

Preservice elementary teachers' science lesson plan analyses and modifications concerning scientific modeling: Insights into teacher knowledge application

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### Abstract

Lesson plan analysis and modification are valuable skills preservice elementary teachers begin to develop in their teacher education courses. In science, these skills are particularly important because they allow preservice teachers to introduce learners to the concepts and processes of scientific modeling. Scientific models, modeling practices, and meta-modeling knowledge (collectively, “scientific modeling”) are often novel ideas and pedagogies for preservice teachers, so prior to teaching others, preservice teachers must first learn what scientific modeling entails, from the perspective of the learner as well as the teacher. In this study, we investigate preservice teachers’ analyses and modifications to elementary science lesson plans before, during, and after instruction on scientific modeling. More specifically, we examine preservice teachers’ attention to elements of scientific modeling in the presence and absence of directive prompts. Our findings suggest that even with very limited instruction on scientific modeling, preservice teachers begin to attend to lesson plan elements of scientific modeling in their lesson plan analyses and modifications. Assignments that contained directive prompts elicited more evidence of preservice teachers’ attention to scientific modeling than did assignments lacking these directive prompts. These findings suggest that additional forms of support may be needed to encourage preservice teachers’ continued thinking about scientific modeling in lesson planning.

## Introduction

As part of their educational preparation, preservice elementary teachers learn to teach a variety of subject matters to K-6 students. Elementary science teacher educators have the unique task of helping preservice elementary teachers learn to teach science, particularly in ways that are consistent with current reform-oriented teaching approaches advocated by science educators. Part of learning to teach science effectively and in reform-oriented ways means that preservice teachers must learn to negotiate elementary science curriculum materials. Often, school elementary science curriculum materials are not fully aligned with the recommended elementary-level science content and process educational standards advocated by individual state departments of education or national standards-setting bodies, such as the National Research Council and the American Association for the Advancement of Science. For this reason, teachers often choose to adapt classroom curriculum materials so that they better reflect the standards-based learning outcomes for which their students will be held responsible. Teachers also choose to adapt curriculum materials to better fit the unique circumstances of their learners and classrooms. Thus, teacher educators prepare preservice teachers to become agents of curriculum material customization and change. Research into how preservice elementary teachers critique and adapt curriculum materials shows that preservice elementary teachers can indeed make principled and productive changes to instructional materials on the bases of what they learn in their science teaching methods courses (Davis, 2006).

To teach science in reform-oriented ways, preservice teachers must also gain knowledge and understanding about teaching science through the use of scientific modeling. Throughout this paper, the term “scientific modeling” refers to scientific models, modeling practices, and knowledge *about* scientific models and modeling practices (termed “meta-modeling knowledge,”

(Schwarz & White, 2005), or MMK). Teacher educators and others have integrated these more authentic approaches to “doing science,” teaching science, and learning about science into their teacher education methods courses with some success (Hug, Kenyon, Teo, Nelson, Cotterman, & Davis, 2008; Windschitl, Thompson, & Braaten, 2008b). This is a recent and currently growing area of research, as trends in science education indicate a movement toward model-based reasoning in science teaching and learning (Windschitl, Thompson, & Braaten, 2008a).

There is currently a gap in the literature connecting these two bodies of research. This study, then, begins to bridge this gap by examining how preservice elementary teachers apply their changing knowledge and understandings about scientific modeling in the context of lesson plan analyses and modifications. As the data in this study reveal, preservice elementary teachers begin to attend to aspects of scientific models, modeling practices, and MMK in lesson plans during and after limited instruction on these topics. This finding is encouraging, and suggests that there is more work to be done by researchers and teacher educators to support preservice elementary teachers in understanding and using modeling-based approaches to elementary science instruction.

#### Literature review and theoretical framework

Underlying the work in this study is a theoretical framework that presupposes preservice teacher learning derives from multiple sources and experiences, including their university teacher education courses; engagement with curriculum materials (Collopy, 2003; Davis & Krajcik, 2005; Remillard, 2005); interactions with teacher educators, cooperating teachers, and other “more knowledgeable others” (Vygotsky, 1978); interactions with peers; their own histories as student participants in an “apprenticeship of observation” (Lortie, 1975); and other significant activities and experiences that locate them as beginners within a community of elementary

teaching practice (Lave & Wenger, 1991). Within this theoretical framework, teacher learning is purported to be cognitive, sociocultural, and contextually situated in nature (Putnam & Borko, 2000), notions which are foundational to understanding both the approach to and the sense-making associated with this study.

*Preservice teachers learning to critique and adapt curriculum materials*

As part of their undergraduate training, elementary teacher education programs typically require that teacher candidates enroll in methods courses designed to help preservice teachers improve their fledgling instructional techniques. Another function of these methods courses is to introduce preservice teachers to current “best practices” in instruction in the various content areas, as well as innovative teaching approaches that align with the goals set out in national standards documents (American Association for the Advancement of Science, 1993, 2009; National Board for Professional Teaching Standards, 2002; National Research Council, 1996). In science, this often means that preservice teachers learn to teach in ways that differ quite markedly from the ways in which they learned science as students (Windschitl, 2003).

Beginning elementary teachers’ science content knowledge is often tenuous at best (Appleton, 2006; Davis, Petish, & Smithey, 2006; Smith & Neale, 1989). At the same time they are learning science teaching methods, preservice teachers may also be re-learning science content. Additionally, in their methods courses, preservice teachers learn education-related content in the form of subject matter-specific and -nonspecific pedagogical considerations, teacher moves, techniques, teaching methods, etc., that comprise teacher education courses. Often the pedagogical aspects of what preservice teachers learn are intercalated with the subject matter; for example, a preservice elementary teacher may learn to teach about the water cycle using an instructional approach that emphasizes scientific models and modeling practices. In

some cases, relevant pedagogy may be discussed in more abstract and general terms, or ways that are not explicitly tied to a specified science content area. For example, preservice elementary teachers may learn to adopt an inquiry-oriented approach to teaching science that highlights the role of asking and answering scientific questions, using evidence to formulate and support claims, and communicating and justifying explanations (National Research Council, 2000) but without reference to specific science topics.

In enacting the methods they learn about in their teacher education courses, preservice teachers use a variety of curriculum materials that may (or may not) be useful teaching tools. Particularly for beginning teachers, curriculum materials are extremely important components and determinants of teaching practice (Grossman & Thompson, 2008). Often the curriculum materials available to preservice teachers in their field placements do not reflect the ideas emphasized in national science standards documents (Kesidou & Roseman, 2002; Stern & Roseman, 2004) and in their science teaching methods courses (Strangis, Pringle, & Knopf, 2006). To address this mismatch, teacher educators emphasize critique and adaptation of curriculum materials in science teaching methods courses (Davis, 2006; Schwarz, Gunckel, Smith, Covitt, Bae, Enfield, & Tsurusaki, 2008).

So, then, in order to include and apply their new knowledge about content and teaching methods in science instruction, preservice teachers must learn to analyze and make principled and productive adaptations to existing curriculum materials (Davis, 2006). To this end, preservice teachers benefit from having support in analyzing curriculum materials in light of the subject matter and pedagogy, and the unique circumstances of their own classrooms, learners, developing teaching styles, and contexts (Barab & Luehmann, 2003; Davis, 2006; Kern, Bambara, & Fogt, 2002). Teacher educators should be mindful that although the products of

preservice teachers' lesson plan analyses and modifications may be linked to learning goals, the pathways used to arrive at a final lesson plans are often anything but linear and logical (Strangis et al., 2006) and may draw largely upon firsthand personal experiences in science (Windschitl et al., 2008b). Well-designed scaffolds that aid preservice teachers in analyzing and modifying lesson plans can facilitate learning these important skills (Davis, 2006).

Teacher educators can help preservice teachers learn to analyze and adapt lesson plans through the use of lesson plan analysis (LPA) assignments in undergraduate science teaching methods courses (Jacobs, Martin, & Otieno, 2008; Strangis et al., 2006). In these assignments, preservice teachers may be asked to evaluate a lesson plan in response to specific prompts, such as "What are the lesson's connections to science Standards documents?", or they may be asked to comment on how well the lesson plan elicits students' prior knowledge. In these assignments, preservice teachers may be asked to analyze lesson plans with highly-specific criteria in mind, or they may be asked to analyze lesson plans on the basis of self-selected criteria. Using their analyses, preservice teachers are then asked to suggest lesson plan modifications to improve the lesson's quality along the dimensions of the metric criteria.

In addition to providing preservice teachers opportunities to engage in the authentic work of science lesson planning, these LPA assignments provide a window into preservice teacher learning for the teacher educator. Evaluation of preservice teachers' lesson plan analyses and modifications allows teacher educators to see what preservice teachers are appropriating as useful and applicable knowledge and experiences from their methods courses (Beyer, in preparation; Davis, 2006; Forbes, in preparation). In addition, preservice teachers' lesson plan analyses and modifications suggest that which the preservice teachers view as relevant among all that they have learned in their teacher education courses. Finally, these artifacts of preservice

teachers' work can suggest how preservice teachers are constructing their knowledge and practice of approaching science lesson planning.

*Preservice teachers learning about scientific models, modeling practices, and meta-modeling knowledge*

Trends in science education suggest a movement toward model-based science teaching and learning (Windschitl et al., 2008a). For preservice teachers, this necessitates learning about scientific models and modeling practices, and gaining meta-modeling knowledge. Toward this goal, preservice teachers must develop understandings of models- and modeling-related terminology, become familiar with scientific practices and methods involving models and modeling, and learn to apply this knowledge and these methods in the teaching and learning of science. But what does this mean, exactly?

For the purposes of this study, a scientific model is defined as an abstracted representation of objects, systems, or phenomena, whose central features are highlighted, and who may be used to make explanations or predictions (Harrison & Treagust, 2000; Nelson, Beyer, & Davis, 2008). Scientific models may take the form of mental models (Johnson-Laird, 1983), referred to here as “idea models,” or they may be “expressed models,” which are instantiations of the concepts or ideas that allow for communication of the underlying idea model (Gilbert & Boulter, 2001; Harrison & Treagust, 2000; Ritchie, Tobin, & Hook, 1997). Modeling practices are defined as “Construction, Use, Explanation, and Revision” (CUER) and are defined in terms of actions involving a scientific model (Justi & Gilbert, 2002b; Kenyon, Schwarz, & Hug, 2008; Nelson et al., 2008; Reiser, Krajcik, Davis, Fortus, Schwarz, Hug, Kenyon, & Roseman, 2007). Scientific model construction entails the creation of a scientific model; determining the key components and relationships of a system or phenomenon that are to be



represented in the scientific model of that system or phenomenon, and determining how one will represent these components and relationships. Scientific model use is manifold: scientific models are said to be “used” when employed in the services of sense-making, making predictions, or communicating, each for various purposes and audiences (individuals or groups). Evaluation of scientific models entails analysis of how well the scientific model meets its intended purpose: for example, does the particular scientific model clearly portray the phenomenon such that a naïve user can understand the components and processes depicted? Not surprisingly, scientific model evaluation criteria are closely linked to the model’s purpose, but usually involve decisions about the model’s scientific accuracy, consistency with evidence, clarity, salience, and explanatory power, for example. Finally, scientific model revision involves making productive changes to a scientific model to improve how well the model meets its intended purpose(s) and satisfies its evaluation criteria, usually in light of new evidence or ideas, or following model evaluation (Kenyon et al., 2008; Nelson et al., 2008; Schwarz, Reiser, Davis, Kenyon, Acher, Fortus, Schwartz, Hug, & Krajcik, accepted pending revisions).

Meta-modeling knowledge, or MMK (Schwarz & White, 2005), is another novel concept for most, if not all, preservice teachers. Here, meta-modeling knowledge is defined as knowledge *about* scientific models and modeling practices. Meta-modeling knowledge regarding scientific models includes ideas such as the following:

- Different types of scientific models have different strengths and limitations
- Scientific models should be consistent with all the experimental evidence
- Scientific models are generative; they allow users to develop understandings and predictions around the phenomena they represent
- Scientific models can and do change as understandings of the phenomena change

- Scientific models and modeling practices are authentic elements of how real scientists “do” science

Meta-modeling knowledge about scientific modeling practices refers to awareness of what one is doing while one is doing it (e.g., “We are engaging in model *use* when we conduct erosion experiments with our stream tables.”) as well as an understanding of what the practice entails (e.g., “Clarity and consistency with evidence are two important criteria to consider when evaluating a scientific model.”). Usually, meta-modeling knowledge is implicit in science lessons; rarely is attention called to the fact that scientific models and modeling practices are being employed in the service of science learning. Making such information explicit can help students gain a better understanding of just what it is that they are doing and why they are doing it (Grosslight, Unger, Jay, & Smith, 1991; Kenyon et al., 2008; Schwarz & White, 2005).

In addition to learning this new content around scientific models, modeling practices, and MMK, preservice teachers are exposed to ideas about how to apply this learning in the form of scientific modeling-oriented teaching methods. Again, these ideas are typically new to preservice teachers who have not experienced teaching or learning about science in this manner (Windschitl, 2003). In fact, many *experienced* science teachers hold naïve views about the purposes, uses, and nature of scientific models (Justi & Gilbert, 2002a; Van Driel & Verloop, 1999, 2002), which helps explain why preservice teachers’ knowledge and understanding of scientific models are similarly naïve. Interventions aimed to increase preservice secondary science teacher knowledge about scientific models, modeling practices, and MMK have shown limited success in moving preservice teachers’ knowledge and understanding of scientific models and modeling toward sophisticated knowledge and understandings typical of experts and practicing scientists (Crawford & Cullin, 2004; Grosslight et al., 1991; Schwarz & Gwekwerere,

2007; Smit & Finegold, 1995; Van Der Valk, Van Driel, & De Vos, 2007; Van Driel & De Jong, 2001; Windschitl & Thompson, 2006). Results from these and similar studies provide some insight into just how difficult it is for teacher educators to develop sophisticated models-based reasoning in those who are already well-versed in science (Van Driel & De Jong, 2001); it stands to reason that this task should only be more challenging with preservice elementary teachers, who do not tend to be as strong in science (Andersen & Mitchener, 1994; Appleton, 2006).

*Learning lesson planning and scientific modeling*

In essence, then, the preservice teachers in this study are learning how to effectively couple content in science with appropriate science teaching methods, using curriculum materials as tools, to create plans for and enact science instruction that fosters meaningful, authentic learning experiences for their students. A modeling-based approach to envisioning the nature of science and science instruction is usually novel for preservice teachers. Consequently, preservice teachers may struggle to conceive of the scientific content in this manner, and are faced with the task of determining how science content might be taught using these unfamiliar pedagogies (Windschitl, 2003; Windschitl & Thompson, 2006; Windschitl et al., 2008b). Complicating the picture is the relative lack of curriculum materials in elementary science that espouse such models-centric notions of science and its instruction; this presents a variety of challenges for beginning science teachers, as alluded to in the previous section. How, then, can preservice teachers combine new ideas about scientific modeling within existing elementary science lesson plans that lack such a perspective? To help explain this, I return to the notion of situated cognition in preservice teacher learning, and briefly discuss how this theoretical framework sheds light on the current study and the challenges therein.

*Situated cognition in preservice teacher learning*

Knowledge gained is dependent upon activity, context, and culture: three integral and interdependent determinants of learning (Brown, Collins, & Duguid, 1989). Further, learning is a process of enculturation, in which authentic activities are performed by novices as part of the learning that occurs (Brown et al., 1989). In applying this framework to preservice teacher learning, Putnam and Borko (2000) underscore the importance of preservice teacher teachers' abilities to access and apply situated knowledge in new contexts. Part of the role of the teacher educator as a participant in the preservice teacher's learning environment lies in shaping teacher learning; providing appropriate guidance and support during the various stages of preservice teacher learning (Putnam & Borko, 2000).

Applying these notions to preservice teacher learning in science has illuminated some approaches and guiding principles for teacher educators. Case studies are often employed as learning tools in teacher education; preservice science teachers can grow in their knowledge and understanding of practicing teachers' knowledge and practices by carefully studying the practicing teachers' conceptual case knowledge, procedural case knowledge, and socially shared identities and beliefs (Kim & Hannafin, 2008). Laboratory-based learning in science has been a valuable tool in science teacher education that preservice teachers have successfully transferred to teaching settings (Sweeney & Paradis, 2004). However, such transfer often does not occur spontaneously; active reflection and explicit support underlie successful transfer of knowledge and skills to new situations (Schwartz, Lederman, & Crawford, 2004). Taken together, these findings have interesting implications for a situated cognition approach to preservice elementary teacher education in science.

In this study, preservice elementary teachers learned about scientific modeling by engaging with models-based lesson plans and activities from the perspectives of both science learners and science teachers. Additionally, preservice teachers gained experience in applying scientific modeling ideas within the authentic contexts of lesson plan analysis and modification. To promote transfer and metacognitive skills, preservice teachers were asked to reflect upon their analyses and modifications, and cite rationales for their claims and proposed lesson plan changes. Through applying models-based concepts to existing lesson plans, preservice elementary teachers learn and develop abilities to critique and modify elementary science lesson plans in ways that mirror the work of reform-oriented, practicing elementary science teachers (Davis, 2006; Davis & Smithey, in press).

#### *The current study*

To bring together these elements of the literature, I study how preservice elementary teachers consider and modify lessons to include their knowledge of scientific models, modeling practices, and MMK (hereafter referred to as “scientific modeling”), focusing on which aspects of scientific modeling are incorporated. Generally speaking, this study considers the following question: *What ideas about scientific models/modeling are taken up by preservice elementary teachers as evidenced by their lesson plan modifications both in the presence and absence of guiding prompts?*

Specifically, my research questions are:

RQ1: When preservice teachers experience a lesson on scientific modeling, what sorts of ideas do preservice teachers "take up" and use as evidenced in their required models and modeling-related work? Specifically, what types of modifications to activities and lessons containing scientific modeling do preservice teachers make when prompted to do so?

When reasons are provided, why do preservice teachers choose to make these modifications?

RQ2: When preservice teachers are asked to teach science lessons in their field placements, do any of them freely choose to highlight and/or incorporate elements into their lesson plans that are consistent with notions of scientific modeling? If so, what elements of scientific modeling do they focus on and how do they use these elements in their teaching plans?

To address these questions, I studied the work of preservice elementary teachers as detailed in the following section.

## Methods

### *The context of this study*

This study took place during the Fall 2007 Elementary Science Teaching Methods course (“EDU 421”) at the University of Michigan. Major course elements included inquiry-oriented science instruction, lesson plan analysis and modification, and eliciting student thinking, and have been described elsewhere (Davis & Smithey, in press). Study participants were college students in their third semester of the University of Michigan undergraduate elementary teacher education program. Typically, these are Caucasian female college seniors in their early twenties.

### *Data sources*

During the Fall 2007 semester of EDU 421, one course period (3 hours) was dedicated to instruction about scientific models, modeling practices, and meta-modeling knowledge—a new aspect of the course. Instruction was led by the author and consisted of a short reading entitled “Incorporating Modeling in Elementary and Middle School Classrooms” (Nelson et al., 2008) that was assigned and to be completed in advance of class, a Powerpoint presentation given at

the beginning of class (which recapped the main points of the reading assignment), a science activity focused on the movement of water through plants designed to give preservice teachers experience engaging in scientific modeling practices from the perspective of elementary students, and, finally, a plan for another activity (“Germ Transmission Activity Critique”) designed to help preservice teachers think about scientific models, modeling practices, meta-modeling knowledge, learning goals, and lesson plan evaluation and modification from the teacher’s perspective.

A pre/post test was administered to assess preservice teacher knowledge about scientific models, modeling practices, and meta-modeling knowledge. This instrument was given to all preservice teachers in the form of a homework assignment (“Modeling Journal Assignment”) that was completed individually and submitted electronically twice during the semester as both a pretest (approximately 2 weeks prior to instruction relating to scientific modeling) and as a posttest (approximately 2 weeks following instruction relating to scientific modeling). The purposes of this assignment were to establish a baseline of preservice teacher knowledge about scientific modeling (pretest) and to elucidate areas of preservice teacher understanding and confusion following instruction on scientific modeling (posttest). Specifically, item seven on the pre/post test asked preservice teachers to indicate a preference for one of two lesson plans that convey the topic of erosion using a models-based approach. One option focused on embedded modeling practices while the other focused on MMK and explicit modeling practices as described in detail below. Preservice teachers were asked to explain the reasoning for their preference, and also asked whether they would make modifications to the preferred lesson plan. This pre/post test item is included as Appendix A.

Another data source used for this study was the Germ Transmission Activity Critique (Appendix B). This assignment was designed to explicitly support preservice teachers' thinking about scientific modeling in the context of a lesson, and was completed by preservice teachers in pairs or triads during the methods course period on scientific modeling. In brief, a description of a hand-shaking activity intended to simulate germ transmission was provided, and preservice teachers were asked to analyze and modify this activity on the basis of how well they thought this activity would help their students learn about scientific modeling. Preservice teachers were also asked to justify their analyses of and modifications to the activity.

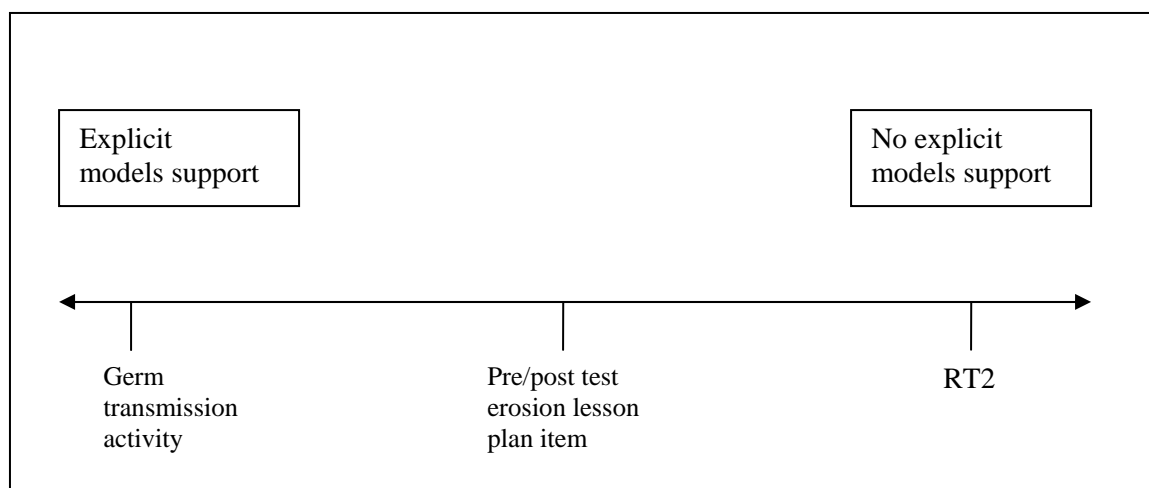
The third data source used in this study was a subset of the Reflective Teaching 2 assignments, in which scientific modeling was a lesson plan element (Appendix C provides an outline of the RT2 assignment). Preservice teachers were asked to select three criteria to guide their analysis and modification of the science lesson they would teach in their field placement classrooms, prepare the lesson, enact it, and then provide a structured, written reflection on the experience. The RT2 assignments were completed individually, submitted both electronically and in hard copy, and occurred weeks after the course period dedicated to scientific modeling. As the assignment description in Appendix C indicates, the RT2 did not contain any specific prompts that would necessarily lead preservice teachers to consider scientific models, modeling practices, or MMK in their lesson plans.

To gain more insight into preservice teachers' thinking about scientific modeling, I conducted pre- and post-interviews one-on-one with four preservice teachers. I selected interviewees on the basis of their responses to the pretest erosion item. Preservice teachers who indicated a preference for lesson plan option 1 ( $n=2$ ) and lesson plan option 2 ( $n=2$ ) were interviewed 1-2 weeks prior to the course period dedicated to scientific modeling and again 3-4



weeks following the course period dedicated to scientific modeling. Pre- and post-interview protocols are included as Appendices D and E, respectively.

Data sources used in this study varied in terms of their explicitness and level of support in helping preservice teachers consider scientific modeling-related aspects of the lesson plans (or activity) in question. Figure 1 shows the relative placement of the data sources in terms of how explicitly their prompts provoked preservice teachers to analyze the lesson plan or activity on the basis of scientific modeling-related criteria.



*Figure 1.* Continuum of explicit models, modeling practices, and MMK-related support in data sources for this study.

Data sources in this study can also be considered in light of their timing with respect to instruction about scientific modeling in the elementary science teaching methods course. Figure 2 depicts the chronology of the collection of data sources in this study.

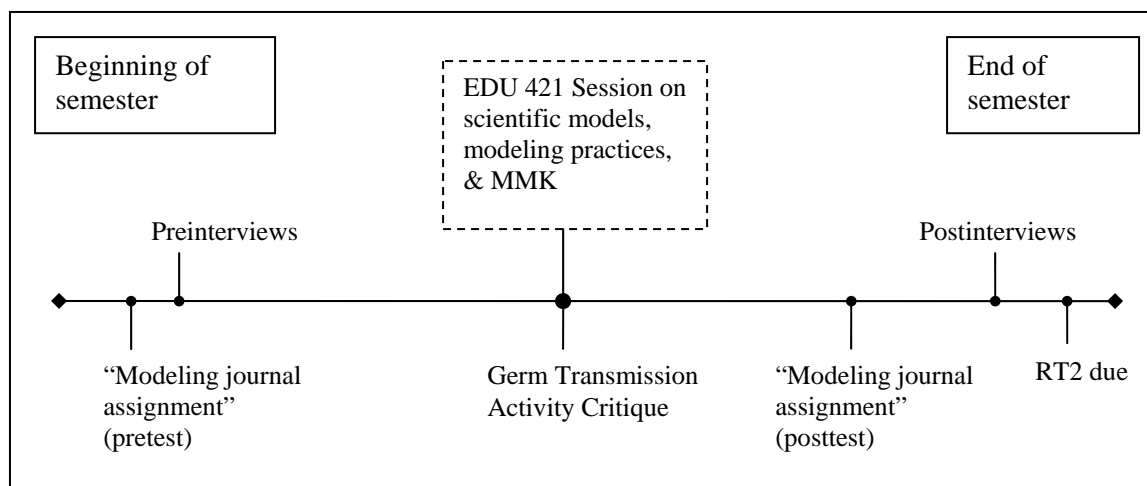


Figure 2. Timeline of data sources for this study

### *Data collection and analysis*

Data were collected and analyzed according to the research question(s) the data addressed. Table 1 displays this study's data sources and the relevant research questions.

Table 1

*Data sources for this study*

<b>Research Question</b>	<b>Data Source</b>	<b>What questions can be answered with this data?</b>
RQ1: Prompted analysis	Pretest/Posttest Question 7	Do preservice teachers prefer the lesson plan that has explicit modeling practices and implicit MMK, or the lesson plan that has implicit modeling practices and explicit MMK? Why? What changes would preservice teachers make to the preferred lesson plan and why?
RQ1: Prompted analysis	Germ Transmission Activity Critique	When preservice teachers are specifically asked to evaluate a lesson plan in consideration scientific modeling, what sorts of changes do they suggest to help students learn about scientific models and modeling in science? Why?
Both	Pre/Post Interviews	What are the more detailed reasons for preservice teachers' answers in the pretest and posttest erosion question? What sorts of ideas about scientific modeling did preservice teachers discuss when completing the germ transmission activity critique? Did preservice teachers consider scientific modeling in their RT2 assignments, and if so, how and why?
RQ2: Unprompted analysis	Reflective Teaching Assignment 2	When preservice teachers are not prompted to evaluate scientific modeling in science lesson plans, a) do they attend to these features of the lesson and b) if so, what sorts of lesson plan changes do they make regarding elements of scientific modeling?

Preservice teachers' written work was collected primarily electronically as described and compiled for analysis. Data from preservice teachers' methods course assignments were analyzed using separate coding schemes, with one coding scheme for each data source. Anticipated codes relating to preservice teachers' understanding of scientific modeling, rationales for choosing scientific modeling-based instructional approaches, and lesson plan modifications were derived from the literature on preservice teachers and scientific modeling, and the literature on preservice teachers and lesson plan analysis and modification as reviewed above. Additional emergent codes were added to the coding schemes consistent with a grounded theory approach (Corbin & Strauss, 2008; Glaser & Strauss, 1967).

Tables 2 and 3 show the coding schemes used to analyze pre- and posttest responses to item seven.

Table 2

*Rationales for erosion lesson plan preference*

<b>Data Codes</b>	<b>Explanations/examples</b>
General pedagogy reasons	Individual work/thinking, collaborative work/thinking, community building, fun/engaging, student-directed, clarity of lesson plan, etc.
General science pedagogy reasons	Inquiry-based instruction, authenticity/this is what real scientists do, nature of science, content + process, hands-on, making predictions (with no mention of models), other scientific practices, etc.
MMK: Models can change	As ideas change, with new evidence, etc.
MMK: Models vs. reality	Comparison between the model(s) in this lesson plan and how erosion happens in the real world
MMK: Models have strengths & weaknesses	Models can't explain everything, certain models explain some things well, etc.
MMK: Models have purpose and/or utility and/or importance	Models are useful for communication, making explanations, sense-making, etc. OR models are important to use in science OR models have purposes for their use
MMK: Idea models and expressed models	Any mention of idea models and expressed models (e.g. for one idea model there can be several expressed models)
MMK for modeling practices	"Metatalk" about the modeling practices, including calling out the modeling practice while the students are doing it
MMK: Model consistency with data	Models should be consistent with empirical data
Modeling practices-related	Construct, use, evaluate, or revise specifically mentioned (as tracers and usually without a metacognitive component)
Other	Student metacognition, assessment, preservice teacher reiterates/summarizes the lesson plan, etc.—anything not adequately captured by the other categories
Focus on content	Prefers focus on erosion rather than models, modeling

Table 3

*Preservice teachers' suggested modifications to preferred erosion lesson plan*

<b>Data codes</b>	<b>Explanations/examples</b>
General pedagogical changes	Changes to discussion formats, add writing component, assessment, rearrange elements of the lesson, add/subtract lesson elements for general pedagogical reasons
General science pedagogical changes	Add prediction/explanations (not explicitly model-based), add experiment, nature of science discussion, omit science-specific elements of lesson for pedagogical reasons specific to science
More information about models	Lesson should include more information about models OR a separate lesson on models
Less focus on models, more focus on content	Lesson should focus more on erosion and less on models
Add MMK	Add anything related to MMK for models or modeling practices
Add practices	Construct, Use, Evaluate, Revise (includes having students use model to predict, explain, test ideas, etc.)
Idea/expressed model	Changes to lesson plan related to idea model & expressed model
Other	Anything not captured by the other categories
No change or no answer	Nothing provided

As the coding scheme suggests, preservice teachers' written responses were coded by lesson plan option preference, rationales cited for this preference, and suggested lesson plan modifications and their rationales.

The germ transmission activity critique coding schemes are provided in Tables 4 and 5. Here, preservice teacher answers were categorized on the bases of analysis criteria, rationales, and suggested modifications and the rationales for those modifications.

Table 4

*Changes to germ transmission activity, scientific modeling focus*

<b>Code</b>	<b>Explanation/example</b>
General pedagogical changes and/or science pedagogical changes	Change discussion formats, add assessment, add prediction (not models-specific), add driving question, etc.
Make activity model components, relationships, and/or purpose explicit	Call out these aspects of the activity's model so that students are aware of them
Address completeness or scientific accuracy of model	Improve model completeness or accuracy by adding an activity or through discussion
Students brainstorm model components & relationships	Students, rather than teacher, suggest what should be included in the model
Add or make MMK explicit	Teacher adds or alerts students to MMK
Make modeling practices explicit	Teacher announces modeling practices while students engage in them
Extend lesson	Add elements to this lesson, such as "how to prevent germ transmission"
Add modeling practices	Construct, Use, Evaluate, Revise
Other	Anything not captured above

Table 5

*Rationales for changes to germ transmission activity, scientific modeling focus*

<b>Code</b>	<b>Explanation/example</b>
Incompleteness of model/Scientific accuracy/Other models work	Model in this activity is not complete or is scientifically inaccurate
Allows/Enhances student ability to engage in modeling practices	Specific to students' abilities to do the modeling practices
Enhances student MMK for practices	Specific to students' knowledge about the modeling practices (knowing when/how they are engaging in a modeling practice)
Enhances student MMK for models/modeling	General to students' MMK about scientific models and modeling (in toto)
Pedagogical or class management preference	Reasons having to do with general teaching strategies
More focus on content/relate the model to the content	Reasons highlighting germ transmission or connecting the model in the activity to germ transmission
Students exposed to all modeling practices	Students experience all modeling practices rather than a subset of them
Other	Anything not captured above

Finally, the description guide used to characterize RT2s is indicated in Table 6 and the RT2 scientific modeling scoring rubric is indicated in Table 7. Only those RT2s determined to contain models were analyzed according to this coding scheme. The final coding category represents a classification of these RT2s on the basis of what they reveal about the preservice teacher's knowledge, skills, and abilities to analyze and modify science lessons using a scientific modeling lens. Increasing levels of modeling-related knowledge and lesson plan analysis and modification are indicated by higher scores.

Table 6

*RT2 descriptors*

<b>Field</b>	<b>Description</b>	<b>Explanation</b>
Original lesson plan model?	Present/absent	A model is (present/absent) in the original lesson plan
Role of model in original lesson plan	Implicit/explicit	The model in the original lesson plan is (implicitly/explicitly) identified as a model
Modeling as analysis criterion?	Yes/no	The preservice teacher (did/did not) select scientific modeling as a lesson plan analysis and modification criterion
Modeling standards/benchmarks	Yes/no	The preservice teacher (did/did not) identify the lesson's connection to modeling-related science education standards or benchmarks
Modeling-related lesson plan changes	Add/delete/no change Models/practices/MMK	The preservice teacher (added/deleted/did not change) the (scientific models/modeling practices/MMK) elements of the original lesson plan

Table 7

*Sophistication scoring rubric for RT2 with respect to scientific modeling*

<b>Score</b>	<b>Description</b>
3	This lesson plan provides evidence that the preservice teacher was thinking about AND incorporating ideas about scientific models, scientific modeling practices and/or MMK into the original lesson plan. Preservice teacher appears to have a good beginning understanding of scientific models, scientific modeling, and MMK in science instruction.
2	This lesson plan provides evidence that the preservice teacher was thinking about OR incorporating ideas about models, modeling and/or MMK mostly correctly into the original lesson plan. Preservice teacher appears to have a mediocre beginning understanding of scientific models, modeling, and MMK in science instruction.
1	This lesson plan provides evidence that the preservice teacher was thinking about OR incorporating ideas about models, modeling and/or MMK mostly <i>non-scientifically</i> (i.e. a layperson's notion of models) into the original lesson plan. Preservice teacher appears to have a poor understanding of scientific models, modeling, and MMK in science instruction.
0	This lesson plan provides no evidence that the preservice teacher was thinking about or incorporating ideas about models, modeling and/or MMK into the original lesson plan. Preservice teacher's understanding of scientific models, modeling, and MMK in science instruction cannot be ascertained from this lesson plan.



In addition to analyzing preservice teachers' written work, I conducted interviews to elicit further information about preservice teachers' ideas about scientific modeling, particularly in reference to the course assignments. Interviews were audiotaped and transcribed in full. Interview data were parsed on the basis of thematic analysis (Boyatzis, 1998). Statements relating to specific assignments were grouped together and further subcategorized on the basis of common themes, such as mention of MMK within the pre/post test erosion item.

Inter-rater reliability using the above coding schemes was conducted with another graduate student. A Cohen's kappa coefficient of 0.80 or greater was achieved in the initial round of coding comparisons for the germ transmission activity and RT2 data (Cohen, 1960). Inter-rater discussions about the data followed by additional rounds of coding scheme modification and subsequent data coding (and recoding) were required to reach a Cohen's kappa coefficient level of 0.80 or greater for the pre/post test data. Discrepant codes were discussed until agreement was reached, and a final, overall Cohen's kappa coefficient (averaged across data sources) of 0.87 was attained.

### Findings

As indicated above, the data sources and findings in this study were considered in light of their contexts with respect to (a) explicitness of support for preservice teacher thinking about scientific modeling (Figure 1) and (b) chronology relative to preservice teacher instruction about scientific modeling (Figure 2). Recall that the research questions in this study focus on preservice elementary teachers' lesson plan analyses and modifications in the presence and absence of directive prompts. I present results related to the pre/posttest item first; this data source falls in the middle of the support continuum and thus sets the stage. Then, I present results related to the presence and absence of directive prompts, respectively.

*Mid-continuum support: Pre/posttest erosion item*

Prompts in the pre/post test erosion item (“Which lesson plan would you be most inclined to use? Why?”) were open-ended and did not require preservice teachers to comment upon the scientific modeling features of the two lesson plan options. However, the larger context of the erosion question (within the “modeling journal assignment”) situates this item in an assignment where preservice teachers are considering scientific modeling almost exclusively. The within-the-modeling-assignment context is held constant in the pretest and posttest; what varies is the timing of the assignment item relative to methods course instruction about scientific modeling.

Keeping this in mind, the portion of the question that solicited preservice teachers’ rationales for their lesson plan preference permitted them to comment upon whatever they viewed as the salient features of the two lesson plans. Lesson plan option one was designed to include scientific modeling practices in an embedded manner, whereas lesson plan option two was designed to include scientific modeling in a more explicit fashion that highlighted elements of meta-modeling knowledge. Table 8 reveals the unequal distribution of lesson plan option preferences in the pre- and posttests.

Table 8

*Distribution of erosion lesson plan preferences among preservice teachers*

<b>Lesson Plan Preference</b>	<b>% of preservice teachers, Pretest</b>	<b>% of preservice teachers, Posttest</b>
Option 1 (embedded practices)	15%	5%
Option 2 (explicit MMK)	85%	95%

N=41

The pretest data in Table 8 show a large bias in preference for lesson plan two (explicit MMK, 85%); this result became slightly more pronounced in the posttest (95%). For a range of reasons,

preservice teachers tended to prefer lesson plan option two. A distribution of preservice teachers' rationales for their lesson plan option preference is represented in Figure 3.

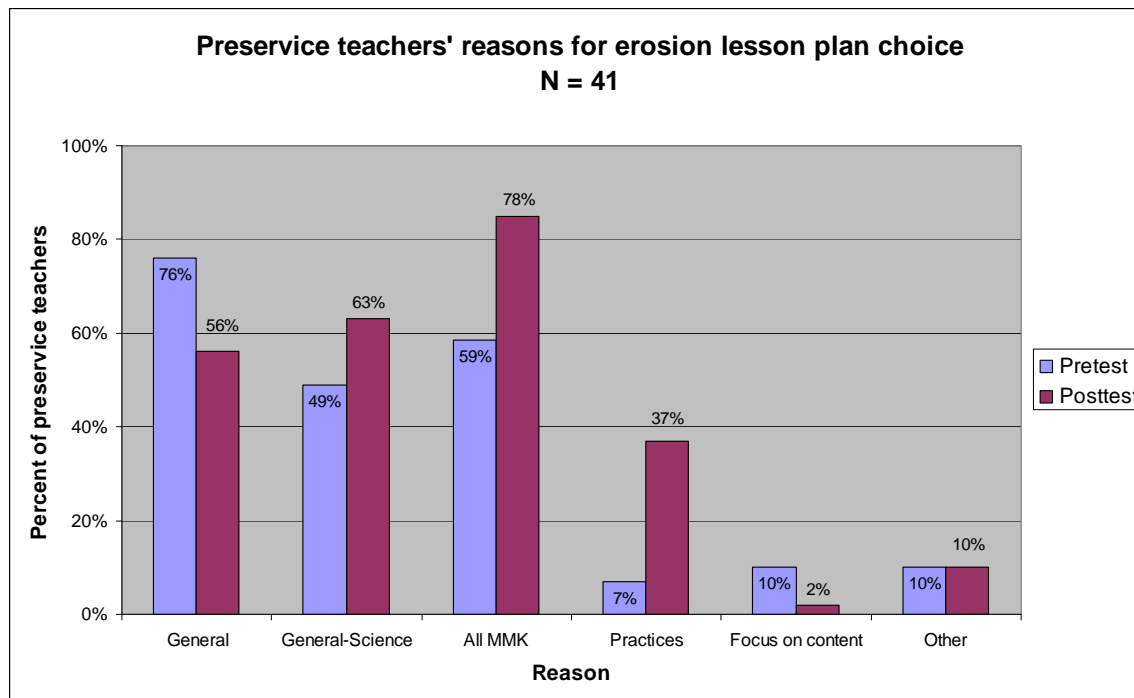


Figure 3. Preservice teachers' reasons for erosion lesson plan preferences

As Figure 3 indicates, many preservice teachers explained their preferences on the basis of general pedagogical concerns, such as classroom management and discussion formats, and general science pedagogical concerns, such as how inquiry-oriented they perceived the lesson to be. The largest rationale-associated changes from pretest to posttest were in terms of modeling practices, which increased by 30%. The following quote from one preservice teacher's posttest illustrates a rationale typically present in the posttest but not the pretest:

This lesson plan goes through all of the steps of creating a good model too:  
Construct, use, evaluate, and revise. (June, posttest)

Another major change was related to general pedagogical concerns, which decreased by 20% from pretest to posttest. One preservice teacher's general pedagogical focus is captured in the following excerpt from a pretest:

It would also contribute to building a classroom community where students are able to share their ideas with one another. (Andrea, pretest)

This type of response was infrequent in the posttest, whereas responses such as the following general science pedagogy-related rationale appeared to increase somewhat (14%) from pretest to posttest:

I would be more inclined to use the second lesson plan. It is much more inquiry-based... (Rosie, posttest)

In light of this study's research questions, more interesting pre- to posttest changes were observed in the "all MMK" and "practices" categories. Specifically, the frequency of all MMK-related rationales increased from pretest to posttest (+19%). Elements of meta-modeling knowledge in the erosion lesson plans that appeared to be most salient to preservice teachers included the distinction between idea and expressed models. This result was not surprising, as idea and expressed models are not something preservice teachers were likely to have been exposed to prior to the pretest. The following excerpts are taken from different preservice teachers' posttest responses, and illustrate the point that idea models and expressed models were new (and still unclear) concepts:

When I first read these and wasn't yet familiar with model vocabulary, I was a little confused about how the 'idea model' and the 'picture model' differ in option #2, except for the fact that one is an idea in the students head and the other is a diagram drawn on paper... I think it's important for students to understand that sometimes, although you might have a very clear model in your head, that could be very difficult to fully and accurately represent on paper or with materials... (Gwen, posttest)

I would modify the lesson to explain in greater detail what the difference between and "idea model" and a "picture model" is. It is still unclear as to what either mean. (Marc, posttest)

The novelty and confusion around the idea model/expressed model concept for preservice teachers suggests that it is not likely to be something they would expect elementary students to grasp easily. In at least one case, the idea model/expressed model component of lesson plan option two was rejected by a preservice teacher who preferred lesson plan option one:

...but I think this lesson is really confusing and just throwing in the idea model and the picture model was like...I thought it took away from the content. And it was very unclear, are you trying to teach modeling or are you trying to teach erosion? I thought it was too much. (Molly, postinterview)

Within the category of "All MMK," data indicate that the most oft-cited meta-modeling knowledge in lesson plan option two were the emphases on models' strengths and weaknesses, comparisons between models and reality, and models' purposes. Even in their pretest responses, some preservice teachers were attuned to these MMK elements of lesson plan option two, as the following pretest response excerpts illustrate:

I would choose Option #2 because it draws a nice parallel between models and real-life events (Kim, pretest)

It is important to note that in real life there are a host of factors that also contribute to the erosion that were not possible to represent in the classroom models. (Shannon, pretest)

Preservice teachers' notions of the meta-modeling knowledge elements in the erosion lesson plan option two appeared to increase in sophistication following instruction. For example, one preservice teacher elaborated upon her reasons for liking the meta-modeling knowledge aspect of erosion lesson plan two:

...I really like the idea of how you would need to discuss with the class what happens in a real stream and what isn't in their stream table, I think that you always need to connect things to the real world. 'Cause then it wouldn't have that much engagement, or deeper meaning to them, I think they could walk out and not really care anymore afterward like we built something but afterwards if you

keep the connections between this is the real stream, we did this stream table as a model of the real stream, but let's connect what we can find in both of them and what isn't there in the other one, that's definitely what needs to happen, and that's why I really like this lesson because it gets the students' ideas out there about the real world versus what they're doing in the classroom. (Mitzi, postinterview)

Here, Mitzi appears to be integrating themes of meta-modeling knowledge, relating science content to students' lives, making connections between classroom learning and real-life phenomena, student engagement, and fostering connections between all these elements. Another preservice teacher, Pam, discussed MMK and the purposes it served in lesson plan option two:

I think after your explanation of the meta-modeling stuff I found that the lesson...two did a nice job of making it apparent to the students, that they were learning about modeling, and the different kinds of models, the idea of model versus your drawing of your model and the revision of the model, I think the students knew that they were engaging in a process of making a model and the teacher did a good job of incorporating that into a science lesson, so that she had two purposes. (Pam, postinterview)

In this interview excerpt, Pam highlights the lesson plan's features of helping students to learn science content in a models-based approach while also focusing on student knowledge and awareness about scientific models and modeling practices.

In contrast to preservice teachers' frequent recognition of models versus reality, model strengths and weaknesses, and purpose/utility of models as elements of erosion lesson plan option two, MMK concerning model consistency with data was essentially ignored. Preservice teachers did not mention this element of erosion lesson plan option two in either the pretest (0%) or posttest (3%). Model consistency with data was not emphasized during in-class instruction, and was implicit within the lesson plan option two description. Comparing this with the other MMK data suggests that explicit instructional emphasis and/or explicit mention of MMK in lesson plans is helpful in guiding preservice teachers' attention to individual pieces of meta-modeling knowledge.

Another aspect of meta-modeling knowledge that *was* emphasized during instruction was enhancing students' awareness of engaging in modeling practices. An increase in mention of MMK for practices was observed in the posttest (29%) relative to the pretest (17%). Examples of preservice teachers' posttest responses include:

The students were aware that they were 'modeling'. (Lisa, posttest)

I would use Option #2 because it explicitly names each step of the scientific modeling process as students create, use, and evaluate scientific models. (Annika, posttest)

These statements suggest that some preservice teachers valued their students' understanding of modeling and what it entails.

Despite the changes in rationales for lesson plan option preference from pre- to posttest, there was not much change in the suggested modifications to the preferred lesson plan from pre- to posttest. However, pre- and posttest responses differed in how often preservice teachers suggested adding modeling practices, which went from 12% in the pretest to 27% in the posttest. For example, in her posttest, Annika wrote:

I would also use the prediction part used at the end of Option #1 after the models are revised, as one central purpose of models is using them to predict what will happen in other situations. (Annika, posttest)

Similarly, preservice teachers suggested adding MMK more often in their posttest responses (24%, versus 15% in pretest responses). For example, Tessa wrote:

The final thing that I would want students to do in this lesson is consider is the model useful? I want students to think about why the model is or is not useful and EXPLAIN. (emphasis in original) (Tessa, posttest)

Here, Tessa stresses the importance of her students understanding what the model contributes (or does not contribute) to their understanding of the phenomena the model represents.

*Summary of pre/posttest erosion item data*

The data from the pre/posttest presented here indicate that preservice teachers made some important shifts in their thinking about scientific modeling aspects of lesson plans, presumably as an outcome of their exposure to ideas about scientific modeling in their methods course.

Specifically, preservice teachers attended to important aspects of MMK and modeling practices present in these lesson plans, and suggested modifications that added and/or emphasized MMK and modeling practices in the context of an erosion lesson.

*Attending to scientific modeling in the presence of prompts: Germ transmission activity*

A more direct measure of preservice teacher learning about scientific modeling-based analysis and modification of lesson plans (or in this case, an activity intended to be part of a lesson plan), is provided by the germ transmission activity critique data. Here, preservice teachers were explicitly supported in analyzing a portion of a lesson plan about germ transmission along scientific modeling dimensions. Support came in the forms of written prompts and environmental support, as the germ transmission activity critique took place during instruction about scientific modeling. As part of this exercise, preservice teachers were specifically prompted to consider models- and modeling-related changes to a lesson plan involving a germ transmission modeling activity. Briefly, the activity models germ transmission by having a student dip her hand in baby powder and then shake the hand of another student. That student, who has picked up glitter by virtue of the handshake, continues to pass on the handshake with another student (and so on), thereby passing along successively less glitter as the handshaking continues.

In response to this activity plan, preservice teachers attended to the modeling practices and MMK, specifically the completeness/accuracy of the activity as a tool for teaching content.



When asked “What changes would you make if you were to use this activity to help your students learn about modeling?” groups of preservice teachers most frequently responded that they would want to make the MMK elements of this activity apparent to students to enhance student understanding of modeling. Second and third most commonly-cited modifications were generic changes to the plan (including changes to discussion formats) and adding modeling practice(s), respectively, as revealed in Figure 4.

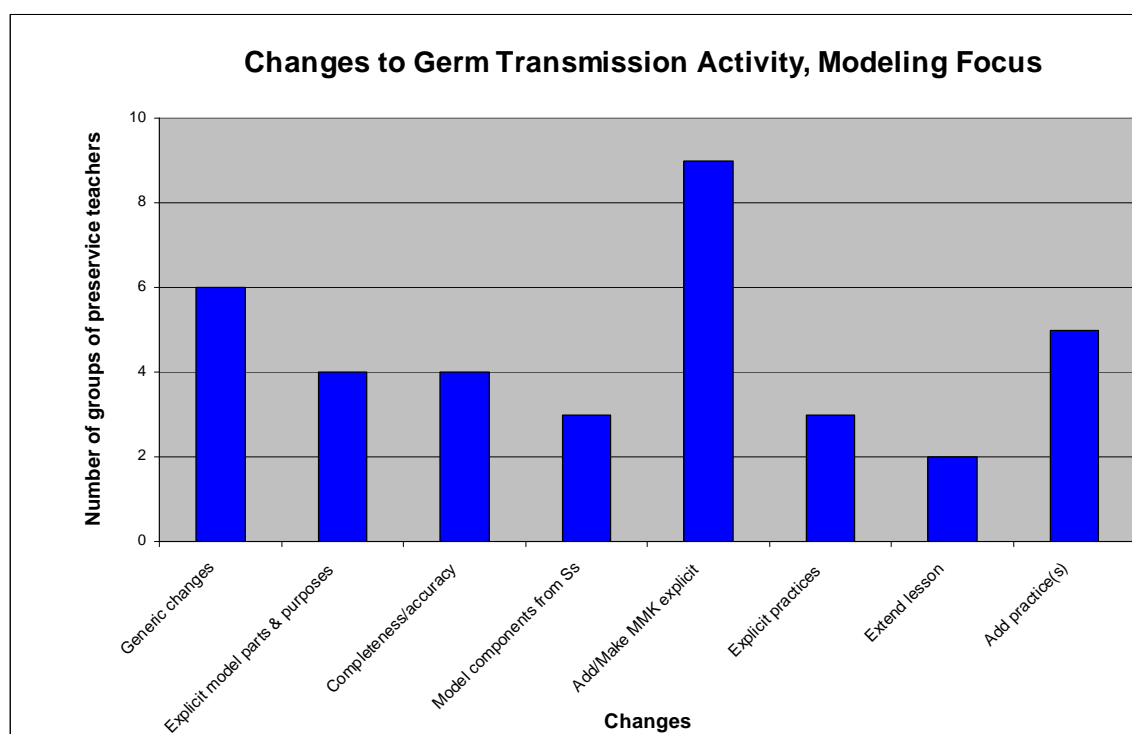


Figure 4. Preservice teachers' changes to germ transmission activity using a modeling focus

When asked to explain why they would make these modeling-focused changes to the activity, preservice teachers most frequently stated that they preferred their suggested change(s) because they thought the modified activity plan would improve MMK for models-based reasoning. Figure 5 shows the range and frequency of rationales supporting the modifications suggested in Figure 4.

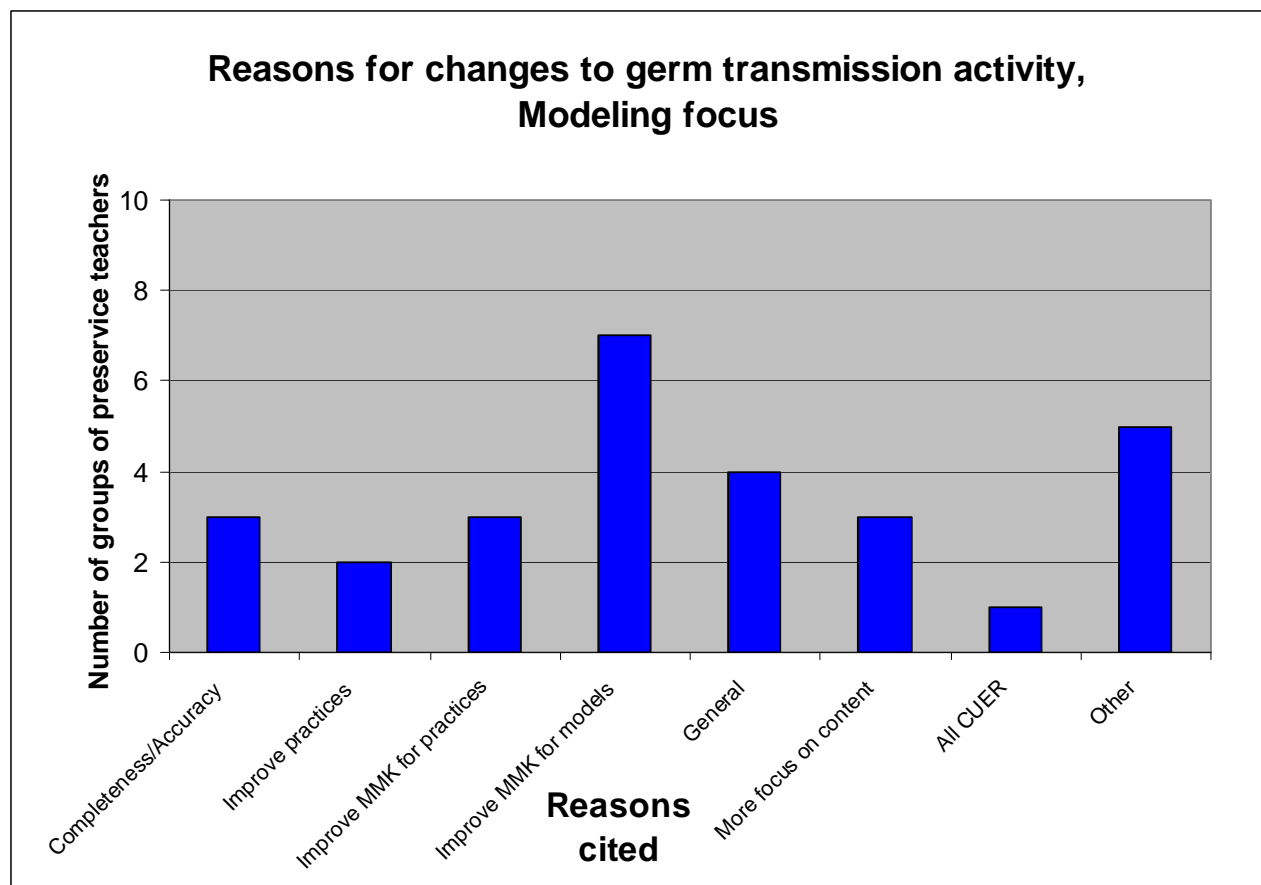


Figure 5. Preservice teachers' reasons for modifications to germ transmission activity using a modeling focus.

Further explanation of preservice teachers' notions of improving MMK for models-based reasoning is contained in the following two example excerpts from the germ transmission activity critique responses:

We would make our changes to help our students understand modeling and what they are doing. We want them to be made aware of what they are doing—while they are doing it so they know the importance of modeling. (Lola & Kim)

So the kids are aware that they are participating in scientific modeling; so they can begin to recognize modeling and think about how the process and purpose of scientific modeling. (Allison & Lucia)

Here, these two student pairs note the importance of their students' MMK for scientific modeling practices.

When asked about her written answers to the germ transmission activity critique, Mitzi elaborated on the modified activity enactment and the importance of making the representations explicit to her students:

I could see maybe the teacher going through this once and then going through it a second time acting almost as the arrows in the drawings that we did saying ok this person is infected...like setting up the different segueways of it, like ok me sticking my hand into powder is symbolizing the fact that I am now infected, now I can hypothetically spread my germs onto the next person just to make it very clear as to what was going on during the demonstration. (Mitzi, postinterview)

Other preservice teachers' responses indicated that general pedagogical concerns prompted modifications. Other reasons commonly cited for proposed changes to the activity centered largely upon the portrayal of other modes of germ transmission to enhance the completeness and/or scientific accuracy of the model.

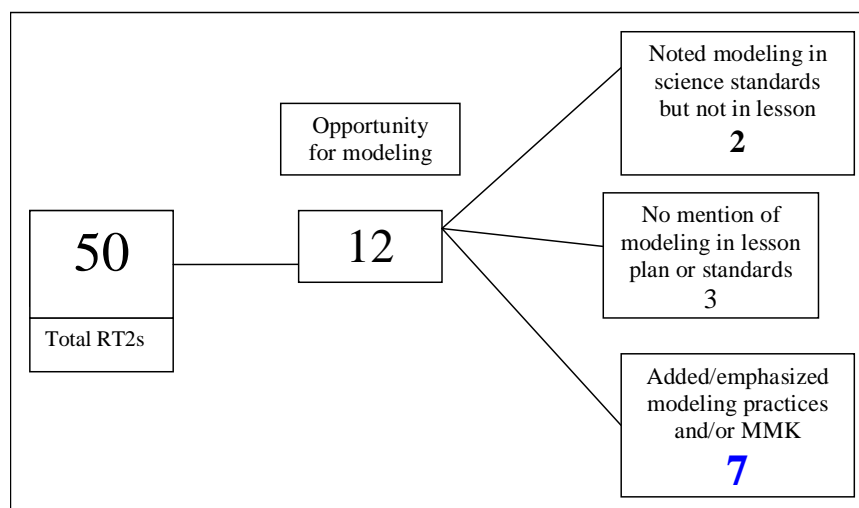
*Summary of germ transmission activity (prompted) data*

As the germ transmission data suggests, preservice teachers attend to ideas about scientific modeling when explicitly and contextually cued to do so. Germ transmission activity analyses and modifications revealed preservice teachers' desires to make MMK explicit for students, have students engage in other modeling practices, and enhance the completeness and scientific accuracy of the model.

*Attending to scientific modeling in the absence of prompts: Reflective teach 2*

When the context of the lesson plan analysis and modification assignment does not explicitly (or strongly implicitly) suggest considerations relating to scientific modeling, preservice teachers do not appear to attend to these aspects of science teaching and learning as frequently or as accurately, as the RT2 data indicate. This suggests that the increased attention to scientific modeling in lesson plan analysis and modification observed in data from the other data

sources is largely contextual and dependent upon prompts that guided preservice teachers to consider scientific modeling. In this portion of the study, I considered only those 12 RT2s whose original lesson plan contained scientific models, modeling practices, and/or MMK. In fact, only 7 preservice teachers voluntarily attended to aspects of scientific modeling in their lesson plan analyses and modifications when not specifically prompted to evaluate their RT2 science lessons along a scientific modeling dimension. Figure 6 depicts how the 50 total RT2 assignments yielded 12 that demonstrated an opportunity for modeling in the original lesson plan, and how those 12 reflected modeling in the preservice teachers' actual RT2 assignments.



*Figure 6. Reflective teaching 2 assignments and scientific modeling*

A closer inspection of the RT2 data reveals that the majority of preservice teachers did not attend to aspects of scientific modeling as lesson plan analysis criteria when scientific modeling elements were present in the lesson plans. However, a third of those with an opportunity for modeling in their RT2 lesson plans connected these lesson plans to science education standards or benchmarks that specifically mention modeling, as Table 8 reveals.

Table 8

*Preservice teachers' attention to reflective teaching 2 assignment lesson plans that contained scientific modeling*

<b>Preservice teacher</b>	<b>Original model: implicit or explicit?</b>	<b>Modeling benchmarks or standards mentioned?</b>	<b>Scientific modeling changes to lesson plan?</b>	<b>Sophistication score</b>
Shannon	Explicit (mold-cast fossils)	Yes	Added MMK	3
Leah	Implicit (erosion demonstrations)	No	No change	0
Jeri	Implicit (sound vibrations)	No	No change	0
Allison	Explicit (drawings of mountains)	No	Added models, modeling practices, MMK	2
Sasha	Explicit (pictorial models of organisms)	Yes	Deleted/deemphasized practices, MMK	1
Rosie	Implicit (drawing of light and opaque materials)	No	No change	0
Mike	Explicit (model bird beaks)	No	Added practices, "mystery" model	2
Mitzi	Explicit (model eardrum)	No	Added practices	1
Maren	Explicit (physical model of Earth)	Yes	Added MMK	2
Karen	Implicit (food web)	No	Added practice	1
Molly	Explicit (graham cracker/frosting plate tectonics)	No	Added MMK	1
Lillian	Explicit (physical model of moon)	Yes	Deleted/de- emphasized models	1

Of the 50 RT2 assignments from both sections of the Fall 2007 methods course, only 12 contained, in some form, scientific models, modeling practices, and/or MMK. Scoring these 12 preservice teachers' evidence of attention to scientific modeling in this assignment ranged from zero (no evidence of attention to modeling) to three (evidence of creation or modification of the lesson plan to include scientific models, modeling practices, and/or elements of MMK; see Table 6). Of the 12 preservice teachers in this subset, none evaluated their lesson's treatment of scientific modeling; rather, most selected lesson evaluation criteria such as eliciting students' ideas and prior knowledge, lesson alignment with Michigan science grade level content expectation standards, and classroom management concerns. Within the criterion of lesson plan/standards alignment, however, four preservice teachers mentioned science standards or benchmarks focused on developing students' knowledge and use of models in science. This standards-mediated connection between the RT2 lesson and scientific modeling is interesting, and is revisited in the discussion and implications sections of this study.

Three of the four preservice teachers who had lesson plans with implicit models did not mention modeling at all in their RT2s. In these cases, the original lesson plan had not labeled the representations as models, and the preservice teachers either failed to recognize these representations as models or ignored the instructional potential they offered as models. For example, Leah referred to the erosion activity in her lesson plan as a "demonstration," rather than a model, throughout her RT2. Of those preservice teachers with explicitly-labeled models in their original lesson plans, two--Lillian and Sasha--downplayed references to models in their modified lesson plans by either focusing on science content at the expense of modeling (Lillian) or omitting peer model evaluation in the interest of time management (Sasha). In contrast, 7 of the 12 preservice teachers in this RT2 subset described modifications to their lesson plans that

resulted in additions of scientific models, modeling practices, or MMK. For example, Molly added a discussion of MMK:

...we will have a short discussion about how scientists sometimes use models to represent what they cannot directly observe. (Molly, RT2)

Allison, on the other hand, added a model itself, as well as the construction and revision practices:

They will create a model (drawing) of a mountain based on their prior knowledge. After listening to a brief informational text about mountains they will reflect on what they learned and make necessary changes to their models based on what they learned. (Allison, RT2)

Despite incorporating lesson plan adaptations that tended to include scientific models, modeling practices, and/or MMK, most of these preservice teachers' RT2s did not suggest well-integrated knowledge of scientific modeling. Most preservice teachers' RT2 written portions revealed incomplete, inaccurate, or unsophisticated understandings of the roles of models and modeling in these science lessons. For example, one preservice teacher wrote:

This lesson also allows the teacher to assess children's understanding of how models are used in science. I think this last assessment will be most difficult because I feel you have to explicitly ask the students if they understand the uses of models in science. (Sasha, RT2)

Sometimes, elements of MMK or modeling practices were added to lessons in ways that appeared to highlight the model's role in promoting sense-making and facilitating predictions and explanations. For example, one preservice teacher asked her students to make a prediction, but never explicitly acknowledged with her students that (1) the food web was an example of a scientific model, and (2) the students were using a model (food web) to formulate this prediction:

I added an end of class check: "What would happen if we removed decomposers from the food web? How would this affect other organisms?" I did this to enhance inquiry; students were required to use the model of the food chain to generate a prediction of how the change would affect other organisms. (Karen, RT2)

In contrast, one preservice teacher did an impressive job of adding discussions of models, modeling practices, and elements of MMK into a lesson plan that already contained models.

Shannon wrote,

They might get confused at first as to how the rock dough and goo are supposed to represent the actual process that occurs in nature. This process happens over thousands of years and we do it in 2 days. So this is a good opportunity to talk about how we use models in science...Talk about how the rock dough is similar to sediment and how their molds compare to real fossils by asking questions such as: What is this process similar to in real life? ...This is also an excellent time to review the idea of a model and how these fossils are just a model of what real fossils are; the limitations, and effectiveness of them. (Shannon, RT2)

Here, Shannon highlights several aspects of MMK and modeling practices in ways that make these elements of the lesson explicit for her learners.

#### *Summary of RT2 (unprompted) data*

These RT2 data paint a complex picture of preservice teachers' voluntary consideration of modeling dimensions in their lesson plan analyses and modifications. On one hand, most preservice teachers did not teach science lessons that obviously lent themselves to modeling in their RT2 assignments. Of the 12 who did teach modeling-related or modeling-amenable lessons, few made connections between modeling and science education standards. Although they did not choose to analyze and modify their lesson plans specifically along dimensions of scientific modeling, 7 preservice teachers did make modifications to their lesson plans that resulted in additions of scientific models, modeling practices, or MMK. This result suggests that ideas about scientific modeling are being taken up by preservice teachers and being used as they think about science instruction, even in the absence of directive prompts guiding them to do so.



*Summary of findings*

Taken together, data from these three data sources create a complex picture of preservice teacher learning about scientific models, modeling practices, and meta-modeling knowledge. During instruction and in the presence of directive prompts, preservice teachers demonstrate their abilities to evaluate lesson plans along scientific modeling dimensions, as is evident in the germ transmission activity critique data. In the “intermediate space,” or the absence of directive prompts and the presence of a modeling context, preservice teachers begin to attend to elements of scientific modeling after experiencing instruction about scientific modeling, as demonstrated by the erosion pre/posttest data. Finally, in the absence of directive and contextual prompts, most preservice teachers do not consider lesson plans in terms of scientific modeling. However, the exceptions to this included preservice teachers who regarded lesson plans’ treatment of scientific modeling in service of other lesson plan evaluation criteria, such as eliciting students’ ideas and alignment with learning goals specific in science education standards and benchmarks.

### Discussion

In this discussion, I first consider the importance of the instructional intervention for preservice teachers’ analyses and modifications of lesson plans along dimensions of scientific modeling. Second, I discuss the important role the supports and their contexts served in promoting preservice teacher thinking about scientific modeling when evaluating and modifying lesson plans. Both these areas connect back to the original research questions in this study, which are about how preservice elementary teachers use modeling-related ideas in their lesson plan analyses and modifications, with and without explicit prompting.

Answers to the first research question highlight the roles of instruction as well as directive prompts in guiding preservice teachers’ thinking during lesson plan analysis and

modification. Data from the germ transmission activity critique and the pre/posttest erosion question suggest that preservice teachers' application of scientific modeling knowledge and pedagogical principles is highly dependent upon the ideas presented during instruction and the context of the assignment.

Answers to the second research question are revealed primarily in the RT2 data, and also suggest the importance of preservice teacher instruction about scientific modeling and the contextual cues (or lack thereof) in the RT2 assignment. In the RT2 assignment, then, evidence of preservice teachers' use of scientific modeling as a consideration for their lesson plan analyses and modifications reveals volitional attention to scientific modeling elements in the RT2 lesson plans.

Relationships between instruction and contextual prompts on one hand and evidence of preservice teachers' lesson plan-based thinking about scientific modeling on the other hand guide the following discussion section.

#### *Importance of instruction about scientific models, modeling practices, and MMK*

As the germ transmission activity critique and pre/posttest erosion question data reveal, preservice teachers used more terminology and ideas associated with scientific modeling during and after instruction. Some preservice teachers explicitly stated on the posttests and in the interviews that much of this models-based subject matter and pedagogy was new to them, as was analyzing and modifying lesson plans in light of scientific modeling concerns. Indeed, others have found that instruction about scientific modeling improves preservice teachers' ability to use the language associated with scientific modeling; however, this does not necessarily indicate deep understanding of the concepts and pedagogical practices associated with scientific

modeling (Crawford & Cullin, 2004; Schwarz & Gwekwerere, 2007; Windschitl & Thompson, 2006), which is also supported by the data in this study.

The RT2 data suggest that a few weeks after instruction focused on scientific modeling, a subset of preservice teachers continued to incorporate meta-modeling knowledge into their lesson plans. Rarely, though, did these preservice teachers explicitly label these ideas as MMK in their written assignments. This is encouraging from the standpoint that even if preservice teachers do not remember the terminology used by researchers to indicate this body of models- and modeling-related knowledge, they are grasping and using many of the important concepts that fall under the MMK umbrella in their planning and instruction. In a related study, Schwarz and Gwekwerere (2007) found that preservice K-8 teachers made gains in their meta-modeling knowledge, although they discuss these concepts as being related to the nature and purpose of models without overtly labeling them “meta-modeling knowledge.”

One aspect of preservice teachers’ post-instruction attention to scientific modeling in lesson plans that was particularly revealing was the connectivity to other topics covered in the elementary science teaching methods course. Although relationships between scientific modeling and other course topics (such as inquiry-oriented learning, eliciting students’ ideas, and standards-based teaching) were not particularly well-emphasized by the scientific modeling instructor, they appeared to gain some traction with preservice teachers as evident in the RT2 data. Here, preservice teachers linked ideas about modeling-based pedagogy with themes such as standards-oriented instruction, which suggests that preservice teachers view scientific modeling as being in the service of other educational goals. In an earlier study, Crawford and Cullin (2004) noted preservice teachers’ increased intentions to use modeling as a strategy to teach content, but commented that preservice teachers did not emphasize the value of teaching about modeling as a

scientific practice in its own right. Taken together, these findings suggest that teacher educators might consider underscoring the importance of teaching about scientific modeling as a hybrid of science content (knowledge about scientific models and modeling) and science process (engaging in modeling practices), as well as demonstrating the interdependence and synergistic power of teaching some science content using a modeling-based approach. By explicitly identifying connections between methods course themes, teacher educators may increase the preservice teachers' perceived relevance of these approaches to teaching science. Linking scientific modeling with ideas that already appear to resonate with preservice teachers, such as classroom management and standards-based learning goals, may enhance the likelihood that models-based instructional methods are employed in preservice teachers' teaching practices.

*Importance of supports and their contexts in eliciting preservice teachers' thinking about scientific modeling while analyzing and modifying lesson plans*

In addition to the instruction about scientific modeling experienced by preservice teachers in the elementary science teaching methods course, wording and context of prompts in preservice teachers' assignments appeared to be highly influential factors in preservice teachers' considerations of lesson plans. Directive prompts that guided preservice teachers to specifically consider aspects of scientific modeling corresponded with data in which preservice teachers attended to aspects of scientific modeling in lesson plans. After instruction, in the absence of directive prompts, 7 preservice teachers voluntarily attended to aspects of scientific modeling in their RT2 lesson plans. Also after instruction, preservice teachers' posttest erosion item responses suggested that some preservice teachers were attending more to modeling-associated ideas and terminology. Recall, however, that the pre/posttest erosion item's context within a "modeling journal assignment" probably predisposed preservice teachers to consider scientific

modeling in their erosion item responses. Other measures of whether preservice teachers were attending to modeling aspects of science lesson plans may be explored in the context of the lesson on scientific modeling (germ transmission activity critique, with modeling-specific prompts) and weeks after the lesson on scientific modeling (RT2, without modeling-specific prompts).

In the germ transmission activity critique, support of preservice teacher thinking about scientific modeling was greatest in terms of both the activity's during-instruction context and the directive wording of the prompts. Within the setting of the methods course, preservice teachers were explicitly and specifically asked to consider the germ transmission activity's utility in helping students learn about scientific modeling, and to suggest changes that would enhance the modeling learning afforded by this activity. Preservice teachers tended to suggest making the modeling aspects of the activity apparent to students by emphasizing the MMK-related elements, for example, explaining how the physical components of the activity represented actual germ transmission.

At the same time, modeling-related directive prompts in the germ transmission activity were intentionally open-ended so that the instructor might gain insight into which aspects of scientific modeling seemed to resonate with the preservice teachers. In critiquing this activity, many groups of preservice teachers attended to criteria relating to the scientific accuracy and completeness of the germ transmission model and how well students might connect the activity model with real-life phenomena. Accordingly, preservice teachers suggested modifications that served to improve the completeness of the model and make the model's components' representations more obvious to students. This may, however, be an artifact of both the topic

(germ transmission) and its treatment (a single activity to model a single mechanism of germ transmission), and may not generalize to other lesson plan analyses.

Returning to a consideration of the “intermediate” level of support provided in the erosion pre/posttest item merits further discussion. Interpretation of preservice teachers’ analyses and modifications of the erosion lesson plans should be tempered by consideration of the item’s wording. It is likely that preservice teachers were focusing on general pedagogical changes to the lesson plans because the two lesson plans in this item were not sufficiently parallel in structure. Consequently, preservice teachers may have been noticing more obvious differences between the lesson plans rather than the more subtle differences in modeling practices and MMK. What preservice teachers attended to in these lesson plans may also relate to their knowledge, understanding, and confidence. Others studies suggest that preservice teachers who have experienced instruction about scientific modeling make gains in their knowledge and understanding of scientific modeling, but still lack knowledge and understanding characteristic of experts (Crawford & Cullin, 2004; Grosslight et al., 1991; Schwarz & Gwekwerere, 2007; Van Driel & De Jong, 2001; Windschitl & Thompson, 2006). In this study, after a single lesson on scientific modeling, preservice teachers may not have known how to make productive changes to (or may not felt comfortable or confident making changes to) a lesson plan that already contained elements of scientific modeling. Alternatively, preservice teachers may have thought the erosion lesson plans did not require changes because the modeling components of the lesson were perceived as present and/or complete. Although the attention to general pedagogical concerns and science pedagogy is interesting, in order to better- elicit preservice teachers’ thoughts about the modeling aspects of these two lesson plans the item wording should have been changed so that the two lesson plans were more equivalent in general pedagogical terms.

Responses to this item suggest that preservice teachers would have benefited from more similarly-structured lesson plans, more directive prompts, and/or appropriate scaffolding in analyzing and modifying lesson plans that may already contain elements of models, modeling practices, and/or MMK.

Finally, in the absence of any supports guiding preservice teachers' thinking about scientific modeling, and weeks after instruction, the majority of preservice teachers did not consider RT2 lesson plans in light of scientific modeling concerns. There are a variety of potential explanations for this result. Many preservice teachers may have enacted science lessons on topics that did not easily lend themselves to a models-based teaching and learning approach. Also, preservice teachers may not have had enough practice in recognizing less-obvious or implicit scientific modeling in lesson plans. Notable exceptions in which preservice teachers did mention the models and modeling aspects of their RT2 lesson plans, however, were very revealing. Ideas such as "models have strengths and limitations" and "models are different from the real phenomenon" appear to be ideas that gained some traction with or were especially memorable for preservice teachers. Perhaps these ideas resonated with them in terms of their own experiences using models in science. Or perhaps preservice teachers felt that these elements of MMK may have been particularly accessible to the students they were teaching.

It is important to remember that the preservice teachers in this study have little experience teaching science lessons, most of them are not science majors and/or they may not feel confident in their knowledge of elementary science subject matter (Appleton, 2006), and they are encountering unfamiliar subject matter around scientific modeling (Crawford & Cullin, 2004; Schwarz & Gwekwerere, 2007; Windschitl & Thompson, 2006). Considering also that time had elapsed since the single, 3-hour scientific modeling course session and the RT2

assignment, and the numerous other concerns that accompany novice teachers' initial teaching experiences (Lotter, 2004; Watson, 2006), it seems unreasonable to expect that most preservice teachers would spontaneously focus their RT2 analyses primarily on scientific modeling. Indeed, the result in which models appear to serve an ancillary role in satisfying preservice teachers' other instructional goals has been observed before (Crawford & Cullin, 2004). Further, in fulfilling the requirements for the RT2, preservice teachers also had to negotiate the demands of the methods course assignment and the demands of their field placement classrooms.

Considering these and other constraints associated with real-world elementary classrooms in which preservice teachers teach only a handful of lessons during their pre-student teaching semester, and coupled with the other challenges that beginning teachers typically face (Davis et al., 2006; Davis & Smithey, in press; Feiman-Nemser, 2001), it stands to reason that most preservice teachers enacted their RT2 assignments with a high degree of fidelity with respect to the curriculum materials used in their placement classrooms (Forbes & Davis, 2009) and privileged themes such as working with students' ideas and standards-based instruction that were more heavily-emphasized throughout the elementary science teaching methods course (Davis & Smithey, in press).

Overall, the data in this study demonstrate that with instruction and the appropriately worded and situated scaffolds to guide their thinking, preservice teachers can analyze and modify lesson plans in light of considerations about scientific modeling. One lesson, however, is not enough; very few preservice teachers attend to aspects of models and modeling in their open-ended RT2 lesson plan analyses, even in lesson plans that have potential to be analyzed and modified on the bases of their treatment or usage of scientific models. Accordingly, teacher educators should provide preservice teachers with more educative, concrete, situated, and well-



supported experiences with scientific modeling in elementary science instruction. This will help successfully prepare these beginning teachers to teach science in ways that enable their future students to see the value and importance of scientific models, modeling practices, and metamodeling knowledge in science.

### Implications

Since it appears that most preservice teachers are not effectively attending to these ideas about scientific modeling after experiencing one lesson, teacher educators will need to rethink their approaches to including this element of science instruction in their science methods courses. As this study's findings suggest, preservice teachers need more exposure to and practice in the use of scientific modeling in teaching and learning elementary science. Teacher educators will likely need to make explicit and well-supported whatever it is that they hope to get preservice teachers gain by learning about models-based science pedagogy. Teacher educators should also pay careful attention to the manner in which the material about scientific modeling is "delivered" to preservice teachers. By stressing the relationships between scientific modeling in science instruction and topics that are already on the minds of preservice elementary teachers, such as classroom management and standards-based instruction, teacher educators may be able to present models-based science pedagogy in ways that preservice teachers can easily relate to and therefore increase the chance that preservice teachers will use these innovative teaching methods.

In order to support preservice teachers in models-based science instruction, teacher educators will need to better demonstrate how to analyze curriculum materials and how to modify lesson plans to infuse models-based pedagogy. In other words, teacher educators will need to "model" the process of analyzing and modifying lesson plans using scientific modeling as a lens. Presumably, this will better acquaint preservice teachers with the authentic approaches

to and outcomes of lesson plan analysis and modification that are typical of experienced teachers (Kim & Hannafin, 2008). Preservice teachers would also benefit from learning more about which topics in elementary science lend themselves to a models and modeling-based learning approach, and what characteristics (such as the involvement of a process) render these topics amenable to modeling (Kenyon, Davis, & Hug, 2009). And in general, teacher educators can demonstrate for their preservice teachers how to take an existing lesson plan and (a) recognize the potential for using modeling and (b) modify the lesson plan accordingly. Such an approach would render the process and products of lesson plan analysis and modification more concrete and situated within authentic science teaching practice.

Teacher educators also need to consider how to better structure and support preservice teachers' thinking about scientific models, modeling practices, MMK. By linking ideas about models, modeling practices, and MMK with other topics in science teaching methods courses, teacher educators increase the likelihood of preservice teachers' associations between things like "generating predictions" and "scientific models," and thereby improve the odds that preservice teachers will employ models-based pedagogical approaches in the service of meeting the learning goals they have for their students. Toward this end, teacher educators could consider weaving a modeling element throughout their methods courses, which would allow teacher educators to take a scaffolding approach to supporting preservice teachers in considering elements of scientific modeling in science instruction: provide substantial, explicit, and situated initial supports that are gradually faded throughout the semester as preservice teachers begin to attend to these notions on their own.

Teacher educators must also gain a better understanding of what is difficult about scientific models, modeling practices, MMK for preservice teachers. As this is a relatively new

area for research, it will require much “learning from experience” in order for teacher educators to develop pedagogical content knowledge (Shulman, 1986) around teaching preservice teachers the ins and outs of scientific models-based approaches to elementary science teaching. To develop this PCK, teacher educators may consider having preservice teachers work directly with curriculum materials they are likely to encounter in classrooms, and “model” for them the processes of analyzing and modifying a range of lesson plans (and/or unit plans) to infuse modeling. Teacher educators might also consider having preservice teachers experience models-based science teaching and learning from both sides of the teacher’s desk, as well as having them experience and analyze a models-based and not-models-based approach to teaching the same science lesson.

Finally, teacher educators should help preservice teachers put scientific modeling into a larger context of elementary science pedagogy. In doing so, teacher educators will help preservice teachers realize when to use a models-based approach to teaching science, how to do this effectively, and why it is so important for their students to understand how science works. Here, teacher educators have the added challenge of helping preservice teachers overcome curriculum materials’ inattention to scientific modeling.

### Conclusions

This study contributes to the literature about preservice teachers and scientific models, modeling practices, and metamodeling knowledge in ways that are consistent with others’ findings (Crawford & Cullin, 2004; Hug et al., 2008; Schwarz & Gwekwerere, 2007; Van Driel & De Jong, 2001; Windschitl & Thompson, 2006; Windschitl et al., 2008b). Specifically, this study’s findings lend support to the claims that preservice elementary teachers’ knowledge about scientific models, modeling practices, and meta-modeling knowledge is weak at best, however,

teacher educators can support preservice teacher learning about scientific modeling through their work with preservice teachers in teacher education courses.

The unique contribution of this study to the knowledge base about preservice elementary teachers and scientific modeling lies in its findings concerning preservice teachers' analyses of and modifications to elementary science lesson plans. With ample support instructionally, syntactically, and contextually, preservice teachers can progress in their abilities to analyze and suggest modifications to science lesson plans to better incorporate scientific modeling. What is perhaps most promising about the findings from this study is that given very limited instruction (a single 3-hour class session!) about scientific models, modeling practices, and meta-modeling knowledge, preservice teachers demonstrated growth in their thinking about these topics as ascertained through post-instruction interviews and their methods course assignments during, shortly following, and well after instruction. This finding, then, provides a basis for further development of models-based instruction by teacher educators. Providing preservice teachers with more educative opportunities to grapple with ideas about scientific models, modeling practices, and meta-modeling knowledge, particularly in the contexts of actual lesson plans they are likely to encounter in their student teaching classrooms, will be an important next step in both preservice elementary science teacher education and further research about preservice elementary teacher learning in science teaching methods courses.

Ironically, the bottom line of this work for teacher educators can be summed up in two words: more modeling. By seeing how methods instructors apply the knowledge they possess regarding scientific models, modeling practices, and meta-modeling knowledge to analysis and modification of actual elementary science lesson plans, preservice teachers will gain insight into how they, too, might approach this aspect of their own science teaching.

## Appendices

### Appendix A. Pre/post test

#### Using Scientific Models Journal Assignment

**Question 7:** Imagine you are going to teach a science lesson about erosion. Below are two briefly described options for lesson plans, each using a working model of a stream table. (A stream table is a reservoir—imagine a section of PVC pipe cut in half—whose surface can be covered with soil, and that can be placed on a slight incline to allow water to flow by gravity from one end to the other, simulating a stream.)

Option #1: After a whole class discussion about the motion of water and erosion, ask students, “How can a stream cause erosion?” Have students discuss their ideas in small groups and have each small group draw a picture model of stream erosion. Next, give each small group the materials to build a stream table and demonstrate for them how to set it up. Explain that each small group will be using their stream table model to test erosion of several different soil types (for example, topsoil, clay, and sand). After allowing time for the experiments and organization of the data, have each small group present their findings and talk about how their data either agrees or disagrees with their initial ideas in their picture models. Have each small group revise their picture model so that it accounts for what they observed in their stream table. As a whole class discussion, ask students to consider their picture models (and/or their stream table models) as they predict what would happen if there were large rocks or underwater grasses in the stream. Alternatively, ask them to predict how a rise in the stream water level would affect stream erosion.

Option #2: After a whole class discussion about the motion of water and erosion, ask students, “How can a stream cause erosion?” Have students spend time thinking silently about their “idea model” of how a stream can cause erosion and then have them each draw a picture of their idea model (which will be called the “picture model”) that they can use to explain their ideas about stream erosion to a classmate. Discuss the different purposes models can serve for scientists and people learning science. Next, divide the class into small groups, and give each small group the materials to build a stream table. Demonstrate for the class how to set up a stream table, and explain that each small group will be using their stream table model to test erosion of several different soil types (for example, topsoil, clay, and sand). After allowing time for the experiments and organization of the data, have students compare the results they observed with their initial picture models to see if the results they observed agree with (a) their idea model and (b) their picture model. Have students discuss whether they would change their idea model or their picture model or both models to account for their new data. Talk about why they are considering the strengths and limitations of all the models. As part of a class discussion, ask students to consider what else happens in a real stream that is not included in their stream tables. Ask how those differences between their stream table and a real world

stream might affect their idea model of stream erosion, their picture model of stream erosion, or both models.

7a. Which lesson plan would you be most inclined to use? Why?

7b. What modifications (if any) would you make to the lesson plan you chose in question 7a?

## Appendix B. Germ Transmission Activity Critique

### Germ Transmission Activity

Imagine that you will be using the following activity as part of a lesson about germ transmission for 4<sup>th</sup> graders:

Pose the following question to students: *What causes people to get sick?* Generate a list of student answers on the board. Someone will probably mention "germs." When they do, ask *What are germs? Where do germs live?* to get an idea of what students' ideas about germs might be. Ask students to name off some ailments that are caused by germs. Ask students, *How do germs spread?* Have students draw a picture (model) of how they think germs spread. Then, perform a demonstration illustrating how germs can be passed from one person to another.

- Pour baby powder into a zip-locked bag.
- Ask two to four students to come to the front of the room.
- Begin by putting your hand in the baby powder and getting a lot of powder sticking to your hand and then shake hands with the person beside you. Have them shake hands with the person next to them, and so on.
- Some powder should stick to everyone's hands (simulating the way germs are spread). Make sure everyone washes their hands well to clean off the powder.

Ask students, *Based on this activity, what are some ways that germs (and, thus, diseases) spread? How could we prevent germs from spreading?* Have students revisit their picture models of germ transmission and determine if they need to make any changes to their models based on what they saw in the germ transmission demonstration.

(Note: This lesson plan was modified from a lesson plan on the CASES website)

1. If you were going to use this activity to help your students learn about germ transmission, what changes (if any) would you make?

Why would you make these changes?

2. If you were going to use this activity to help your students learn about scientific modeling, what changes (if any) would you make?

Why would you make these changes?

3. Now, imagine the students have experienced the lesson you just read about, as well as a few others that get at other aspects of germ transmission. Then the students drew models of their ideas about germ transmission. Below are two examples of germ transmission picture models drawn by students. Please assess these models and write down some of the feedback you might give to the students:

Model #1



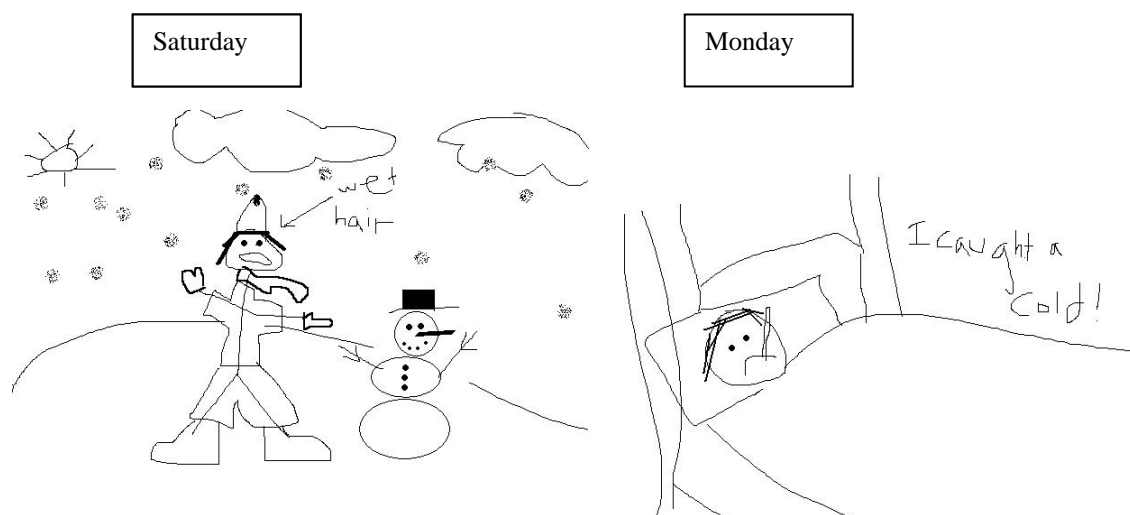
Piko, B. F. et al. Health Educ. Res. 2006 21:643-653; doi:10.1093/her/cyl034  
Copyright restrictions may apply.

(Note: The student who made this drawing is from Hungary)

a. Assessment and feedback on model #1:



## Model #2



b. Assessment and feedback on model #2:

c. Do you think assessing models and giving feedback is related to the modeling practices of evaluating and revising scientific models? Why or why not?

## Appendix C. RT2 Assignment Description

### ED421 Reflective Teaching Assignment

Overview: You will teach science in your practicum classroom twice during the semester. Each cycle of planning, teaching, and reflecting is called a reflective teaching (RT) assignment. For each RT assignment, you will use existing curriculum materials to develop a science lesson, teach it to students in your placement classroom, reflect on your teaching, and analyze some student work. The reflective teaching assignments are intended to help you

- modify existing science lessons to be more inquiry-oriented and appropriate for your class
- practice teaching science lessons effectively
- learn how to use written student work to understand and assess kids' ideas
- reflect on your lesson and students' work to figure out changes to make for the future
- develop an artifact that's appropriate for inclusion in your teaching portfolio

What lesson should I teach?

In preparing to teach this lesson, you should find an existing lesson plan, rather than developing one from scratch. Your CT will probably give you lessons to teach. If not, ask him or her for resources to help you find an appropriate lesson, or find one yourself (for example, check on CASES to see if there's a lesson that fits your needs). Also talk with your CT about your plans well in advance. Be sure your CT understands what you plan to do, and has budgeted the necessary time. Also go through the experiment or activity in advance with the actual materials you'll use in the classroom. Use this as a chance to anticipate any management issues that might come up and develop a plan for dealing with them.

This assignment has two parts:

Part 1: To be completed before teaching your lesson

- 1a. Lesson Plan Analysis: Assess the strengths and weaknesses of the lesson and make changes to the lesson based on your teacher sense and what we've done in class.
- 1b. Revised Lesson Plan: Write a revised lesson plan description that addresses the weaknesses you identified. (This section is organized around the Planning Framework you've used in previous courses.) You will teach this lesson in your field placement.
- 1c. Lesson Plan Rationale: This section makes your thinking visible about the decisions you made as you selected and modified your lesson.

Part 2: To be completed after teaching your lesson

- 2a. Reflective Journal: Reflect on your lesson enactment and on your students' work.
- 2b. Documents: Turn in a copy of the original lesson; any handouts, worksheets, overheads, etc. you use in your lesson; and 3-5 examples of student work referred to in your reflection.

Due Dates:

For the first RT assignment, Part 1 should be turned in and your lesson taught by October 23 or 25, and Part 2 should be turned in by October 30 or November 1.

For the second RT assignment, Part 1 should be turned in and your lesson taught by November 20, and Part 2 should be turned in by November 27 or 29.

Upload Part 1 and 2 of the RT assignment as word documents onto CASES by the above due dates (except for the original lesson plan and student work, which you will hand in during class).

## Part 1: To be completed before you teach your lesson

### Part 1a: Lesson Plan Analysis Task

Teachers possess ideas about effective science teaching and they use those ideas to determine whether curriculum materials have those characteristics. To do a good job at analyzing curriculum materials, you need to have some criteria by which you can judge the materials. In this part of the assignment, you will analyze your lesson plan with regard to **3 criteria of your own choosing**. You can select criteria that you've recently learned about in class or select your own criteria.

Use the following questions to guide your description and use of the criteria in your analysis.

**For each criterion**, answer the following questions:

1. What criterion did you choose?
2. Why did you choose to use this criterion in your analysis?
3. What are the indicators for this criterion? (Identifying indicators will help you identify important characteristics of the criterion that you can use to guide your analysis.)
4. For each indicator: Does the lesson plan meet the indicator? Explain why you think this and provide examples from the lesson plan to support your ideas. For the weaknesses you identify, what specific changes could you make to the lesson to better meet the indicator?

Remember to address these four questions for each of the three criteria.

Criterion #1

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Criterion #2

--

Criterion #3

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Part 1b: Revised Lesson Plan**Title of Lesson:****Grade level:****Length of lesson:****Overview:**

- Provide a short description of the lesson:

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**Learning Goals:**

- What do you want students to know and be able to explain at the end of this lesson?
- What do you want students to be able to do (with regard to inquiry)?

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**Connections to Standards/ Benchmarks/ Curriculum:**

List the standards as written in the *Michigan Curriculum Framework* (or the *Science Grade Level Content Expectations* document, which clarifies the MCF), *National Science Education Standards*, or *AAAS Benchmarks*. Write down what chapter, section, and grade level you drew the standard from, in addition to the source itself.

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**Context of Lesson:**

How does the lesson fit within the unit as a whole?

--

**Materials:**

--

**Students' Ideas:**

- What ideas should students understand before beginning the lesson?
- What potential alternative ideas might students hold?

--

**Teaching Strategies: Intro**

Think about the following questions as you describe how you will introduce the lesson:

- How will you connect this lesson to the previous one?
- What is your investigation question or problem for the lesson?
- How will you elicit students' existing ideas?

**Teaching Strategies: Main Lesson**

Think about the following questions as you describe the steps of the lesson:

- What will you do? What will your students do? Do not assume someone reading your lesson plan has access to the original lesson plan! Be clear and complete.
- Do the activities support students in engaging in scientific inquiry? How will you help students make predictions? Collect data and make observations? Look for patterns in data? Build evidence-based explanations?
- What will you do to manage materials/movement around the classroom/transitions?
- Do the activities support students of all achievement levels? What will students do who finish an activity early? Who do not finish?

**Teaching Strategies: Wrap-up**

Think about the following questions as you describe how you will close the lesson:

- What explanations will your students construct?
- How will you help students connect their explanations to the investigation question?
- What specific questions will you ask students to help them interpret their in-class experiences and connect them to scientific ideas and their own ideas about the phenomena? What questions will you ask to help students progress from their initial ideas and predictions elicited at the beginning of the lesson?
- How will you help students connect to previous and subsequent science lessons?

**Assessment:**

- What evidence will you gather to let you know if your students achieved the learning goal(s)? How will you collect this information?
- Does your assessment focus on understanding of key ideas and practices and require application of ideas?
- Are you able to assess each student's understanding?

## Part 1c: Lesson Plan Rationale

### I. Use of Science Curriculum Materials

1. Which of the following best characterizes how you started planning for this lesson?
  - ☐ I had a general idea of the topic I wanted to cover but no materials yet
  - ☐ I had an idea for a student activity or investigation and built a lesson plan around that.
  - ☐ I had an existing lesson plan that I planned on using
  - ☐ Other
2. How explicit was your learning goal before you started developing your lesson?
  - ☐ Very explicit (I knew specifically what I wanted by students to learn and how they would demonstrate their understanding)
  - ☐ Somewhat explicit (I knew specifically what I wanted by students to learn)
  - ☐ Not very explicit (I had identified specific parts of a scientific concept I wanted my lesson to address but wasn't sure about exactly what I wanted students to learn)
  - ☐ I really didn't have a learning goal at first (I had a general sense of what scientific concept(s) I wanted my lesson to address but wasn't sure exactly what I wanted students to learn)
3. What existing lesson plans, curriculum materials, and other resources did you use to develop your lesson? Please list them here.

	Name/Title	Type of Resource	Source	Additional Information
<i>Ex</i>	<i>Take Me To Your Liter</i>	<i>Existing Lesson plan</i>	<i>My CT and/or placement classroom</i>	<i>From FOSS science curriculum</i>
1.				
2.				
3.				
4.				
5.				

- a. What did you like about features of the curriculum materials you used? What didn't you like? Why?
- b. Were they good choices for developing an inquiry-oriented lesson? Why or why not?
- c. What other factors did you have to consider in using these resources?

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### II. Adapting Science Curriculum Materials

4. Please think about **each of the changes you made** to your lesson. List each one and briefly describe it. Then, **for each change** you made, please answer the following:
  - a. How did this change **improve upon** what was already in the existing lesson?
  - b. Did this change make your lesson **more or less inquiry-oriented**? If so, how?
  - c. What **other factors** did you consider in making this change?

--

5. How inquiry-oriented do you think your lesson is?

- ☐ Very inquiry-oriented
- ☐ Somewhat inquiry-oriented
- ☐ Not very inquiry-oriented
- ☐ Not at all inquiry-oriented



Please explain your answer to question #5. Why do you think your lesson was or wasn't inquiry-oriented?

6. Please include any other comments you have about your lesson.

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### Teach Your Lesson

Now you're ready to teach your lesson. On the day of your lesson, be sure you're ready to go, with all the materials (including handouts) prepared. Also, make sure your field instructor knows when you're teaching.

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## **Part 2: To be completed after you teach your lesson**

### Part 2a. Reflective Teaching Assignment Post-enactment Reflective Journal

Now that you've taught your lesson, please reflect your lesson enactment in the box below. We've specifically included some questions to help you think about teaching science as inquiry and using science curriculum materials to help you do so, our two big goals for the semester.

1. How did it go? What went well? What didn't go so well? Were the changes that you made to your lesson before enacting it effective? Why or why not?
2. Did your students meet your learning goals? Analyze your students' work and look for things they wrote that show alternative ideas that changed or lingered. Refer explicitly to student work to make evidence-based assertions about their learning.
3. How did your enacted lesson compare to the lesson you planned? Did anything go differently than you expected? If so, please describe how. (*Please refer back to specific portions of your lesson plan*)
4. What did you learn from this experience? How did this experience influence your understanding of inquiry-oriented science teaching and factors you need to consider in teaching science as inquiry?
5. Based on what you learned from this experience, would you further modify this lesson? If so, how would you modify it for the next time you teach it?
  - Would you use additional resources and/or science curriculum materials? If so, describe them and talk about why.
  - What additional changes, if any, would you make to your lesson? Why would you make these changes?
6. Please feel free to address anything else you think is relevant.

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Part 2b. Documents

(1) Turn in the **original lesson plan**. (2) Turn in **3-5 examples of student work** that you refer to in your reflection. (Your lessons should have kids develop some kind of written or physical artifact. This could be a worksheet, a picture, a journal entry, or anything else that you can analyze to get a sense of the students' ideas.) (3) Attach copies of any **handouts, activity sheets, overheads**, etc. that you used in your lesson.

## Appendix D. Preinterview protocol

PT pre-modeling interview questions:

Initial comments/questions:

Ok to audiotape?

There are no right/wrong answers to these questions, mostly just want to get some insight into what your thoughts/opinions are and why.

### General Questions about Science Teaching, Attitudes, and Experiences

1. Before you came to college, did you enjoy learning about science in school? What were some memorable experiences (good & bad)? (refer to the CASES journal entry/survey on this topic)
2. In general, how comfortable would you feel teaching a science lesson to students? Why? Do you have experience teaching a science lesson to students? If yes, what was that like for you? If no, how do you feel about teaching your first science lesson to students?
3. Do you think that teaching science is important in elementary school? Why? As an elementary teacher, what sorts of supports would you want to have for teaching elementary science in schools?
4. Have you observed your CT (or another elem teacher) teaching science? If yes, what did you see? If no, what do you think you would see happening in this classroom?
5. How would you describe the work done by scientists? Do you think students learn about scientists' work when they are doing science in an elementary classroom? What do they learn? Are there similarities? Differences?
6. The next couple of questions will deal a bit with some of your answers on the CASES modeling journal assignment. But before we get into those questions, I was wondering...have you ever made or used a scientific model? What was that experience like? [practices/definition of sci model]

### Questions referring to the pre-test:

Next, I would like to talk to you about some of your pretest responses. There are no right or wrong answers, but we want to hear more about what you were thinking in your responses.

7. First, we are trying to get a sense of what kinds of resources if any, people are using to help them with their ideas for the questions. Can you tell me a little bit about where your ideas came

from for your answers to the these questions. Did you use google or wiki or some other website/external reference, no resources? [prior knowledge about modeling, sources of answers on pretest]

8. definition of models, scientific models, (Q1-4), probe for more understanding of what they think is a model or a SM. [nature of SM, definition of SM, purposes of SM, types of SM] Why do you think this? etc. (Be sure to refer to the interviewee's specific answers for Q1-4) example of one of their answers for SM, "how would a scientist use \_\_ (one of their answers for SM) \_\_\_\_ as a scientific model?" "what is involved with creating a SM like the one I just mentioned?"

9. probe Q7 erosion. Tell me more about your answer for Q7. What do you see as being the important differences between LP1 and LP2? What did you base your answer on? Can you say more about why you chose LP1 or LP2? Why might you choose to include or exclude the different types of models (idea, picture, working stream table) from your lesson about erosion? [PCK for SM, MMK vs practices] (Be sure to refer to the interviewee's specific answers for Q7)

10. On a scale of 1-10, how comfortable would you feel teaching a lesson (like the erosion lesson) that involves scientific modeling?

### Teaching Scenarios

11. You are a teacher. One of your learning goals is to have your students learn about scientific modeling. What do you think your students would think you mean if said "Ok class, today we are going to learn about scientific modeling?" What might you do next? [PCK for SM, getting at students' prior knowledge and/or ideas about SM]

Follow up with Why/why not? questions about the next 5 scenario options.

Do you have any questions or comments for me?

The following is a list of ideas or scenarios that you might teach in elementary science.

Read them, and then decide whether that scenario represents how you would teach, does not represent how you would teach, or whether you are unsure.

Number	Scenario	Would Teach	Unsure	Wouldn't Teach
1	You want students to learn the phases of the moon. You decide to ask your students to observe and make sketches of the moon each night for a period of one month. You ask the students to use their sketches to make a model of the moon's phases and have them predict the moon's phase on different nights during the next month. You also have them predict when the next blue moon (second full moon in one calendar month) will occur.			
2	You, as the teacher, are teaching a unit on matter and molecules. In order to help your students better understand how gas molecules move, you demonstrate several models of motion (including using a tray with marbles) in front of the class.			
3	In a unit on cells, you, as a teacher, decide that the best way to learn about parts of a cell is for students to create a "jello cell," where various shaped candies represent different cell parts.			
4	You, as a teacher, decide that your students are having a hard time understanding the concepts of condensation in the water cycle. You organize a time for a whole class discussion so that children can talk to each other about their ideas. As part of this whole class discussion, you record students' ideas on the board and work on the beginnings of a shared concept of condensation.			
5	You, as a teacher, are teaching a unit on the weather. You decide to have your class take pictures of the cloud patterns in the sky, record daily temperature and pressure measurements and organize those data into a chart that your students will use to explain the recent weather trends to their parents.			

## Appendix E. Postinterview protocol

### Post-Interview for Modeling lesson with Preservice Teachers

What does this measure?	Related Learning Goal(s)	Question
What was new? What did they learn? What was interesting to preservice teachers?		What did you learn from the class on modeling that you didn't know before? Why does this stand out for you?
What are the main ideas re: models/modeling/MMK that were internalized?		If you were to teach a lesson about models/modeling to another preservice elem teacher, what would you emphasize and why?
K/B/A about models/modeling/MMK in their own teaching How to incorporate m/m-ing/MMK in science teaching practice	6, 7	Do you think you will use SMs in your own science teaching? Why/why not?
Attitudes & beliefs about models/modeling/MMK for students Likelihood of models/modeling/MMK in their own teaching?	2, (4—indirectly)	Do you think it is important for elem students to know about models & modeling? Why? Do you think it is important for elem students to have exposure to/engage in modeling practices? Why?
Did preservice teachers incorporate aspects of models/modeling/MMK into their own practice? How and what was incorporated—hints at K/B/A about what is important about models/modeling/MMK for students. K/B/A about models/modeling/MMK in their own teaching?		You've had a chance to teach one (2?) science lesson(s) at this point and reflect on it (them)... Did you consider use of models/modeling in your lesson(s)? Why/why not?
		START REFERING TO THEIR WORK

What does this measure?	Related Learning Goal(s)	Question
Did the preservice teachers grasp the distinction between idea model & expressed model? Do they gain more traction with one or the other?	5	(REFER TO PLANT WATER MVMT SHEET FROM CLASS—What did you change in your “revised” model compared to your initial model? How would you characterize these changes (for example, idea was the same & drawing changed, idea changed & drawing changed)
Did preservice teachers use own ideas, outside resources, class resources, etc to complete the modeling journal? Did they look at their original answers when doing the assignment the second time?		Next questions will be about your modeling journals. When you completed the modeling journal the second time, what resources did you draw on for your answers? Did you use the reading material about models/modeling?
Familiarity with terms, knowledge of distinction between models & scientific models. Looking for evidence of change (or no change) in thinking before vs after the lesson (were previous ideas built upon/replaced/unchanged?)	1, 3	Modeling Journal questions 1-4: (which of these are models, why? which are SM, why?)  Did any of your ideas change between the first time you did this assignment and the 2 <sup>nd</sup> time? Why and how? or why not? SPECIFIC ?s REFERRING TO PT’s PRE/POST
Lesson plan analysis—again, looking for any change in reasoning that might provide evidence of learning or new knowledge/belief/attitude		Question 7—Erosion question—Did any of your ideas/answers change between the 1 <sup>st</sup> and 2 <sup>nd</sup> time you answered this question? Why and how (or why not)? SPECIFIC ?s REFERRING TO PT’s PRE/POST
K/B/A about incorporating models/modeling/MMK into a science lesson		?s related to germ transmission: why did you answer this question the way you did, what influenced your answer, did you and

What does this measure?	Related Learning Goal(s)	Question
Utility of exercise		your partner have similar ideas, do you think you would use this activity in your own teaching?
Comparison—look for evidence of change in ideas btwn pre & post		Include the mini-scenarios from the first interview for comparison purposes
Clarity/appropriateness/practicality of lesson, reading, etc.		What do you think was most clearly explained (either in reading, lecture, or both)? What would you want to have more clarity about?
		Do you have any questions for me?

### Learning Goals for Preservice Teachers

#### MoDeLS TE group

short form—preservice teachers will:

1. gain familiarity with terminology
2. understand importance of student modeling (authentic sci practice, develop understanding) & begin to want to do so
3. describe a scientific model , differentiate between “model” and “scientific model”
4. describe SM practices
5. recognize distinction between idea models & expressed models, see importance of using both together
6. begin to recognize purposes of models—predictive, illustrative, explanatory. sensemaking & communicating.
7. recognize models in CMs & enacted lessons, incl for pedagogical reasons typically
8. gain experience in modeling practices
9. gain experience in identifying & using set of criteria for evaluating (consistent with model’s purpose). Criteria for expressed vs idea model. Recognize strengths/limitations of competing models.
10. identify one or more instructional strategies for supporting students in engaging in MPs and developing MMK
11. begin to identify instructional sequences that can be used to engage students in modeling practices
12. gain experience analyzing CMs—how well do instr strategies/sequences support engaging students in modeling practices & developing MMK?



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