International Journal of Science and Mathematics Education
https://doi.org/10.1007/s10763-024-10453-7

Designing Educative Curriculum Materials for Teacher Educators: Supporting Preservice Elementary Teachers' Content Knowledge for Teaching About Matter and Its Interactions

Deborah Hanuscin[1] · **Emily Borda**[1] · **Josie Melton**[1] · **Jamie N. Mikeska**[2]

Received: 31 March 2023 / Accepted: 29 January 2024

Abstract

Research on teacher educators' professional learning has gained increasing interest within science education. Curriculum materials have been suggested as a means of supporting *teacher* learning for several decades but have not yet been examined as a potential tool for supporting the learning of *teacher educators*. In this paper, we conceptualize a set of design heuristics to guide the development of educative curriculum materials for teacher educators. We illustrate how these heuristics guided the identification of specific educative features, which we included when developing prototype educative curriculum materials for elementary science teacher educators in content and/or method courses to support the development of preservice teachers' content knowledge for teaching about matter and its interactions.

Keywords Teacher educators · Educative curriculum materials · Content knowledge for teaching

Teacher educators enter the profession through different entry points and from different disciplinary backgrounds (Berry & van Driel, 2013). This, combined with

✉ Deborah Hanuscin
hanuscd@wwu.edu

Emily Borda
bordae@wwu.edu

Josie Melton
meltonj2@wwu.edu

Jamie N. Mikeska
jmikeska@ets.org

[1] Science, Math, and Technology Education, Western Washington University, Bellingham, WA, USA

[2] ETS, Princeton, NJ, USA

Published online: 22 February 2024

the likelihood that preparation for teaching teachers was not an explicit component of their graduate education (Abell et al., 2009), means that teacher educators vary greatly in their knowledge and preparedness. Recent decades have seen numerous calls for supporting teacher educator learning (Cochran-Smith, 2003; Park Rogers et al., 2021), much of which occurs “on-the-job” (Dinkelman et al., 2006). One approach that has not been undertaken and examined is the design and development of educative curriculum materials for *teacher educators*.

Curriculum materials have been suggested as a means of supporting *teacher* learning for several decades (Ball & Cohen, 1996; Bruner 1960 ; Davis & Krajcik, 2005). A growing body of evidence is demonstrating the potential of curriculum materials as a tool to support teacher learning as well as student learning (Arias et al., 2016a, 2016b; Bismack et al., 2015; Davis et al., 2017; Donna & Hick, 2017). Based on this research, we hypothesize that curriculum materials could also be designed to support the professional learning of *teacher educators*. We note that unlike many curriculum materials that are primarily intended to support K-12 student learning, *educative curriculum materials* (ECM) (Davis & Krajcik, 2005) are specifically and intentionally designed to support the learning of teachers as they implement the materials with students. While curriculum materials designed for use by teacher educators exist, we know of none that have been systematically developed as tools to support their learning along with preservice teacher learning.

This work is part of a larger program of design-based research supported by the U.S. National Science Foundation in which we are interested in supporting the development of preservice elementary teachers’ content knowledge for teaching about matter and its interactions. In this article, we discuss research and theoretical frameworks for considering ECM as a support for K-12 teacher learning, using this as a basis for conceptualizing how such materials might be designed to support *teacher educators*’ learning. We then explain how we built on the empirically and theoretically driven design process for ECM described by Davis et al. (2014) to develop a set of design heuristics and educative features to support the development of teacher educators’ knowledge and skills in one challenging aspect of their work: deepening preservice elementary teachers’ content knowledge for teaching about matter and its interactions. We provide examples of how the design of our materials evolved based on evidence we collected, as well as how they are grounded in our design heuristics and theoretical framing. While specific to one particular focus of science teacher education, the processes we outline may be useful to others working to develop materials to support the learning of teacher educators in other areas.

The Relationship Between Teachers and Curriculum Materials

Curriculum materials include a host of resources designed to be used by teachers in classrooms to guide their instruction (Stein et al., 2007). In elementary science, for example, these materials may take the form of textbooks, kit-based instructional units, or stand-alone modules and teaching resources. Teachers’ curricular knowledge (Shulman, 1986) encompasses not only knowledge and awareness of available materials for teaching a topic but also the capacity to make informed curricular decisions for specific teaching situations, that is, their pedagogical design capacity (Brown, 2009). Teachers' personal resources such as their experiences, beliefs, knowledge, and instructional goals (Brown, 2009; Remillard, 2005) help teachers make sense of curriculum materials and shape how they implement them (Cohen & Ball, 1999). In turn, features of the curriculum materials can offer varied affordances or constraints to teachers in different situations and contexts. As summarized by Lloyd, "Teachers' individual views and experiences impact their implementation of curricula and features of the curriculum materials influenced teachers' unique implementations" (2008, p. 66). This "participatory" view of the teacher-curriculum relationship stands in stark contrast to earlier perspectives focused on teachers' fidelity of curriculum implementation by acknowledging that teachers' adaptations to curriculum materials are desirable—indeed necessary—to addressing the challenges and building on the strength of their students and teaching contexts.

Educative Curriculum Materials

In alignment with this participatory curriculum use perspective, ECM are designed with educative features, e.g., call-out boxes, illustrative cases or scenarios, and content information (Schneider & Krajcik, 2002), that can help "increase teachers' knowledge in specific instances of instructional decision making but also help them develop more general knowledge that they can apply flexibly in new situations" (Davis & Krajcik, 2005, p. 3). Ball and Cohen (1996) suggested that curriculum materials can be educative for teachers by supporting them in thinking about (a) content beyond the level suggested for students, (b) underlying pedagogy of the materials, (c) development of content and a learning community across time, (d) students, and (e) the broader community. Davis et al. (2014) summarize how materials can help teachers add both general and content-specific ideas to their teaching repertoire, connect general principles with content-specific teaching approaches (bridging theory and practice), and enact and adapt materials in ways that are consistent with the literature and faithful to the underlying vision of the curriculum developers. Research demonstrates that ECM can support the development of teachers' subject matter knowledge (Donna & Hick, 2017), promote productive design decisions by teachers when they are planning (Beyer & Davis, 2009), and enhance teachers' ability to engage students in science and engineering practices (Arias et al., 2016a, 2016b; Bismack et al., 2015).

Why Design ECM for Teacher Educators?

While K-12 teachers teach *science*, teacher educators are teaching about *teaching science*. As such, the knowledge base for teacher education is distinct from that of K-12 teachers (Abell et al., 2009) and their K-12 experience, while valuable, does not translate directly into teaching teachers (Bullock, 2009; Cooper et al., 2015). Those who do not have explicit preparation in graduate study for teaching teachers (Abell, 1997) may find themselves "thrown into the practice of teacher education"

(Wilson, 2006, p. 315) and because opportunities for professional learning are often lacking, they must learn on the job (Dinkleman et al., 2006). Self-studies by teacher educators have highlighted the difficulty they experience transitioning into their roles (e.g. Wood & Borg, 2010) and the complexity of developing a pedagogy of teacher education (Loughran, 2013).

There is widespread recognition that the knowledge base for teacher educators is distinct from that of teachers. For example, Smith (2000) identified knowledge important for elementary science teacher educators including (1) awareness of the conceptions that preservice teachers bring to their learning, (2) strategies for teaching preservice teachers, (3) curriculum materials and activities that are effective for preservice teachers to construct knowledge of teaching, and (4) representations of content that can help preservice teachers learn. There is also knowledge teacher educators need for preparing elementary teachers in science that those entering teacher education from the sciences or from secondary education may lack. For example, this knowledge includes understanding how science fits into the larger elementary curriculum, the kinds of content knowledge appropriate to elementary learners, and how to support classroom management during hands-on science activities. Given the unique and diverse learning needs of teacher educators, ECM can be an effective mechanism for offering a wide range of supports that align with the goals and purposes of elementary science teacher education.

What Should ECM for Teacher Educators Focus on?

ECM for a K-12 audience have been designed to support teachers' enactment of science practices (Arias et al., 2016a, 2016b), facilitation of scientific argumentation (Arias et al., 2017), and understanding of the nature of science (Brunner & Abd-El-Khalick, 2020). In the preparation of teachers there is widespread agreement that teachers must both deeply understand content *and* have knowledge that enables them to support their students' learning of that content. Yet, in science teacher education, the teaching of content and pedagogy are most often separated. Some science teacher educators teach "methods" courses focused on pedagogy while others teach "content" courses focused on developing subject matter knowledge in science. The division between their learning of content and methods challenges preservice teachers to integrate this knowledge on their own. We posit that ECM focused on developing preservice teachers' content knowledge for teaching (Ball et al., 2008) would support better integration of preservice teachers' learning of science content and teaching methods and would be well-suited to meeting the goals of elementary science teacher education and the varied instructional responsibilities and backgrounds of science teacher educators.

Ball and colleagues (2008) proposed a theory of content knowledge for teaching (CKT). CKT refers to the specialized science knowledge that teachers need, which differs from that of the scientist, and includes understanding content in ways that are "tailored to the work that teachers do with curriculum, instruction, and students" (Ball et al., 2005, p. 16). CKT is a key mediator in science teachers' abilities to engage in critical teaching practices such as interpreting students' ideas, constructing explanations, and selecting and modifying resources for instruction (Davis et al., 2006; Windschitl et al., 2012). Ball and colleagues (2008) further developed their framework to include teaching strategies that are useful in developing CKT. Whereas their work focused on *mathematical tasks of teaching*, our work utilizes a framework called the *Work of Teaching Science* (WOTS) (Mikeska et al., 2018). The WOTS framework focuses on the content challenges that novice elementary science teachers face and is organized by the instructional tools and practices that elementary science teachers use in their daily work. Examples from the framework are shown in Table 1.

In our work, we chose to focus on CKT about *matter and its interactions*. As emphasized in the *Next Generation Science Standards* (NGSS; National Research Council [NRC], 2013) and *Framework for Science Education* (NRC, 2012), the concept of matter is central to understanding many scientific ideas. While there is robust literature highlighting student difficulties and possible learning progressions for matter (cf. Tsarpalis & Sevian, 2013), there is little documentation of content-specific teaching knowledge relevant to teaching about matter in the elementary years (Hanuscin et al., 2018; Smith & Plumley, 2016). Building from the *Framework* and NGSS, we focused on content ideas in five broad categories of concepts: (1) properties of matter; (2) materials; (3) the small particle model of matter; (4) changes in matter; and (5) conservation of matter.

We operationally define CKT as the intersection between specific content ideas and teaching practices of the WOTS framework. For example, teachers must be able to select investigations that will facilitate students' understanding of key ideas such as the conservation of matter. Similarly, they need to evaluate phenomena to determine which will be most relevant to students and know how to engage students in critiquing models to develop explanations of changes matter undergoes.

Table 1 Work of teaching science framework (Mikeska et al., 2018)

Instructional tools	Example science teaching practices
1. Instructional Goals, Big Ideas, and Topics	1.2 Identifying the big idea or concept an activity is intended to illustrate
2. Scientific Resources (texts, curriculum, etc.)	2.1 Evaluating materials and resources for their accuracy and age appropriateness
3. Scientific Models and Representations	3.2 Engaging students in using, modifying, creating, and critiquing scientific models and representations that are matched to instructional goals
4. Student Ideas	4.1 Analyzing student ideas in relation to intended scientific learning
5. Scientific Language, Discourse, and Vocabulary	5.1 Identifying the connections between students' talk and work and scientists' talk and work
6. Scientific Explanations	6.2 Selecting explanations of scientific phenomena that are accurate and accessible to students
7. Scientific Investigations and Demonstrations	7.3 Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question

The Design Process: Developing ECM for Teacher Educators

Just as ECM can help develop teachers' CKT (Ball et al., 2008), we hypothesize that ECM can support the development of *teacher educators*' knowledge and skills related to supporting the development of preservice teachers' CKT. Research with K-12 preservice and in-service teachers has laid the groundwork in terms of methodological approaches for developing, enacting, and studying teacher educators' uptake of ECM. Most notably, our work draws on the empirically and theoretically driven design process described by Davis and colleagues (2014). In their work the researchers analyzed the curriculum materials for potential opportunities for teacher learning by systematically observing the enactment of the materials in two classrooms. They used this data to identify strengths, struggles, and missed opportunities in the enactments to inform the design and incorporation of theoretically grounded educative features. This work built upon design heuristics (Davis & Krajcik, 2005) for educative features. Our design process necessarily differed from their process in two key ways. First, because there were no design heuristics to guide the development of ECM for teacher educators when we started this work, we needed to generate those heuristics. Second, given the variety of curriculum materials and course contexts in science teacher education, we chose to develop materials that would be complementary to, versus being embedded within, existing curricula. In the sections that follow, we outline the steps in our design process, and how these resulted in a set of design heuristics that guided development of prototype ECM with educative features specific to teacher educators' learning needs.

Review of Existing Curriculum Materials

To begin the process, we conducted a search of the literature to identify knowledge for and curriculum materials related to teaching and learning about matter in the elementary years. The literature search focused on identifying elements of the knowledge base for teaching and learning matter, informed by Smith and Plumley's (2016) review and prior work (Hanuscin et al., 2018). We also examined currently available curriculum materials related to matter for elementary students (i.e. curricula designed for use by K-12 teachers), professional learning materials for elementary teachers, and curricula developed for use by teacher educators in science courses for teachers.

Familiarizing ourselves with the literature on K-12 ECM along with this knowledge base for teaching and learning matter helped us begin to formulate answers to the question: *What might curriculum materials look like if they were designed with the intent of supporting teacher educators' learning?* For example, we noted that teachers responded well to examples from practice (Bismack et al., 2015) and task-based scenarios (Nabors Oláh et al., 2018). Based on this, we decided that teaching scenarios and lesson examples from K-12 curricula might prove beneficial to include. Yet, in conceptualizing ECM for *teacher educators*, we acknowledge there are important distinctions between the contexts of K-12 teaching and teacher education. While there are numerous curricular programs for K-12 science (textbooks, kit-based programs, technology-based materials, etc.) that schools may adopt for wider use across districts and states, higher education does not participate in a similar adoption process. There are several curricula designed for use in content courses for preservice teacher education, such as *Physical Science and Everyday Thinking* (Goldberg et al., 2008), *Life Science and Everyday Thinking* (Donovan et al., 2008), *Physics for Elementary Teachers* (Goldberg et al., 2006) or *Physics by Inquiry* (McDermott, 1995), and many commercially published elementary science method textbooks, which typically focus primarily on pedagogy and cover a wide range of content ideas across disciplines rather than being content-specific. Faculty are afforded a high level of academic freedom in making decisions about which, if any, of these materials to use in their courses and programs, and decisions vary greatly across different institutions of higher education.

Focus Group Convening

A second phase of our empirical work included focus groups with teacher educators. We purposefully selected a diverse group of instructors who could provide us with an understanding of what teacher educators with different backgrounds, experiences, and expertise prioritized, needed, and would likely use in supporting their preservice teachers in developing CKT. The group of eight teacher educators included science faculty from chemistry, biology, physics, and geology; former K-12 teachers work as adjunct instructors, science education faculty, and lecturers with varied length of experience teaching teachers (2–20 years). The two focus groups (four participants each) completed a ranking task in which they individually and collectively justified the relative importance, relevance, and perceived difficulty of (1) content ideas about matter and (2) the science teaching practices from the WOTS framework. Our purpose was to ascertain their existing understanding, emphasis, and needs related to helping preservice teachers understand matter and its interactions and prepare them for the work of teaching science. Their responses helped us identify potential entry points for expanding teacher educators' current repertoire, areas in which they most needed support, and ideas they felt to be most relevant to their respective teaching contexts (i.e. content or methods). For example, focus group teacher educators simultaneously highlighted the importance of the small particle model (SPM) of matter to understanding other concepts and its relevance for teachers to understand to align instruction with the NGSS. However, they also noted that they did not typically emphasize SPM in their courses, citing a lack of resources. Instructors of both content and methods courses also placed a high level of emphasis on eliciting students' ideas and becoming aware of common alternative conceptions, which we noted as a potential entry point for materials that focused on CKT about understanding students' ideas about the small particle model.

We also asked focus group participants to share characteristics of curriculum resources and materials they currently utilized in their courses. This complemented our analysis of existing curriculum materials. Teacher educator responses indicated they commonly used "ready-made" materials developed for K-12 science education, such as formative assessment probes (Keeley, 2015), and shorter practitioner-focused readings from journals of the *National Science Teaching Association*. They also expressed appreciation for flexible options representing different levels of time commitment.

Making Design Decisions

Taken together and combined with the extant literature on ECM for teachers, this analysis guided our thinking about the potential form and functions of ECM for a teacher educator audience. From a design perspective, this suggested to us that "modular" or stand-alone curriculum materials might be a productive format of ECM for teacher educators. Therefore, rather than creating an entire course of study or curriculum, we sought to design materials that would be *complementary to* and could be used *in conjunction with* an instructor's existing curricular resources. We also determined the task-based nature of the mini-cases as being a promising format for us to model our materials on (Nabors Oláh et al., 2018), with elicitation tasks (similar to formative assessment probes developed for a K-12 audience) forming a central element.

In the sections that follow, we characterize the development of our prototype educative materials for teacher educators. First, we describe the development of design heuristics in response to the process described above, making connections to both the literature and our empirical data. We then elaborate on how we used these design heuristics to identify appropriate educative features.

Developing Design Heuristics

Davis and Krajcik (2005) articulated a set of nine design heuristics for ECM that are intended to promote *teachers*' pedagogical content knowledge for science topics and scientific inquiry, as well as subject matter knowledge. As defined by these authors, a design heuristic includes three components: (a) a description of what the curriculum materials should provide, (b) how the materials could help teachers understand the rationale behind recommendations, and (c) how teachers could use these ideas in their own teaching. As there are no existing design heuristics to guide the development of ECM for *teacher educators*, we needed to generate those heuristics. Like Davis and Krajcik (2005), we use the term "design heuristics" rather than "design principles" as this work is in its early stage and has yet to be empirically tested.

We began by considering challenges teacher educators may encounter, building on the insights from our focus groups and our review of literature and curriculum materials related to matter, as well as additional research describing the specialized knowledge necessary for teaching teachers (Abell et al., 2009; Appleton, 2008; Cite et al., 2017; Smith, 2000). Specifically, we considered the following:

- Important knowledge and skills related to teaching about matter and its interactions that comprise preservice teachers' CKT, and the difficulties they have developing this knowledge and skills

- Key challenges teacher educators face in preparing preservice teachers, both internal (related to their own learning) and external (related to available time, resources, etc.)
- Characteristics of teacher educators' existing resources and practice that might provide potential entry points for—and enhance the likelihood of—them utilizing educative materials

For example, we noted the focus group teacher educators spoke of the ways in which preservice teachers underestimate the difficulty and complexity of teaching science. We further noted that, particularly for those transitioning from K-12 teaching, teacher educators needed to develop new knowledge of *learners* that was different from their knowledge of K-12 students (Smith, 2000). Additionally, we were cognizant of the challenges of developing deep content knowledge situated in classroom practice (Appleton, 2008). This helped us generate three overarching design heuristics to frame our ECM (Table 2).

Educative Features

"Educative features" are the specific tools and supports written into ECM to support educator learning (Arias, 2016a, 2016b; Brunner, 2019). Davis et al. (2017) suggested that educative features should (a) suggest adaptations to meet time constraints and students' needs; (b) be grounded in practice; (c) take multiple forms; and (d) work together to support a range of teachers' learning needs. ECM for K-12 teachers have incorporated supports such as expository and narrative information included in lesson plans (Bismack et al., 2015), suggested questions and sample student responses (Donna & Hick, 2017), teaching tips and assessment tools (Land et al., 2015), and practice overviews (Arias et al., 2016a, 2016b). We drew from our previous steps in the design process to consider types of educative supports to incorporate into the materials in ways that align with the three design heuristics we developed. Below, we briefly characterize four categories of educative features we developed, making connections to both the literature and our empirical data. These include task-based supports, context/background supports, implementation supports, and customization supports. We illustrate these using examples from the prototype we developed.

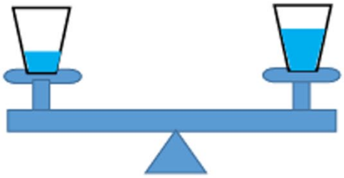
Our preliminary model of ECM for teacher educators was designed to address CKT related to students' ideas about the small particle model of matter (SPM). The decision to focus on this aspect of CKT for our initial prototype was based on what we learned from our focus group teacher educators; specifically, while they commonly focused on the pedagogical practice of eliciting and responding to elementary students' ideas, they did not focus on the content idea of the SPM in their courses (despite recognizing this as one of the most important, but challenging, ideas related to teaching about matter). Thus, we felt focusing on student ideas could serve as an entry point for teacher educators to address this content idea in line with their existing course goals and emphases.

Task-Based Supports. Based on the popularity of Keeley's formative assessment probes (2015) among teacher educators and the success of the task-focused

Table 2 Design heuristics for ECM for teacher educators

Heuristic #1: ECM should support teacher educators in engaging preservice elementary teachers in the Work of Teaching Science	ECM should provide teacher educators with productive experiences that make the work of teaching science visible to preservice teachers and provide rationales for why this work is important. Instructional materials should help teacher educators adapt and use resources with their preservice teachers in pedagogically appropriate ways. ECM should make explicit how specific science teaching practices correspond to different concepts and ideas and by providing recommendations for how those practices, concepts, and ideas might be introduced to preservice teachers in different contexts and courses.
Heuristic #2: ECM should support teacher educators in anticipating, understanding, and responding to preservice elementary teachers' ideas about science and science teaching	ECM should help teacher educators understand how preservice teachers develop content knowledge for teaching about science. Materials should support teacher educators in anticipating, eliciting, and interpreting preservice teachers' ideas, and provide insight into how teacher educators might address those ideas in their teaching; for example, by giving suggestions of assessment probes, discussion questions, and activities likely to confront preservice teachers' initial thinking about teaching science in productive ways.
Heuristic #3: ECM should support teacher educators in developing preservice teachers' content knowledge in the context of teaching	ECM should provide teacher educators with tools for helping preservice teachers develop a deep conceptual understanding of science content as a foundation for building content knowledge for teaching. Materials should help teacher educators support preservice teachers in assessing their own understanding, confronting gaps in their understanding or misconceptions, making connections across concepts, and understanding why strong content knowledge is important for teaching. Materials should emphasize key differences between the content understanding required of preservice teachers and of their elementary students.

mini-cases (Nabors Olah et al., 2018) in mathematics education, we decided to make the CKT elicitation task the anchoring feature of the materials. This decision was supported by the literature that emphasized teachers' uptake of educative features grounded in examples from practice (Bismack et al., 2015). Each scenario-based CKT elicitation task is situated at the intersection of an element of the WOTS (Hanuscin et al., 2018) and a content idea about matter. For example, consistent with Design Heuristic 1, the task shown in Fig. 1 engages preservice teachers in analyzing student ideas for common misconceptions regarding intended scientific learning (WOTS 4.1) related to the small particle model of matter. We drew on Keeley's (2015) formative assessment task formats, research literature, and our own prior experiences teaching about SPM with elementary teachers and students to develop a task to elicit preservice elementary teachers' CKT.



Below are five fifth grade students' ideas about the particles that make up each liquid, and how those might be used to explain why two different volumes of liquid can have the same mass.

Shawn Both cups contain the same number of particles. The particles in the cup on the right are more spread out than the particles in the cup on the left, so they take up more space.

Jo The cup on the right contains more particles than the cup on the left, so it is more full than the cup on the left.

Kenya Both cups contain the same number of particles, but the particles in the cup on the right are larger, so they take up more space than the particles in the cup on the left.

Jamie The particles in the cup on the left are heavier than the particles in the cup on the right.

Riley Both cups have the same number of particles, but the particles on the right are floating through more liquid than the particles on the left.

As you review each student response, consider:

- What assumptions are students making about the particles themselves?
- Which aspects of the students' ideas are scientifically accurate? Which are not?
- What, if anything, is missing from each of the students' ideas?
- What questions would you ask each student about his/her model to further elicit their ideas?

Fig. 1 Scenario-based CKT elicitation task *Two Cups of Liquid*

As an educative support, we developed an elaborated answer key that unpacked common misconceptions evident in each students' explanation, reasons that preservice teachers might provide for choosing different responses, and questions that teacher educators might use to probe their thinking. This support was intended to help teacher educators anticipate possible ideas their preservice teachers might hold and respond to those during instruction (Heuristic #2). Figure 2 shows an excerpt of this feature that discusses one of the sample student ideas from the task.

Context and Background Supports. Expository text at the beginning of each module provides background information for teacher educators. This text includes support for identifying key ideas related to the content focus and WOTS practice emphasized in the module and the alignment to standards. As shown in Fig. 3, we also provided support to help teacher educators choose appropriate entry points

Part B: Student Ideas

Shawn ***Both cups contain the same number of particles. The particles in the cup on the right are more spread out than the particles in the cup on the left, so they take up more space.***

Shawn's model would work to explain the situation if the particles in each case had the same mass. However, if the particles had different masses, different numbers of particles would be necessary for the two liquids to have the same mass. Shawn's model implicitly incorporates the idea of empty space between the particles, but follow-up questions should press for additional information about this student's beliefs about the space between particles, as students will often believe there is air or other particles in that space. Empty space is an important facet of the small particle model of matter, but Shawn's explanation does not explicitly recognize that the properties of the particles themselves can be different.

Follow-up questions might include: What, if anything, is between the particles in both cups? (If air is an answer, what is between the particles of air?), Are the particles in both cups the same weight? Do they have to be the same mass? Is there the same number of particles in each cup, or does one have more particles than the other?

Fig. 2 Excerpt from an elaborated answer key

The CKT tasks are intended to help you elicit and probe preservice teachers' CKT. For example, the *Two Cups of Liquid* task might be a useful exercise prior to engaging students in selecting or adapting assessment tasks, as it helps them consider how to elicit and interpret students' understanding of specific content ideas—in this case, the small particle model of matter. Alternately, it could be used in a content-focused course to help preservice teachers contextualize their learning about the small particle model within their role as future teachers, helping them understand ways in which what they teach young learners about this concept will be similar to—but also different from—what they are learning as adults.

Fig. 3 Example of support and guidance for planning how to utilize the CKT elicitation task

for using the materials in their courses (Heuristic #3) based on the focus of their course and instructional goals (Fig. 3).

Implementation Supports. In recognition that teacher educators appreciated flexible options in terms of time commitment needed to implement resources, we developed two different suggested implementation plans: a single-session plan for using the CKT elicitation task and a longer instructional plan representing a full Learning Cycle (Bybee et al., 2006), a model often used in elementary science and science teacher education. Schneider and Krajcik (2002) found that in-service teachers attended to educative features most closely related to specific lessons, as opposed to the overall unit, so we incorporated embedded supports such as "callout" boxes with teacher tips or rationales for teaching moves as used by others (e.g. Arias et al., 2016a, 2016b). For example, one of the activities in the implementation plan encourages preservice teachers to consider how they would use the small particle model to explain the *Two Cups of Liquid* scenario posed in the CKT task—an annotation in the margin indicates:

Preservice teachers might use concepts and vocabulary like density or atoms and molecules in their reasoning, yet these are not introduced in the elementary grades. This is an opportunity to examine the NGSS more closely and to understand the vertical alignment of topics across grade levels.

This educative feature not only supports teacher educators in anticipating their students' ideas (Heuristic #2) but also supports them in making explicit how specific science teaching practices correspond to different concepts and ideas (Heuristic #1). Figure 4 shows an example of these embedded supports.

As requested by teacher educators in our focus group, we included short, targeted Reading Pages (Fig. 5) as supports to develop preservice teachers' CKT by helping them identify gaps in their thinking, make connections across concepts, and understand key differences between the content understanding required of them as teachers and of their elementary students (Heuristic #3). Reading Pages include discussion questions to support teacher educators in deepening preservice teachers' understanding of content (Heuristic #3) as well as teacher decision-making (Heuristic 1).

***Customization Supports*.** Our team developed a final form of educative supports with the intent of supporting teacher educators in modifying the materials to meet the needs of their context and preservice teachers, as well as to meet

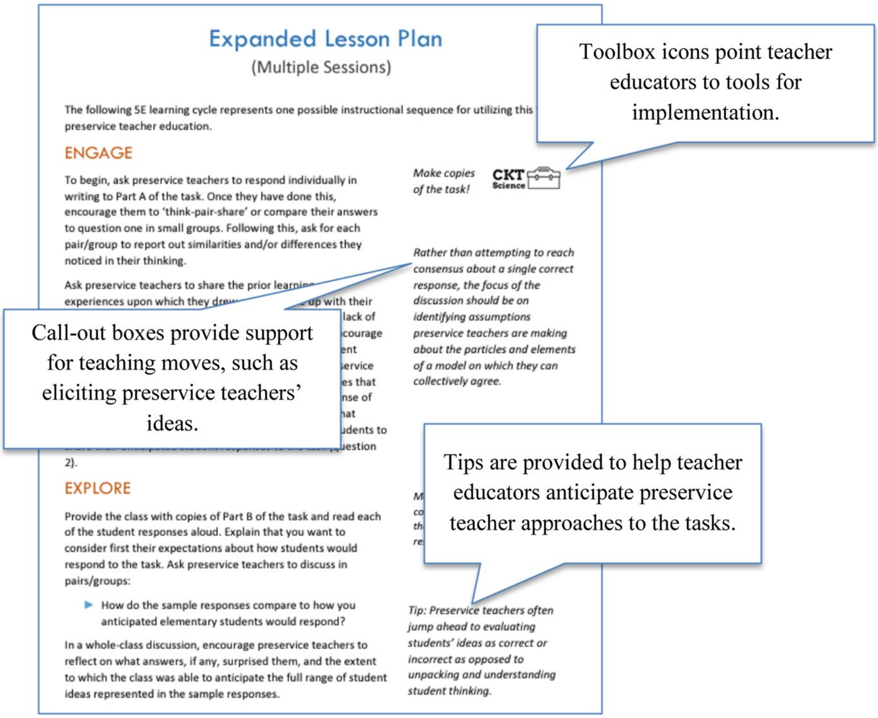


Fig. 4 Example of educative supports embedded in implementation plans

Reading Page

The Small Particle Model of Matter

CKT Science

When asked what single piece of knowledge should be kept if the rest of human thought were somehow destroyed, physicist Richard Feynman said the following: "All things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. In that one sentence ... there is an enormous amount of information about the world" (Feynman, 1996). The small particle concept indeed has tremendous explanatory and predictive power, and thus teaching this model at the elementary level at varying degrees of detail over the grades gives students an even more powerful tool for reasoning about matter.

The small particle model appears in the Next Generation Science Standards as PS1.A: "Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means." At the elementary level, the small particle model need not (and probably should not) include details about atomic structure. However, a simple "billiard ball" model of the atom, in which the atom is modeled as a spherical small particle, can explain a wide range of characteristics of matter, such as the phases of matter, gas pressure, and mass. Features of a small particle model that elementary students should be supported to develop include:

- Matter is made of small particles with empty space in between them.
- The small particles are too small to be seen, even with very powerful microscopes. However, we can make inferences about small particles by making observations about the properties of matter on a macroscopic scale.
- There are different types of small particles. Each type has a different mass (or weight since these two concepts are not distinguished in early grades).
- Small particles associate with other small particles, either of the same or different type, to make different types of substances with different observable properties.
- Small particles are in constant, random motion. This random motion is measured by temperature: Increasing speed of motion is indicated by increasing temperature.
- Small particles are attracted to each other. If they are strongly attracted, they make a solid. If they completely escape their attractions, they make a gas. In a liquid state, the small particles are associated with each other but constantly moving around to make associations with new particles.

At primary grade levels, students should first be supported in making observations of the physical properties of substances. By making connections between these properties and the identity of a substance, they build a foundation for thinking about these properties as being "created" by the identity of and interactions between small particles in intermediate grade levels. The level of abstraction of small particle theory lends itself to difficulties and nonnormative ideas (or

23

Fig. 5 Sample reading page

their own learning needs. While not embedded in the implementation plans themselves, *Options for Going Further* (see Fig. 6) provide suggestions for engaging preservice teachers more deeply in applying their CKT in activities that approximate teaching practice (Heuristics #1 and 2). Also in this section, relevant research literature, practitioner articles, and web-based resources are provided to support teacher educators in building their own understanding and

ADDITIONAL RESOURCES

Options for Going Further

Note: Many preservice teachers might believe an appropriate pedagogical response to elementary students' ideas is to provide students with the 'correct' small particle model of matter. While this is not a focus of this particular task, we have included the distinction between students' modeling and teachers using models as teaching tools in the Reading Page: *Scientific Models* should you wish to extend the class discussion to address that idea.

To further extend preservice teachers' learning, we recommend having them:

- Interview an elementary student using the task, and provide an analysis and evaluation of the student's ideas.
- Evaluate an activity (in the form of lesson plan, article from practitioner journal, etc.) in terms of the extent to which it effectively elicits students' ideas and/or offers appropriate responses to those ideas (see note above)
- Evaluate the strengths and limitations of a teaching model (simulation, representation, etc.) of the small particle model of matter
- Participate in a 'model lesson' about matter while taking the perspective of one of the five students in the sample responses. (See Additional Resources for possible lessons.)
- Identify another scenario (similar to the cups or cubes) that might help elicit students' understanding of the small particle model of matter.

Related Research

The following articles helped inform the development of these materials and can enhance your own understanding and ability to support preservice teachers' CKT about matter.

Kokkotas, P., Vlachos, I., & Koulaidis, V. (1998). Teaching the topic of the particulate nature of matter in prospective teachers' training courses. *International Journal of Science Education, 20*(3), 291–303.

Nakhleh, M. B., & Samarapungavan, A. (1999). Elementary school children's beliefs about matter. *Journal of Research in Science Teaching, 36*(7), 777–805.

Schwarz CV, Reiser BJ, Davis EA, et al. (2009) Developing a Learning Progression for Scientific Modeling: Making Scientific Modeling Accessible and Meaningful for Learners. *Journal of Research in Science Teaching* 46: 632-654.

Smith, P. S. & Plumley, C. L. (2016). *A review of the research literature on teaching about the small particle model of matter to elementary students.* Chapel Hill, NC: Horizon Research, Inc. Available: http://www.horizon-research.com/spmlitreview

Tsaparlis, G., & Sevian, H. (2013). *Concepts of Matter in Science Education* (Vol. 19). Dordrecht: Springer. https://doi.org/10.1007/978-94-007-5914-5

Fig. 6 Example of additional resources and extra-lesson supports

identifying additional resources to support preservice teacher learning (Heuristic #2). Given the varied learning needs of teacher educators and the varied contexts in which they teach (Hanuscin et al., 2021), we designed this set of features to better position them to utilize the materials in productive ways.

Developing and Refining the Materials

As described above, we drew on the design heuristics to incorporate educative features into an initial prototype ECM focused on helping preservice teachers understand and interpret students' ideas about the small particle model (SPM). The decision to focus on this aspect of CKT was chosen as a starting point because we learned from our focus group teacher educators that while they commonly focused on eliciting and responding to elementary students' ideas, they did not focus on the idea of the SPM in their courses (despite their recognition of the SPM as one of the most important, but challenging, ideas related to matter).

Once the initial prototype CKT packet was developed, the focus group and our project advisory board (composed of four researchers with expertise relevant to our project) reviewed the prototype and provided feedback. We provided questions to prompt specific feedback about (1) the extent to which the packet adhered to the three design heuristics, (2) the user-friendliness and overall presentation of the materials, and (3) the depth to which CKT was addressed throughout the packet. Feedback was positive regarding alignment to heuristics and specific educative features, with the bulk of the critique focusing on readability, design layout, and organization. We made changes to improve these aspects, such as ensuring reading pages could easily be photocopied to distribute to preservice teachers.

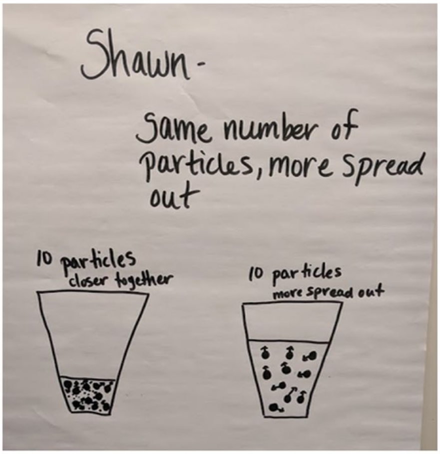
The prototype was then implemented by three initial users who are elementary science teacher educators at the institution where the materials were developed. Two implemented the prototype materials in elementary science methods courses while one implemented them in a science content course for preservice teachers. Members of the CKT team observed the implementation, making note of elements of the materials and specific educative features utilized during implementation, as well as the interactions of instructor and preservice teachers while engaging in the CKT elicitation tasks. Following implementation, the instructors and observer met to debrief and review the affordances and challenges of the materials and the feasibility and usefulness of the suggested implementation plans. Ideas generated in this discussion were used to further refine the materials. Some of these changes were minor (e.g. clarifying wording or adding more explicit instructions for teacher educators in how to implement activities regarding grouping students) while others were more substantive. For example, given the complexity of preservice teacher sensemaking about student ideas, we generated sample responses from the implementation to highlight assumptions they made about student ideas that were not explicit in the student responses (Fig. 7).

These refinements, though based on a small number of enactments, affirmed the utility of the suite of educative features we had developed, as well as the ability of instructors to identify appropriate entry points for using the materials in different contexts. Following this, we developed five more modules using the prototype as a model. Each of these addresses a different combination of a content idea and one aspect of the Work of Teaching Science:

- Choosing appropriate scientific investigations and demonstrations to help students understand conservation of matter

Sample Teacher Responses

The following examples illustrate possible ways in which preservice teachers might interpret each of the elementary students' ideas, and assumptions they may make as they do so.



Shawn: Both cups contain the same number of particles. The particles in the cup on the right are more spread out than the particles in the cup on the left, so they take up more space.

This group of teachers has portrayed Shawn's small particle model explanation showing the particles as the same number of particles of identical size occupying different amount of space. **The size of the particles themselves was not made explicit in Shawn's response, so this is an assumption they are making in interpreting Shawn's ideas.**

Fig. 7 Examples of responses to the task highlighting assumptions preservice teachers made beyond what was stated by the elementary students in the task

- Aligning activities with instructional goals for teaching about materials
- Engaging students in developing and refining a small particle model of matter
- Evaluating student explanations of changes in matter
- Supporting students in asking questions and planning investigations to understand changes in matter

These additional materials were also reviewed by the project's advisory board and focus groups and implemented by teacher educators to enable further refinement. The full set of six educative curriculum modules is now freely available online at [website blinded].

Designing ECM for Teacher Educators: Implications and Conclusions

Our work comes in response to the growing interest in supporting the professional learning needs of science teacher educators (Park Rogers et al., 2021) and builds on previous efforts in K-12 science education to articulate a design process for ECM (Davis & Krajcik, 2005; Davis et al., 2014). Most notably, we extend these efforts by designing materials for *teacher educators*, an audience who have not been previously considered as users and beneficiaries of ECM. The design heuristics and educative features we developed acknowledge the learning needs of teacher educators vary as a function of their backgrounds, graduate preparation, and entry points into teaching teachers (Berry & van Driel, 2013). The supports within the CKT modules should position teacher educators to engage preservice teachers in content-rich experiences learning about pedagogy (or vice versa) across multiple contexts, such as science content or science methods courses, and contribute to their capacity to leverage the materials in productive ways (Brown, 2009; Drake & Sherin, 2006).

A second area of contribution of this work lies in our focus on CKT, and more specifically CKT related to matter. Concepts related to matter are recognized as being both "complex to teach and difficult to learn" (Tsarpalis & Sevian, 2013, p. 1). The adoption of the NGSS added an additional layer to this complexity in specifying at the elementary level that students be taught about "particles" as opposed to atoms or molecules. This requires not only different approaches at the elementary level to teaching about matter, but at the university level as well in science teacher education. Content courses at the university prepare teachers to understand content at a level that is beyond the understanding required of elementary students, which makes developing preservice teachers' CKT related to content ideas about the small particle model even more important for successful teaching (Hanuscin et al., 2018; Smith & Plumley, 2016; Smith et al., 2017).

> Researchers have cautioned that educative curriculum materials are not a panacea, and that professional development is instrumental to teacher implementation and learning (e.g. Pringle et al., 2017). Davis et al. (2017) have suggested that future research on ECM should examine how professional development and ECM work together to support teacher learning, as well as student learning. In the next phase of our work, we have been collaborating as a professional learning community with a diverse group of science teacher educators from various career stages, institutions, backgrounds, and entry points into science teacher education. We plan to build in-depth, qualitative case studies to characterize teacher educators' uptake and use of the educative features in the CKT modules as well as to examine impacts on preservice elementary teachers' CKT. Beyond our own work, however, we believe our design heuristics and suite of educative features we developed for our prototype materials are an important first step that can be used to inform future research and development efforts to enhance the professional learning of teacher educators (Ping et al., 2018). Furthermore, we believe this process can be applied more generally to the development of materials to address other aspects of CKT elementary teachers need, not only for teaching about matter and its interactions.

Funding This material is based upon work supported by the National Science Foundation under grants DRL-1814275 and DRL-1813254.

Declarations

Ethical Approval The study was reviewed and deemed exempt by the Western Washington University (WWU) Institutional Review Board (Study #4360EX21).

Disclaimer Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Abell, S. K. (1997). The professional development of science teacher educators: Is there a missing piece? *Electronic Journal of Science Education [On-line], 1*(4).

Abell, S. K., Rogers, M. P., Hanuscin, D. L., Lee, M. H., & Gagnon, M. J. (2009). Preparing the next generation of science teacher educators: A model for developing PCK for teaching science teachers. *Journal of Science Teacher Education, 20*(9), 77–93.

Appleton, K. (2008). Developing science pedagogical content knowledge through mentoring elementary teachers. *Journal of Science Teacher Education, 19*(6), 523–545.

Arias, A. M., Davis, E. A., Marino, J. C., Kademian, S. M., & Palincsar, A. S. (2016a). Teachers' use of educative curriculum materials to engage students in science practices. *International Journal of Science Education, 38*(9), 1504–1526.

Arias, A. M., Bismack, A. S., Davis, E. A., & Palincsar, A. S. (2016b). Interacting with a suite of educative features: Elementary science teachers' use of educative curriculum materials. *Journal of Research in Science Teaching, 53*(3), 422–449.

Arias, A. M., Smith, P. S., Davis, E. A., Marino, J. C., & Palincsar, A. S. (2017). Justifying predictions: Connecting use of educative curriculum materials to students' engagement in science argumentation. *Journal of Science Teacher Education, 28*(1), 11–35.

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6–14.

Ball, D. L., Hill, H. C., & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? *American Educator, 30*(3), 14–46.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching. *Journal of Teacher Education, 59*(5), 389–407.

Berry, A., & Van Driel, J. H. (2013). Teaching about teaching science: Aims, strategies, and backgrounds of science teacher educators. *Journal of Teacher Education, 64*(2), 117–128.

Beyer, C. J., & Davis, E. A. (2009). Using educative curriculum materials to support preservice elementary teachers' curricular planning: A comparison between two different forms of support. *Curriculum Inquiry, 39*(5), 679–703.

Bismack, A. S., Arias, A. M., Davis, E. A., & Palincsar, A. S. (2015). Examining student work for evidence of teacher uptake of educative curriculum materials. *Journal of Research in Science Teaching, 52*(6), 816–846.

Brown, M. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J. T. Remillard, B. Herbel-Eisenman, & G. Lloyd (Eds.), *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17–36). Routledge.

Bruner, J. S. (1960). On learning mathematics. *The. Mathematics Teacher, 53*(8), 610–619.

Brunner, J. L. (2019). Teachers' use of educative features in guides for nature of science read-alouds. *Science & Education, 28*(3), 413–437.

Brunner, J. L., & Abd-El-Khalick, F. (2020). Improving nature of science instruction in elementary classes with modified science trade books and educative curriculum materials. *Journal of Research in Science Teaching, 57*(2), 154–183.

Bullock, S. M. (2009). Learning to think like a teacher educator: Making the substantive and syntactic structures of teaching explicit through self-study. *Teachers and Teaching, 15*, 291–304.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. Colorado Springs, Co: BSCS, 5(88-98).

Cite, S., Lee, E., Menon, D., & Hanuscin, D. (2017). Learning from 'rookie mistakes': Critical incidents in developing PCK for teaching teachers. *Studying Teacher Education, 13*(3), 275–293.

Cochran-Smith, M. (2003). Learning and unlearning: The education of teacher educators. *Teaching and Teacher Education, 19*(1), 5–28.

Cohen, D. K., & Ball, D. L. (1999). *Instruction, capacity, and improvement* (Report No. CPRE-RR-43). Office of Educational Research and Improvement (ED), Washington, DC.

Cooper, R., Loughran, J., & Berry, A. (2015). Science teachers' PCK: Understanding sophisticated practice. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 60-74). Routledge.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational researcher, 34*(3), 3–14.
Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review Of Educational Research, 76*(4), 607–651.
Davis, E., Palincsar, A. S., Arias, A. M., Bismack, A. S., Marulis, L., & Iwashyna, S. (2014). Designing educative curriculum materials. *Harvard Educational Review, 84*(1), 24–52.
Davis, E. A., Palincsar, A. S., Smith, P. S., Arias, A. M., & Kademian, S. M. (2017). Educative curriculum materials: Uptake, impact, and implications for research and design. *Educational Researcher, 46*(6), 293–304.
Dinkelman, T., Margolis, J., & Sikkenga, K. (2006). From teacher to teacher educator: Experiences, expectations, and expatriation. *Studying Teacher Education, 2*(1), 5–23.
Donna, J. D., & Hick, S. R. (2017). Developing elementary preservice teacher subject matter knowledge through the use of educative science curriculum materials. *Journal of Science Teacher Education, 28*(1), 92–110.
Donovan, D. A., Rousseau, J., Salter, I., Atkins, L., Acevedo-Gutierrez, A., Kratz, R., Landel, C.C., Mullen, V., & Pape-Lindstrom, P. (2008). *Life science and everyday thinking.* Activate Learning.
Drake, C., & Sherin, M. G. (2006). Practicing change: Curriculum adaptation and teacher narrative in the context of mathematics education reform. *Curriculum Inquiry, 36*(2), 153–187.
Goldberg, F., Robinson, S., & Otero, V. (2006). *Physics for elementary teachers*. It's About Time.
Goldberg, F., Robinson, S., Otero, V., Kruse, R., & Thompson, N. (2008). *Physical science and everyday thinking* (2nd ed.). It's About Time.
Hanuscin, D. Cisterna, D. & Lipsitz, K. (2018). Elementary teachers' pedagogical content knowledge for teaching the structure and properties of matter. *Journal of Science Teacher Education, 29*(8), 665–692. https://doi.org/10.1080/1046560X.2018.1488486
Hanuscin, D., Donovan, D., Acevedo-Gutiérrez, A., Borda, E., DeBari, S., Melton, J., Le, T., Morrison, W. & Ronca, R. (2021). Supporting the professional development of science teacher educators through shadowing. *International Journal of Science and Mathematics Education, 19*(Suppl. 1), S145–S165.
Keeley, P. (2015). *Science formative assessment, volume 1: 75 practical strategies for linking assessment, instruction, and learning.* Corwin Press.
Land, T. J., Tyminski, A. M., & Drake, C. (2015). Examining pre-service elementary mathematics teachers' reading of educative curriculum materials. *Teaching and Teacher Education, 51*, 16–26.
Lloyd, G. (2008). Curriculum use while learning to teach: One student teacher's appropriation of mathematics curriculum materials. *Journal for Research in Mathematics Education, 39*(1), 63–94.
Loughran, J. (2013). *Developing a pedagogy of teacher education: Understanding teaching & learning about teaching*. Routledge.
McDermott, L. C. (1995). *Physics by Inquiry: An Introduction to Physics and the Physical Sciences, Volumes 1& 2*. John Wiley & Sons.
Mikeska, J. N., Kurzum, C., Steinberg, J., & Xu, J. (2018). *Assessing elementary science teachers' content knowledge for teaching science for the ETS Educator Series: Pilot results* (Research Report No. RR-18-20). Educational Testing Service.
Nabors Oláh, L., Howell, H., Lai, Y., & DeLucia, M. (2018, February). *Using mini-cases to support pre-service teachers' Mathematical Knowledge for Teaching.* Paper presented at the meeting of the Association of Mathematics Teacher Educators (AMTE), Houston, TX.
National Research Council. (2012). *A framework for K12 science education: Practices, crosscutting concepts, and core ideas.* Board on Science Education. Washington, DC: National Academies Press.
National Research Council. (2013). *Next generation science standards: For states, by states.* National Academies Press.
Park Rogers, M., Berry, A., Krainer, K., & Even, R. (2021). Finding common ground: A synthesis of science and mathematics teacher educators' experiences with professional growth. *International Journal Of Science And Mathematics Education, 19*(1), 167–180.
Ping, C., Schellings, G., & Beijaard, D. (2018). Teacher educators' professional learning: A literature review. *Teaching and Teacher Education, 75*, 93–104.
Pringle, R. M., Mesa, J., & Hayes, L. (2017). Professional development for middle school science teachers: Does an educative curriculum make a difference? *Journal of Science Teacher Education, 28*(1), 57–72.
Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of educational research, 75*(2), 211–246.

Schneider, R. M., & Krajcik, J. (2002). Supporting science teacher learning: The role of educative curriculum materials. *Journal of Science Teacher Education, 13*(3), 221–245.
Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.
Smith, D. C. (2000). Content and pedagogical content knowledge for elementary science teacher educators: Knowing our students. *Journal of Science Teacher Education, 11*, 27–46.
Smith, P. S., & Plumley, C. L. (2016). *A review of the research literature on teaching about the small particle model of matter to elementary students.* Horizon Research, Inc.
Smith, P. S., Plumley, C. L., & Hayes, M. L. (2017). *Eliciting elementary teachers' PCK for the small particle model*. Horizon Research, Inc.
Stein, M. K., Remillard, J., & Smith, M. S. (2007). How curriculum influences student learning. *Second handbook of research on mathematics teaching and learning, 1*(1), 319–370.
Tsaparlis, G., & Sevian, H. (2013). *Concepts of matter in science education*. Springer.
Wilson, S. M. (2006). Finding a canon and core: Meditations on the preparation of teacher educator-researchers. *Journal of teacher education, 57*(3), 315–325.
Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 96*(5), 878–903.
Wood, D., & Borg, T. (2010). The Rocky Road: The journey from classroom teacher to teacher educator. *Studying Teacher Education, 6*, 17–28.