar (curdling).

(*Continued*)

Content Category	Definition
Conservation of Matter	This sub-area focuses on the conservation of matter during physical and chemical changes. Measurements of mass provide evidence that regardless of the type of change, the total amount of matter does not change. (Boundary: In grades K-5, mass and weight are not distinguished.) Although this sub-area is typically not addressed until upper elementary, in K-2 the manipulation of a finite number of building blocks can introduce students to the concept of conservation of matter. In grades 3–5, this sub-area involves the measurement of the weights of substances before and after heating, cooling, or mixing. This sub-area also involves graphing data and performing calculations to support the idea that matter is conserved. Simple experiments to demonstrate the conservation of matter include the melting and freezing of water and dissolving salt or sugar in water. Some experiments can be designed to address misconceptions such as gases have no weight. For example, the reaction between baking soda and vinegar can be conducted in both sealed and open containers, and the changes in the total weights can be compared.