Knowledge in Use: Examining Elementary Teachers' Content Knowledge for Teaching (CKT) about Matter using Scenario-Based Assessments

Jamie Mikeska & Dante Cisterna, Educational Testing Service

Heena Lakhani, University of Washington

Luronne Vaval & Allison Bookbinder, Teachers College, Columbia University

David Myers, University of Georgia

Overview of Talk

- CKT overview – focus, importance, and measurement approaches
- Study purpose
  - CKT assessment framework
  - Example CKT matter item
- Study methods
- Findings
- Implications and contributions

Background

What is content knowledge for teaching (CKT)?

- Defined as the **professional knowledge** that teachers draw upon as they **engage in the work of teaching** in a specific discipline
- Form of **applied knowledge** that is "tailored to the work that teachers do with curriculum, instruction, and students" (Ball, Hill, & Bass, 2005, p. 16) and includes:
  - Subject matter knowledge
  - Specialized and pedagogical content knowledge
- Recognized by the field as **subject, topic, and concept-specific**

Why is CKT important?

- Evidence suggests CKT is an important factor implicated in how teachers enact various science teaching practices
  - Analyze, interpret, and use students' scientific ideas
  - Evaluate and select scientific models, investigations, and demonstrations for instructional use
- Directly related to teachers' instructional quality (Berry, Freidrichsen, & Loughran, 2015; Carlson & Daehler, 2019; Davis, Petish, & Smithey, 2006; Schneider & Plasman, 2011)
- Impacts student learning (Baumert et al., 2010; Hill, Rowan, & Ball, 2005; Roth et al., 2011)

How is CKT **science** measured?

- Most assessment tools designed to measure science teachers' subject matter knowledge (e.g., AIM, MOSART, ATLAST)
- Measures to assess the specialized, practice-based aspects of CKT involve:
  - Analyzing video recorded episodes of practice (Roth et al., 2011)
  - Participating in think-aloud or cognitive interviews (Henze & van Driel, 2015; Park & Suh, 2015)
  - Conducting classroom observations (Park & Oliver, 2008; Park & Suh, 2015)
  - Using graphic organizers to document their pedagogical content knowledge for teaching particular science topics (Bertram & Loughran, 2012; Loughran, Mulhall, & Berry, 2004)

Study Focus

Overall Research Purpose

Overall Study Focus: Examine how CKT science assessments can be utilized in elementary science method courses to assess and develop preservice elementary science teachers' (PSETs) CKT in the topic of matter and its interactions

Presentation Focus: Explore the extent to which PSETs interact with a set of assessment tasks designed to measure their CKT about matter and its interactions as expected

Study Research Questions

Research Question 1 (RQ1):

To what extent do PSETs use the **intended knowledge and reasoning** when responding to items designed to assess their CKT about matter and its interactions?

Research Question 2 (RQ2):

When PSETs struggle to respond accurately, what are the **reasons for their difficulties**?

CKT Assessment Framework

Work of Teaching Science (WOTS) Instructional Tools

	Instructional goals, big ideas, and topics	Scientific investigations & demonstrations	Scientific resources	Students' ideas	Scientific language and discourse	Scientific explanations	Scientific models & representations
Materials							
Properties of matter							
Model of matter							
Changes in matter							
Conservation of matter							

Assessing teachers' ability to evaluate instructional resources that assess student understanding about examples of matter

Assessing teachers' ability to support students in developing scientific arguments using evidence from investigations to establish that matter cannot be created or destroyed

Work of Teaching Science (WOTS) Framework

Instructional Tools	Examples of Science Teaching Practices
1. Scientific Instructional Goals, Big Ideas, and Topics	Choosing which science ideas or instructional activities are most closely related to a particular instructional goal
2. Scientific Investigations and Demonstrations	Selecting investigations or demonstrations that facilitate understanding of disciplinary core ideas, scientific practice, or cross-cutting concepts
3. 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
4. Student Ideas	Analyzing student ideas for common misconceptions regarding intended scientific learning
5. Scientific Language, Discourse, and Vocabulary	Anticipating scientific language and vocabulary that may be difficult for students
6. Scientific Explanations	Critiquing student-generated explanations or descriptions for their accuracy, precision, or consistency with scientific evidence
7. Scientific Models and Representations	Evaluating or selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals

CKT Matter Item Example

Ms. Wu is preparing a formative assessment for a third-grade unit on matter. She wants to find out if her students understand that matter includes things beyond objects and materials that they can see, feel, measure, and weigh. Ms. Wu locates four resources and each resource includes a list of four different examples for students to consider.
Which of the following is the most useful resource for Ms. Wu's purpose?
1. Resource A: a rock, a wooden board, a steel rod, a plastic ball 2. Resource B: shade, light, sound, heat 3. Resource C: takes up space, has weight, is visible, has color **4. Resource D: rock, dust, ant, air**

CKT Matter Assessment Items

- Variety of item types including:
  - Grid/table items
  - Multiple choice multiple select items
  - Inline choice items
  - Matching items
- Incorporated different stimuli within the opening scenarios (e.g., students' written work, students' talk, video clips, etc.)
- Discrete, automatically-scorable items

Methods

Sample

Participants

- 79 pre-service elementary teachers (PSETs) from across the U.S.
  - 96% Female; 4% Male
  - 77.2% White; 7.6% Hispanic; 3.8% Asian American; 3.8% More than one group identified
- All PSETs in university programs to be certified as elementary education teachers

CKT Items

- 126 items across different teaching practices and content categories
- Each item was given to 5-6 PSETs

Data Collection: Cognitive Interviews

- PSETs received about 7-9 CKT items
- PSETs asked to:
  - Reason about each item using a think-aloud approach
  - Discuss the extent that each item connected to their own or others' teaching practice
  - Discuss whether it was important for elementary science teachers to know how to answer each item

Data Analysis & Coding

Coding Round 1 - Answer Accuracy: Yes or No

Coding Round 2 - Answer Justification: Did their response conform to the item rationale?

- Focuses on whether PSETs are using the intended knowledge & reasoning
- Item rationale example (Ms. Wu)
  - Knowledge about what matter is
  - Knowledge about student difficulties with matter concepts, and
  - Knowledge about how examples can be best used to address specific purposes

Categories of Reasoning around Items

- Did their response conform to the item rationale? Yes or No

- If no, why did they not conform?
  - Difficulty with content (e.g., incorrect content or explicit guessing)
  - Difficulty with teaching (e.g., does not attend to a critical aspect or works on different aspects of teaching)
  - Failure to provide sufficient reasoning (e.g., process of elimination, justification is not a justification)
  - Error (e.g., misread the item)
  - Defensible argument

Findings

RQ1: To what extent do PSETs use the **intended knowledge and reasoning** when responding to items designed to assess their CKT about matter and its interactions?

RQ2: When PSETs struggle to respond accurately, what are the **reasons for their difficulties**?

CKT Matter Item Example

Ms. Wu is preparing a formative assessment for a third-grade unit on matter. She wants to find out if her students understand that matter includes things beyond objects and materials that they can see, feel, measure, and weigh. Ms. Wu locates four resources and each resource includes a list of four different examples for students to consider.
Which of the following is the most useful resource for Ms. Wu's purpose?
1. Resource A: a rock, a wooden board, a steel rod, a plastic ball 2. Resource B: shade, light, sound, heat 3. Resource C: takes up space, has weight, is visible, has color **4. Resource D: rock, dust, ant, air**

	Reasoning Conforms to Rationale	
	Yes	No
Answer Accuracy	n (%)	n (%)
Correct	777 (56.7%)	241 (17.6%)
Incorrect	22 (1.6%)	331 (24.1%)

The n refers to the total number of participant responses across 126 CKT matter items.

Items functioning as intended

Answer Accuracy	Reasoning Conforms to Rationale: Yes n (%)	Reasoning Conforms to Rationale: No n (%)
Correct	777 (56.7%)	241 (17.6%)
Incorrect	22 (1.6%)	331 (24.1%)

The n refers to the total number of participant responses across 126 CKT matter items.

	Reasoning Conforms to Rationale	
	Yes	No
Answer Accuracy	n (%)	n (%)
Correct	777 (56.7%)	241 (17.6%)
Incorrect	22 (1.6%)	331 (24.1%)

The n refers to the total number of participant responses across 126 CKT matter items.

Sample Participant Response: Conformed to Item Rationale

"So, she's trying to get them to understand about gases, I think would be in particular because that would be the **hardest one to grasp**…
If the formative assessment is on matter and she wants students to recognize that matter includes things that they can't touch, feel or see and the **resources probably include something that is not easily touchable or that you can weigh or feel**….
So, I think that would be the **best one** because it includes air in it and so she could assess to see if resource D ... yeah, so she **could assess to see if they do think that air is matter or not**.
I choose resource D."

- **Knowledge about what matter is**
- **Knowledge about student difficulties with matter concepts, and**
- **Knowledge about how examples can be best used to address specific purposes**

	Reasoning Conforms to Rationale	
	Yes	No
Answer Accuracy	n (%)	n (%)
Correct	777 (56.7%)	241 (17.6%)
Incorrect	22 (1.6%)	331 (24.1%)

The n refers to the total number of participant responses across 126 CKT matter items.

Challenge #1: Difficulty with Content

"…It has shade, light, sound, and heat. I'm thinking about this one, and **I'm trying to think of, if those things actually take up space and have mass**.
I'm trying to remember what the qualifiers, or **what ways you have to be matter**.
I'm just trying to think if those things actually do take up space or have mass…
So I think this one is somewhat meeting her goals, being things that you can't see, feel, measure, or weigh."

- **Knowledge about what matter is**
- **Knowledge about student difficulties with matter concepts, and**
- **Knowledge about how examples can be best used to address specific purposes**

35.5% of responses that did not conform to the item rationale showed evidence of difficulty with content.

Challenge #2: Difficulty with Teaching

"Resource C, takes up space, has weight, is visible, has color.
That one stands out to me because that could be things that are objects and materials that they can see, feel, measure, and weigh, or things that don't. Like air takes up space, and that's not something that they can really see or feel, but it's something that takes up space.
I feel like **that that kind of meets her purpose though…because it's like they can kind of determine for themselves, like understand what matter is.**"

- **Knowledge about what matter is**
- **Knowledge about student difficulties with matter concepts, and**
- **Knowledge about how examples can be best used to address specific purposes**

16.9% of responses that did not conform to the item rationale showed evidence of difficulty with content teaching.

	Reasoning Conforms to Rationale	
	Yes	No
Answer Accuracy	n (%)	n (%)
Correct	777 (56.7%)	241 (17.6%)
Incorrect	22 (1.6%)	331 (24.1%)

The n refers to the total number of participant responses across 126 CKT matter items.

Challenge #3: Defensible Argument

- Reasoning for the selected answer that did not conform to the item rationale but…
  - Were compelling
  - Seemed to represent a legitimate way to reason through the item

Challenge #3: Defensible Argument

Observed When…	Implications
PSETs did not need to leverage all of the CKT noted in the intended justification (e.g., certain subject matter knowledge was not used)	Revised the item rationale
PSETs leveraged additional CKT that was not originally identified as part of the intended justification (e.g., used knowledge about specific student difficulties)	Revised the item rationale
PSETs confused by ambiguous language in the item prompt or options	Modified the item prompt or options to be clearer

34.2% of responses that did not conform to the item rationale showed evidence of defensible argument.

Category of Reasoning in Responses	Reason(s) (Percent of Responses)
Difficulty with Content	Incorrect content* (34.3%) Explicit guessing (1.2%)
Difficulty with Teaching	Does not attend to critical aspect of item* (15.3%) Works on different aspects of teaching (1.6%)
Suggests Revision to Task Design	Defensible argument* (34.2%)
Failure to Provide Sufficient Reasoning	Process of elimination (3.4%) Justification is not a justification (8.9%)
Error	Misread the item (1.1%)

Implications & Contributions

Implications & Contributions

- Finding suggests that discrete, automatically-scored assessment items can be designed and used to measure PSETs' CKT
- Cognitive interviews offer important insights into the knowledge and reasoning respondents use, which can be used to:
  - Determine the types of knowledge PSETs use
  - Refine items
- CKT science measures, such as the one used in this study, have the potential to measure science teachers' CKT across contexts (e.g., different teacher education programs) and over time

Visit **cktscience.org** for more information about this research.

This work was supported by a grant from the National Science Foundation (Award No. 1813254). The opinions expressed herein are those of the authors and not the funding agency.