ELEMENTARY TEACHERS' LEARNING TO CONSTRUCT HIGH-QUALITY MATHEMATICS LESSON PLANS

A Use of the IES Recommendations

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ABSTRACT
This study explored a group of elementary teachers' (n = 35) learning to construct high-quality lesson plans that foster student understanding of fundamental mathematical ideas. The conceptual framework for this study was gleaned from the recently released Institute of Education Sciences (IES) recommendations, including (*a*) interweaving worked examples and practice problems, (*b*) connecting concrete and abstract representations, and (*c*) asking deep questions to elicit student self-explanations. Comparisons between teachers' pre- and postsurveys, and among teachers' initial, revised, and end-of-course lesson plans, indicated teachers' growth in using worked examples, representations, and deep questions during their lesson planning. Issues related to teachers' learning as they constructed lesson plans that aligned with the IES recommendations were also revealed.

LESSON plans are "intended curricula" reflecting teachers' thinking about how a lesson should be taught (Clark & Yinger, 1987; Remillard, 1999; Stein, Remillard, & Smith, 2007). Lesson planning closely relates to classroom instruction (Burns & Lash, 1988; Stein et al., 2007) and students' learning outcomes (Peterson, Marx, & Clark, 1978). Yet, the quality and style of many U.S. teachers' mathematics plans are discouraging, especially when compared with those of their counterparts from high-achieving countries (Cai, 2005; Fernandez & Cannon, 2005). These findings call for greater effort to deliberately support teachers' lesson-

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planning skills. This study documents such an instructional effort, reporting how teachers learn to construct high-quality mathematics lesson plans guided by the recently released Institute of Education Science (IES) recommendations (Pashler et al., 2007).

Literature Review

Prior Research on Lesson Planning

Many studies have explored teachers' conceptions of lesson planning (e.g., Sardo-Brown, 1990; Yinger, 1980). Experienced teachers, compared with novice teachers, more strongly believed that they did not need to devote much time to lesson planning (Sardo-Brown, 1990). Elementary teachers held this belief more firmly than their secondary counterparts because elementary teachers felt that detailed plans would hinder their ability to make connections across subjects and prohibit their teaching flexibility (Kagan & Tippins, 1992). The tendency to spend relatively little time developing lessons and to produce outlines (e.g., Brown, 1988; Peterson et al., 1978) appears to be a cultural style specific to U.S. teachers (e.g., Cai, 2005; Fernandez & Cannon, 2005). For example, Cai (2005) studied the difference between Chinese and U.S. teachers' representations of mathematics lessons. Nine Chinese and eleven U.S. distinguished mathematics teachers created introductory lesson plans for the topic of "average." It was found that Chinese plans were more detailed and longer (4–9 pages) than the U.S. plans, which were mainly in "outline and worksheet" formats (1–3 pages).

Although the length of a lesson plan does not necessarily reflect its quality, a brief outline cannot adequately prepare teachers to "unfold tasks" during classroom instruction (Charalambous, 2010). Effective teaching entails deciding "what to teach, how to represent it, how to question students about it and how to deal with problems or misunderstanding" (Shulman, 1986, p. 8). However, U.S. teachers studied in Cai (2005) did not agree on what tasks to use for teaching the same topic, even when teachers were from the same school and used the same textbooks. In addition, U.S. teachers who viewed using manipulatives as indicators of good lesson plans actually meant "collecting and copying materials" rather than how the materials would be used to teach the targeted mathematical concept (Cai, 2005; Fernandez & Cannon, 2005). Failing to carefully consider key teaching components in lesson plans might be due to teachers' beliefs. For example, some teachers believe that students should not be shown how to solve problems and should instead figure out how to solve problems themselves (Burns & Lash, 1988). Beliefs like this were more popular in classrooms where teachers misunderstood constructivism as a theory for teaching rather than a theory of learning (Anderson, Reder, & Simon, 2000). Such beliefs make detailed lesson planning or teacher guidance seem unnecessary. However, minimal guidance during students' problem solving did not work because, in some cases, students searched for irrelevant information that taxed their limited working memory (Kirschner, Sweller, & Clark, 2006). In fact, advocates of problem-based approaches to learning also suggested that teachers carefully structure classroom activities to allow students access to "expert guidance" (Hmelo-Silver, Duncan, & Chinn, 2007). To improve the effectiveness of teaching and learning, teachers should first consider the "design" of classroom instruction, which begins with careful lesson planning (Brown, 2009).

Prior research on lesson planning focused mainly on teachers' natural styles and thinking. Very few studies have explored how teachers can be deliberately supported to construct high-quality mathematics lesson plans. Since lesson planning is a complex process (Fernandez & Cannon, 2005), it might be unreasonable to expect teachers to effectively develop lesson-planning skills by themselves. As such, there is a need to guide and support teachers' lesson-planning practices (Fernandez & Cannon, 2005). This study addresses such a need, exploring how the recently released Institute of Education Science (IES) recommendations for instructional principles can be used as scaffolds to support elementary teachers' lesson planning.

Conceptual Framework for Improving Quality of Lesson Plans

The IES recommendations (Pashler et al., 2007), drawn from numerous evidence-based studies in the fields of cognitive science, experimental psychology, and classroom research, were intended to help teachers organize instruction to improve student learning. Since lesson planning is a critical first step to instruction, it is meaningful to use relevant IES recommendations to support teachers as they craft lesson plans. Among the seven recommendations (simply "Rs"), we recognized R1 (spacing learning over time) as an important element in long-range lesson planning, but chose not to include it because our focus was on developing a single plan. We thought R3 (combine graphics with verbal descriptions) was related to R4 (connect concrete and abstract representations) because R3, the use of graphics, could be considered a concrete representation. For simplicity, we focused on R4. In addition, we excluded R5 (use quizzing to promote learning) and R6 (help students allocate study time efficiently) because these principles are relatively far from the planning and teaching process, and their levels of evidence were low (except 5b, post-quizzing). As such, the recommendations that form a conceptual framework for this study included (*a*) interweaving worked examples with practice problems (R2), (*b*) connecting concrete and abstract representations (R4), and (*c*) asking deep questions to elicit student self-explanations (R7).

Worked examples. Worked examples are problems with solutions given. Effective examples can serve as instantiations of general principles. The use of worked examples may facilitate students' schema acquisition, which enables students to retrieve relevant information to solve new problems, resulting in effective learning (Kirschner et al., 2006; Sweller, 1988, 2006). As such, it is necessary for teachers to know that there are times when worked examples are appropriate and should be included in their lesson plans. However, effective teaching through worked examples involves more than showing procedures and telling solutions. This is because worked examples typically contain unexplained actions (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). When students explain why particular actions are taken, their understanding of an example and the underlying general principles can be enhanced (Atkinson, Renkl, & Merrill, 2003; Chi et al., 1989; Chi, de Leeuw, Chiu, & LaVancher, 1994). Other researchers (e.g., Carpenter, Fennema, Franke, Levi, & Empson, 1999) also found that children construct important mathematical ideas when they participate in activities that allow for meaning making. Therefore, when teaching a worked example, teachers should consider how to engage students' thinking and facilitate

their explanations. In addition, gradually "fading" examples into practice problems (Renkl, Atkinson, & Große, 2004) and interweaving examples with problem solving (Sweller & Cooper, 1985) benefited student learning. In this study, the textbook materials used for teachers' lesson planning included worked examples. We expected teachers to carefully unpack an example and plan corresponding practice problems to improve the effect of example on learning.

Representations. Concrete representations support initial learning because they provide familiar situations that students can draw on to construct meanings for abstract ideas (Resnick, Cauzinille-Marmeche, & Mathieu, 1987). However, an over-reliance on concrete situations may hinder students' transfer of learned knowledge to new contexts (Koedinger, Alibali, & Nathan, 2008). Thus, concrete representations should be linked to abstract ideas in order to prompt students' deep learning of key concepts (Pashler et al., 2007). Recently, cognitive psychologists (Goldstone & Son, 2005) have recommended "concreteness fading" as an effective method for linking concrete to abstract. In Goldstone and Son's study, the concreteness-fading method was used to gradually change the appearance of ants and food from vivid pictures to dots, lines, and patches during students' learning of a scientific principle—competitive specialization. It was found that students who learned through concreteness fading outperformed their counterparts in both initial learning and transfer tasks. Concreteness fading was also reported to be effective in supporting students' learning and transfer of mathematical concepts such as equivalence (Fyfe & McNeil, 2009). In this study, we expected teachers to incorporate the concreteness-fading method in lesson planning to effectively link concrete situations to abstract ideas. For example, a teacher may first present a concrete situation (e.g., story problems with vivid illustrations), then model it using semiconcrete representations (e.g., dots, cubes, number line or tape diagrams), and eventually transform the situation into abstract symbols. In particular, the number line and tape diagrams (drawings that look like tapes, strips, or bars, used to illustrate quantitative relationships), commonly used in Asian curricula (Ding & Li, 2010; Murata, 2008), were powerful tools to connect concrete and abstract (Pashler et al., 2007).

Deep questions. Deep questions target underlying principles, structure, and causal relationships (Craig, Sullins, Witherspoon, & Gholson, 2006). When students are prompted to explain underlying structures or relationships, their "germane cognitive load" is increased, which contributes to schema acquisition and automation (Sweller, 2006) and results in effective learning (Chi et al., 1994). In fact, both the National Council of Teachers of Mathematics (NCTM, 2000) and the American Association for the Advancement of Science (AAAS, 1993) have strongly recommended that students communicate, explain, and justify their mathematical thinking. Thus, teachers should ask deep questions to elicit students' self-explanations (Pashler et al., 2007). Boaler and Staples (2008) found that when teachers wrote questions before teaching a lesson they had specific strategies for drawing students' attention to key mathematical ideas. Indeed, Cai (2005) reported that, unlike U.S. teachers, Chinese teachers uniformly included questions in their lesson plans. In addition, teachers should anticipate deep explanations for their proposed questions. Otherwise, guidance may remain superficial and may stop prompting students' thinking too quickly.

Supporting Teacher Changes through Textbook Experiences

We used existing textbook materials as a basis for discussing how to incorporate the IES recommendations when planning lessons. A large body of research has suggested that curriculum materials play a central role in teachers' curriculum planning and instructional practices (Ball & Cohen, 1996; Nathan, Long, & Alibali, 2002; Remillard, 2005). A variety of factors, including teacher knowledge and beliefs, orientations, personal identities, and local contexts, influence the ways in which teachers read, interpret, and eventually implement curricula (Drake & Sherin, 2006; Forbes & Davis, 2010; Lloyd, 1999; Pintó, 2005; Remillard, 1999, 2005; Valencia, Place, Martin, & Grossman, 2006). Prior studies have suggested that teachers may off-load, adapt, or improvise with curriculum materials. These actions indicate a literal use of curriculum, a combination of using curriculum materials and personal resources, or a minimal reliance on curriculum materials, respectively (Brown, 2009; Remillard, 1999).

Understanding the ways in which teachers interpret and use textbooks may allow teacher educators to better use textbook materials to support teacher learning and change (Remillard, 1999). Left to their own devices, teachers may rely on what is consistent with their experiences as learners and misinterpret the intention of curricular structures and student activities (Lloyd & Behm, 2005). However, recent work in science education has revealed the benefits of supporting preservice teachers' interpretation and adaptation of existing curriculum materials (Beyer & Davis, 2012; Forbes, 2011). Forbes found that preservice teachers were able to adjust curriculum used in elementary school classrooms to provide opportunities for students to formulate questions, gather and interpret data, and communicate and evaluate "evidence-based explanations" (p. 943). As such, our integration of textbook materials in this study may enhance teachers' *pedagogical design capacity*, that is, their ability to "perceive and mobilize existing resources in order to craft instructional episodes" (Brown, 2009, p. 29). The integration of textbook materials and the IES recommendations through lesson planning may also enable textbooks to function as educative curriculum materials that support teachers' learning and changes (Ball, 1996; Davis & Krajcik, 2005; Drake & Sherin, 2006). Indeed, teachers in mathematically high-achieving countries such as China consistently reported that intensive study of textbooks was a necessary part of producing quality lesson plans and teaching (Cai & Wang, 2010; Ding, Li, Li, & Gu, in press).

This Study

This study explores how the IES recommendations can be used to support elementary teachers as they learn to construct high-quality mathematics lesson plans based on existing textbook materials. To the best of our knowledge, our study is among the very first to document such an effort. In particular, we ask two questions: (*a*) To what extent can elementary teachers be supported to learn to use worked examples, representations, and deep questions in lesson planning based with existing textbooks? (*b*) If worked examples, representations, and deep questions are learnable, what challenges might teachers face in learning these components during lesson plan development?

Method

Participants

A group of K–3 in-service teachers ($n = 35$) who participated in a National Science Foundation–funded project at the University of Nebraska–Lincoln took a 2-week intensive summer graduate course. The first author was a lead instructor for the course, and the second author was a teaching assistant. This course was part of a larger professional development program that aimed to increase K–3 teachers' capacity to be intentional, planful, observant, and reflective practitioners. All the participants were female and came from 13 cities statewide. At the time of the course, 28 of the participants were preparing to return to their districts as classroom teachers, and 7 were preparing to be building- or district-level coaches. All of the participants had previous teaching experience ranging from 3 to 40 years.

The Summer Course

One of the goals of the summer course was to improve teachers' lesson-planning skills based on the IES recommendations. Teachers were asked to read the IES document (Pashler et al., 2007) before the summer course. During the first class, we discussed the IES recommendations focusing on the use of worked examples, representations, and deep questions in a general sense. Throughout the 2 weeks, we situated our discussion of these recommendations in three fundamental mathematical topics: (*a*) the concept of equivalence denoted by the equal sign (=), (*b*) the inverse relations between addition and subtraction and between multiplication and division, and (*c*) the basic laws of arithmetic including commutative, associative, and distributive properties. Table 1 illustrates a timeline of the professional development (PD) activities.

As indicated by Table 1, during the first week, we discussed the equal sign, the additive inverses, and the properties of addition (commutative and associative). During the second week, we addressed multiplicative inverses and properties of multiplication (commutative, associative, and distributive). For each topic, we discussed the relevant literature and related the readings to the IES recommendations. For example, for the concept of equivalence, we discussed Li, Ding, Capraro, and Capraro (2008) and investigated students' misinterpretation of the equal sign as an operational rather than relational sign.

Table 1. Timeline and Data Collected for This Study

PD Activities/	Week 1					Week 2					
Data Collected	M	T	W	R	F	M	T	W	R	F	Week 4
Course discussions	Concept of equivalence (=) Additive inverses Properties of addition					Meaning of multiplication Multiplicative inverses Properties of multiplication					
Sample plan 1					X						
Sample plan 2							X				
Initial plan[a]	X	X	X		Feedback						
Revised plan[a]						X	X	X		Feedback	
EOC plan/analysis[a]											X
Presurvey[a]	X										
Postsurvey[a]										X	

[a] Indicates the data collected for this study.

We discussed how the Chinese first-grade textbook introduced the equal sign in a comparison context and used the concreteness-fading method (e.g., fading from vivid animal illustrations to circles, and then to abstract number sentences). We also discussed literature (e.g., Murata, 2008; Resnick et al., 1987) that supported the IES recommendations. We then examined textbook pages selected from K–5 Houghton Mifflin (Greenes et al., 2005), a textbook series that was used by most of our participants at the time they participated in this study. We prompted teachers to think about how they could maximize the use of the existing examples and representations and ask deep questions to support students' learning.

Over the 2 weeks, we discussed two sample plans written by Chinese expert teachers (e.g., Cai, 2005; see Table 1). Both plans addressed the topic of "average." We asked teachers to evaluate the plans using a rubric aligned with the IES recommendations (elaborated below). The purpose of these activities was twofold. First, the activities familiarized teachers with the rubric we would use to evaluate their plans. Second, examining exemplary plans that aligned with the selected IES recommendations offered teachers concrete images of thorough lesson plans that could act as models for their own work.

During the course, teachers were asked to construct their own lesson plans. Initially, teachers were given a textbook page to use as the basis for their plans. These plans were then revised based on instructor feedback (elaborated below). Writing and revising a lesson plan laid a foundation for the teachers' final project, the end-of-course (EOC) lesson plan, which was independent work. The three lesson plans (initial, revised, and EOC), along with pre- and postsurveys, were collected as sources of data for this study (see Table 1).

Data Sources

Three lesson plans. At the end of the first class, we asked teachers to design a plan using a first-grade lesson from the Houghton Mifflin series (see Fig. 1). This lesson targeted the inverse relationship between addition and subtraction. The textbook pages clearly included a worked example around the equations $6 + 3 = 9$ and $9 - 3 = 6$ and suggested different types of representations with varied levels of concreteness. For instance, there was a kitten illustration with six kittens on the left side of the page and three on the right, a part-part-whole mat with yellow and blue cubes on it, and the number sentences $6 + 3 = 9$ and $9 - 3 = 6$. However, the representations were not arranged from concrete to abstract (see Fig. 1). We expected teachers to incorporate the concreteness-fading method—first by using the kitten illustration to situate the example in a concrete context, then to model the problem with cubes and a part-part-whole mat, and eventually fade into abstract number sentences. We also expected teachers to ask deep questions to prompt students to see the inverse relations (e.g., how $6 + 3 = 9$ and $9 - 3 = 6$ are related in terms of the story situation, the part-part-whole model, or the paired number sentences).

Because this was teachers' initial lesson plan, we did not discuss the textbook page with teachers until after it was completed. We simply encouraged teachers to write plans based on their current understanding of planning and the aforementioned rubric. The rubric included six subcategories (see Table 2). Under "worked examples," we expected teachers to (*a*) sufficiently discuss at least one worked example, and (*b*) fade examples into carefully designed practice problems. Under "representations," we expected teachers to (*a*) meaningfully use concrete representations, and (*b*) connect concrete to abstract repre-

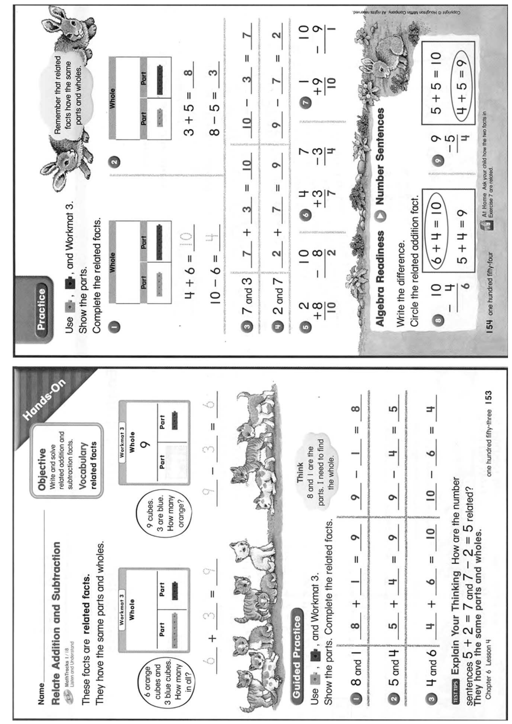

Figure 1. The textbook page used for the initial and revised lesson planning.

Table 2. An Example of Feedback to Teachers' Initial Plan

Category	Subcategory	Feedback
Worked examples	*a*) Sufficiently discuss at least one worked *example*	1. The time allotted to worked example (20 minutes) is appropriate. Yet, your current plan may not take 20 minutes for discussion in actual classrooms. 2. The logic of your discussion is very clear. It is great to ask students to change an addition situation to a subtraction situation. However, you should compare the two number sentences and ask students how these two sentences are related to each other. Students should verbalize their thinking based on the cube problems. This way, you will be able to provide "sufficient discussion" of one worked example with students.
	b) Fade examples to carefully designed *practice* problems	1. The time allotment for this part is appropriate. 2. Good job on providing anticipated student explanations for a few guided practices.
Representations	*a*) Meaningfully use *concrete* representations	1. When discussing the worked examples, it would be great if you can involve more concrete contexts. Could you first create a word problem or show a picture or some objects? You still can use the cubes to model that concrete situation.
	b) Connect concrete to *abstract* representations	1. You did a nice job by generating number sentences based on the cubes situations. 2. It will be better if you can ask your students to refer back to the concrete contexts (e.g., What does 6 mean? Why do we use addition? How are $6 + 3 = 9$ and $9 - 3 = 6$ related?)
Deep questions	*a*) Propose deep *questions* to elicit key ideas	1. You don't need a particular section titled "deep questions." You just need to propose good questions including the deep ones throughout your plan. 2. You need to ask deep questions to stress the relationships between addition and subtraction whenever appropriate.
	b) Anticipate student *explanations* to deep questions	1. It is good that you have provided "anticipated answers" to some questions. For example, under "guided practice," you have provided anticipated student explanation to "$8 + 1$." 2. But you need to write down your anticipated student explanations regarding how addition and subtraction are related.
Other comments (e.g., review, summary)		1. Why do you allot time for the "lesson objective" and "vocabulary" sections? You only need to provide time allotment for the basic instructional parts including introduction/review, new teaching, guided practice, and summary. 2. What will your review problems be? Please write them down. How many of these problems will be modeled and explained? All of them or only the selected ones? How will you guide students to review them? Please write down your questions.

sentations. Under "deep questions," we expected teachers to (*a*) propose deep questions to elicit key ideas, and (*b*) anticipate student explanations to deep questions. The initial lesson plans were turned in on Wednesday of the first week. The first author, as an instructor for the course, graded the initial plans and provided detailed feedback for each teacher in terms of each subcategory (see Table 2 for example feedback). The feedback was a balance between encouraging better incorporation of the IES recommendations and preserving teachers' independent thinking. For example, the first author commented that a lesson could have started from a more concrete situation. Yet, what that situation might be and how it might be presented were left to the teachers. We handed back the feedback to teachers on Friday and asked them to revise their plans based on our suggestions.

The revised lesson plan was turned in the second week along with brief explanations of how each of our comments was addressed. Similar grading processes were applied. The EOC plan was part the final project, and teachers had 2 weeks after the course to complete it. Teachers could select any lesson from their textbooks as long as it was related to a topic covered in this course. Along with the plan, teachers were asked to analyze their use of worked examples, representations, and deep questions and provide an overall reflection of the summer course.

Pre- and postsurveys. To better understand changes in teachers' conceptions of lesson planning, we conducted pre- and postsurveys at the beginning and end of this course. On the survey, teachers were asked, "What are the important factors that you consider during lesson planning?" Although teachers had read the IES recommendations before the summer course, the presurvey was conducted at the beginning of the first class. At that point, no connection between the IES recommendations and lesson planning had been made. This design allowed us to measure teachers' conceptions after reading the IES recommendations but before they were connected explicitly to lesson planning.

Data Coding and Analysis

Three lesson plans. To capture the patterns of teachers' use of worked examples, representations, and deep questions, we further developed the coding rubric using a 0–2 scale denoting "not met" (0), "partially met" (1), and "met" (2) for each of the six subcategories (simply "example," "practice," "concrete," "abstract," "question," and "explanation"; see Table 3).

Although the rubric was developed based on the summer course grading, it went through ongoing revisions during our actual coding. For example, our original scale 2 description for worked example demanded teachers' careful consideration of representation uses and planned questions. If a teacher did not use representations well or did not write down key questions when planning a worked example, points would be taken off from both categories of worked examples and representations/deep questions. To avoid this redundancy in coding, we revised the scale 2 description for worked example by removing the representation and question demands. This way, if a lesson plan presented a worked example with great detail, we could assign a code of 2 even if limitations in using representations or asking deep questions existed. Another refinement in the rubric was related to "meaningfully using concrete representations." Our original scale 2 description for this category demanded that teachers situate worked examples in concrete contexts. However, while many teachers used

Table 3. The Coding Rubric for Three Lesson Plans

Category	Subcategory	0	1	2
Worked examples	Example	No example is visible. Examples and guided practice cannot be differentiated.	There are 1–2 worked examples before student practice or exploration. However, the example is planned in a relatively brief manner, or planned to discuss "many" examples.	There are 1–2 well-discussed worked examples before student practice or exploration. Example clearly shows teacher's attention on the worked-example effect.
	Practice	No practice problems are listed.	Practice problems are listed. However, there is no or little consideration of how to discuss typical problems with students.	Practice problems are listed. There is clear consideration of how to discuss typical problems with students.
Representations	Concrete	Discussions, especially of worked examples, are completely limited to the abstract. No manipulatives, pictures, or story situations are used.	(1) Concrete materials/story situations are involved but not utilized sufficiently for teaching the worked example; (2) Semi-abstract representations such as dots or cubes are used as a context for teaching the worked example	Discussions, especially of worked examples, are well situated in rich concrete contexts (e.g., pictures and story problems). Concrete materials are used to make sense of the target concepts.
	Abstract	Discussions are limited to the concrete and are not at all linked to the abstract representations of the target concept.	(1) Both concrete and abstract representations are involved, but the link between both is lacking; (2) Since all discussions remain abstract, the link between the concrete and abstract is invisible; (3) Opposite: from abstract to concrete.	Concrete representations are used to purposefully link the abstract representations to the target concept
Deep questions	Question	No questions are visible when discussing a worked example or guided practices.	(1) Some questions are written down, but there are obvious missing opportunities to ask deep questions to elicit deep explanations; (2) A set of questions is listed with no clear indication of when and how they will be asked.	Questions are appropriately listed during the context of the discussion of examples or guided practice. There are clear deep questions that may elicit student explanation of the key concepts and underlying ideas.
	Explanation	No student responses are anticipated.	Some responses are provided. However, the explanations related to the target concepts are not anticipated.	Student responses are provided. In particular, explanations related to the target concepts are anticipated.

cubes to teach a worked example in their initial plan, their revised plan involved rich story situations. Using the original description, both plans would be assigned 2 points. Yet, compared with using cubes only, situating a worked example in a rich story situation may be more meaningful because story situations may connect to students' life experiences and facilitate initial learning (Goldstone & Son, 2005; Koedinger et al., 2008). As such, we revised our descriptions for scale 1 to include "semi-abstract representations such as dots or cubes" and descriptions for scale 2 to include "rich concrete context such as pictures and story problems." Each time a revision was made, we went back to the lesson plans we had already analyzed to ensure the consistency of coding.

Using this rubric, the first author coded 34 teachers' initial, revised, and EOC plans (one teacher did not complete her EOC plan), resulting in a total of 102 plans in this study. The second author (co-instructor), who was familiar with the rubric, randomly selected 10% of each of the three lesson plans and independently coded them. Cohen's kappa was computed to check the interrater reliability (usually kappa should be ≥0.7; Leech, Barrett, & Morgan, 2008). The resulting average kappa of 0.805 indicated high agreement between the two coders. We discussed and resolved disagreements.

After coding the lesson plans, we conducted repeated-measures ANOVA tests along with polynomial contrasts (Howell, 2002; Leech et al., 2008) to assess the differences among teachers' three plans in terms of each category. In addition, we qualitatively explored the merits of the plans that received full credit for a particular category and identified common issues of plans that received only partial or no points. Finally, we triangulated our interpretations of teachers' lesson-planning design with their own analyses of the EOC plans, and we read their general reflections on the summer course to hear in the teachers' own words what they learned from this course and their concerns about transferring knowledge into classrooms.

Pre- and postsurveys. To analyze teachers' conceptual changes in lesson planning, we examined whether ideas about "worked examples," "representations," and "deep questions" were mentioned by teachers ($n = 35$) in the surveys. When a teacher's response included a relevant idea, we coded it as 1, otherwise, 0. Both authors independently coded the surveys. The resulting average kappa of 0.65 for the presurvey indicated the challenging nature of the coding. Early in the course, teachers' language was vague, possibly due to the fact that the IES recommendations were not directly linked to lesson planning at the time. After discussion, we decided to err on the side of generosity (e.g., we considered any mention of "manipulatives" as a concrete representation even if it may refer to a collection of materials). This resulted in an improved interrater reliability (average kappa = 0.94). The coding of the postsurveys was relatively straightforward (average kappa = 0.85). A paired *t*-test was used to assess the difference in teachers' conceptions of lesson planning at the beginning and end of this course.

Results

An Overall Picture

In this section, we report an overall picture, including teachers' conceptions and actual skills of lesson planning based on the survey and the lesson plan data. Successive sections provide detailed descriptions of teachers' successes and challenges in using worked examples, representations, and deep questions.

The survey results indicated that over time, teachers' (n =35) awareness of incorporating the IES recommendations into their lesson plans increased. In the presurvey, fewer than half of the teachers discussed the use of examples (28.6%), representations (42.9%), and questions (25.7%). In the postsurveys, most teachers explicitly mentioned the use of examples (74.3%), representations (82.9%), and questions (88.6%). A paired t-test indicated that the above changes from pre- to postsurveys were significant, $t(34)_{example} = 5.35$, $p < .001$; $t(34)_{representation} = 3.40$, $p < .001$; $t(34)_{question} = 7.59$, $p < .001$.

Results from teachers' ($n = 34$) lesson plans indicated an overall improvement in lesson-planning abilities, although six teachers did not carefully follow the assignment instructions for EOC plans and created plans around topics that were not covered in our course. Figure 2 illustrates the means for each of the six subcategories from initial to revised, and to EOC plans. Repeated-measures ANOVA tests, with Greenhouse-Geisser correction, indicated significant changes in teacher' lesson-planning skills, $F(2, 66)_{example} = 21.02$, $F(1.30, 43.00)_{practice} = 10.45$, $F(2, 66)_{concrete} = 17$, $F(2, 66)_{abstract} = 24.02$, $F(2, 66)_{question} = 11.76$, $F(2, 66)_{explanation} = 48.22$; $p < .001$ for each category (the assumption of sphericity was met for testing each category except practice, which was corrected with Greenhouse-Geisser). Examination of these means (see Fig. 2) suggested that teachers' lesson-planning skills increased linearly over time. Polynomial contrasts indicated that, in support of this, there was a significant linear trend for each category, $F(1, 33)_{example} = 29.80$, $F(1, 33)_{practice} = 17$, $F(1, 33)_{concrete} = 22.44$, $F(1, 33)_{abstract} = 42.68$, $F(1, 33)_{question} = 20.43$, $F(1, 33)_{explanation} = 90.61$; $p < .001$ for each category. However, except for the category of practice, these findings were qualified by the significant quadratic trends, reflecting the fact that the increases leveled off, and even fell, from revised to EOC plans, $F(1, 33)_{example} = 10.15$, $p = .001$; $F(1, 33)_{practice} = 1.34$, $p = .26$; $F(1, 33)_{concrete} = 9.84$, $p = .004$; $F(1, 33)_{abstract} = 12.48$, $p = .001$; $F(1, 33)_{question} = 8.36$, $p = .007$; $F(1, 33)_{explanation} = 23.74$, $p = .001$. Below, we present teachers' use of worked examples, representations, and deep questions across three lesson plans. When appropriate, we triangulate these results with the survey data.

Teachers' Use of Worked Examples in Lesson Planning

Figure 3 indicates that across initial, revised, and EOC plans, an increasing number of teachers paid full attention to planning worked examples (11, 28, and 29, respectively) and practice problems (20, 28, and 33, respectively).

Sufficiently discussing a worked example. In the initial plan, more than half of the teachers ($n = 19$) did not sufficiently discuss the worked examples. This finding aligned with the presurvey, where only three teachers mentioned the word *example*. Teachers' plans revealed three issues. First, some teachers provided broad descriptions rather than attempting to unpack an example. For instance, T11 planned to ask students to study an example by themselves and then figure out how the part-part-whole mat, the cubes, and the number sentences are related to each other. T14 said that she would teach an example and use cubes to model it. However, it was not clear what example she might discuss, or when and how the cubes would be used to model the example. Second, some teachers overlooked the underlying idea (inverse relations) and thus missed opportunities to further unpack an example. Most of the lesson plans discussed addition and subtraction in a separate manner, and some

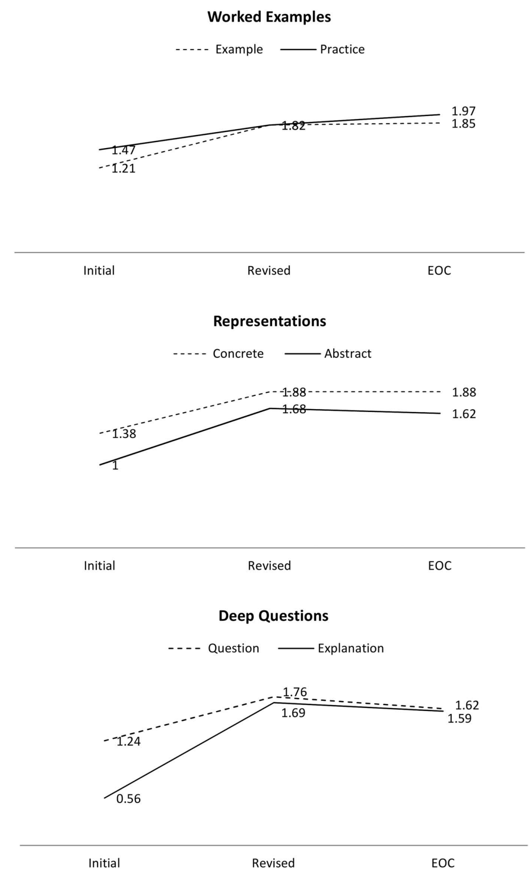

Figure 2. Mean scores for each category across initial, revised, and EOC plans.

placed more emphasis on the former than the latter. For instance, T33 used only one sentence to discuss subtraction. Teachers' overlooking of the lesson's underlying idea might be due to their own incomplete comprehension of the important idea

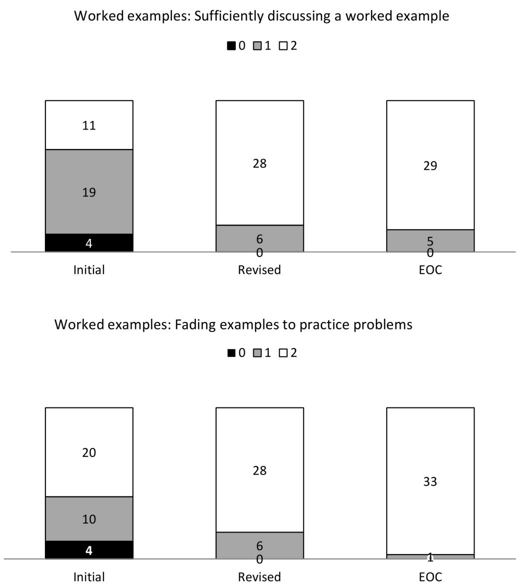

Figure 3. Number of teachers who received a score of 0, 1, and 2 for worked examples.

embodied by an example, or they may have assumed students could automatically see the underlying idea. The third issue was that some teachers planned to work through many examples at a rapid pace rather than unpack a few thoroughly enough to be considered as worked examples. T19 planned a series of examples without variation (e.g., $4 + 2 = 6$ and $6 - 2 = 4$; $3 + 5 = 8$ and $8 - 3 = 5$) in either the problem structures or the amount of teacher guidance on each example. We addressed these issues in the written feedback to individual teachers (see Table 2 for an example) and discussed them in our Friday class. We emphasized targeting the underlying ideas based on thorough discussions of one worked example, as opposed to covering many examples in a short time period. We also suggested that teachers consider representations and deep questions when unpacking an example.

In the revised plans, most teachers ($n = 28$) sufficiently discussed their examples and stressed the inverse relation between addition and subtraction. T13 spent three pages on a worked example involving a pair of inverse story problems about three boys and four girls. She first discussed the addition story problem using a tape diagram, which led to a number sentence, $3 + 4 = 7$. She then changed her addition story along with the diagram to a subtraction problem, which led to another number

sentence, $7 - 3 = 4$. The teacher then planned a particular section titled "exploring relationships," during which addition and subtraction problems were explicitly compared and the term *related facts* was revealed.

In the EOC plans, the majority of teachers ($n = 29$) discussed a worked example in great detail. This is consistent with the postsurvey, on which typical responses were similar to "be more intentional and purposeful about 1 or 2 good worked examples versus presenting students multiple procedural problems" (T20). For instance, in order to teach the equal sign to kindergartners, T29 created a worked example about "$4 = 4$," using an activity of "sorting classmates" (four boys and four girls). After students obtained a sense of "equal groups," she continued to unpack this example using the concreteness-fading method. It should be noted that, even though in this study we encouraged teachers to use existing textbooks as a basis for lesson planning, most teachers' worked examples were self-created and were not found in the corresponding textbook pages.

Fading examples to practice problems. We expected teachers to fade instruction as they transitioned from examples to guided practice in their plans. We also expected teachers to plan a discussion around a few typical practice problems. In their initial plans, four teachers (11.8%) did not plan any practice problems. Ten teachers (29.4%) provided a list of practice problems without any plans. The remaining 20 teachers (58.5%) met our expectations in this category (see Fig. 3). We discussed fading instruction to practice problems in our Friday class. In both the revised and the EOC plans, teachers' attention to practice problems improved considerably. Almost all of the plans ($N_{revised} = 28$, $N_{EOC} = 33$) planned discussions around typical practice problems. Interestingly, although many teachers tended to create their own worked examples, they used textbook materials to plan practice problems. For example, T29's EOC plan used a "tea party" activity (an optional activity in the textbook) to reinforce students' understanding of the equal sign. T20 used the textbook's worked example as a guided practice problem.

Teachers' Use of Representations in Lesson Planning

Figure 4 shows teachers' use of representations. Across the initial, revised, and EOC plans, the number of teachers who effectively used concrete representations increased from 13 to 30 (for both the revised and EOC stages), while the number of teachers who successfully connected concrete to abstract improved from 4 to 24 (revised), but fell to 21 (EOC). It appeared that teachers were more skillful in using concrete representations than connecting concrete to abstract.

Using concrete representations. A prevalent issue in teachers' ($n = 21$) initial plans was the limited use of concrete situations in the worked examples, that is, starting from the cubes but not the rich story situations. This finding was consistent with teachers' comments on the presurvey in that many mentioned the use of manipulatives, but not story contexts. In fact, all but four teachers completely ignored the kitten situation suggested in the textbook (see Fig. 1). In our feedback to individuals, we suggested, "Could you start from a more concrete situation such as a story problem?" (see Table 2 for an example). Our Friday class discussed the kitten illustration. We asked, "Why does the textbook include this picture? Can we utilize it as an example for teaching? How?" It was not until our class discussion that many teachers realized that the kitten illustration actually matched the pair of number

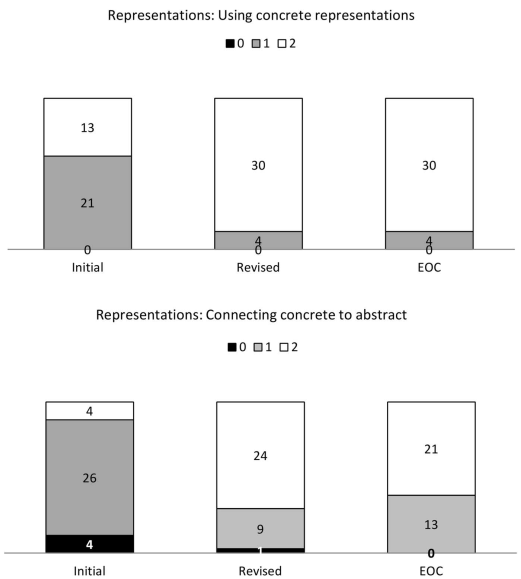

Figure 4. Number of teachers who received a score of 0, 1, and 2 for representations.

sentences, 6 + 3 = 9 and 9 − 6 = 3. Therefore, we encouraged teachers to study textbooks intensively and to use existing resources sufficiently.

In the revised and EOC plans, most teachers (n = 30 for both plans) successfully situated their worked examples in concrete story situations. This result was consistent with the postsurvey, on which 66% of the teachers mentioned that they would use realistic examples to help students understand big mathematical ideas. The EOC lesson plans indicated that teachers were critically analyzing and adapting curricula to do so. For example, T27 planned a first-grade lesson about the commutative property of addition. This teacher situated her worked example in a story situation: "Nathan caught 2 fireflies in one part of the yard and 3 fireflies in another. Hannah caught 3 fireflies in one part of the yard and then 2 fireflies elsewhere. Who do you think caught more fireflies?" In her EOC analysis, T27 explained that her textbook moved to a semiconcrete model, unifix cubes, too quickly. Thus, she departed from the textbook and created the story situation to make it sensible to students.

Connecting concrete to abstract. In the initial plan, most teachers did not connect concrete and abstract representations. First, some teachers' lesson plans remained at the concrete stage, or their concrete story situations were not utilized to stress the additive inverses. For example, T24 started her lesson by reading a story about addition called "Elevator Magic." She asked students to generate addition number sentences for each page. Although the concrete situation may have piqued children's interest or supported their understanding of addition, these stories were not modified further to teach subtraction and the additive inverses. A second issue was that some teachers directly introduced the abstract vocabulary *related facts* at the beginning of the lesson plan as the textbook suggested, rather than situating this abstract term in a concrete situation. In our feedback to teachers, we stressed the connection between concrete and abstract and emphasized that the use of concrete situations should be gradually faded out to serve the purpose of teaching underlying concepts.

In the revised plans, teachers progressed in connecting concrete to abstract, as indicated by their use of concreteness-fading methods (see Fig. 4). T13 explained that she decided to revamp her plan using what she had learned from this course. This teacher modeled her worked example using schematic representations, tape diagrams, which were not suggested in the textbook. In the EOC plans, six more teachers used tape diagrams, and 21 teachers demonstrated full attention to connecting concrete to abstract. Among those 21 teachers, T29's lesson plan about the equal sign was a typical example of concreteness fading. This teacher faded the actual four boys and four girls into stick figures and eventually into 4 = 4. In her lesson plan analysis, T29 explained, "Students are now shown how they can count and match the stick figures on the grid, just as they could count and match the 'real' boys and girls."

Although teachers made progress in connecting concrete to abstract, difficulties remained (10 revised and 13 EOC plans receive partial/no credit; see Fig. 4). For example, although T24 improved her revised plan by adapting the events (elevator up and down) to teach both addition and subtraction, she still did not use the situations to stress the inverse relations between addition and subtraction. We suspect that she overlooked the underlying ideas. In her EOC plan, T24 planned a lesson about place value—a topic that was not discussed in the course. Although this plan incorporated various representations such as money and tiles, as well as the number sentence 10 + 2 = 12, the planned teaching appeared to be rapid and lacked careful connections between concrete and abstract representations.

Teachers' Use of Deep Questions in Lesson Planning

As Figure 5 indicates, the number of teachers who successfully proposed deep questions increased from initial to revised plans but fell on the EOC plan (9, 26, and 21, respectively). The same pattern was observed with anticipating deep explanations (3, 24, and 20, respectively). This finding was in contrast to the survey data, in which teachers' awareness of questioning improved most.

Proposing deep questions. Twenty-five teachers' initial plans (73.5%) revealed issues that needed attention. One plan did not include any questions, and others provided a question list titled "deep questions" either at the beginning or at the end. It was not clear when or under what contexts these questions would be asked. A third issue was that some plans did not include "deep" questions to address the inverse relation. For example, the teachers who noticed the kitten picture (T4, T8, T15) simply asked, "Why is the kitten here?" without further prompts. This again might be related to teachers overlooking the underlying ideas embodied by the example. A

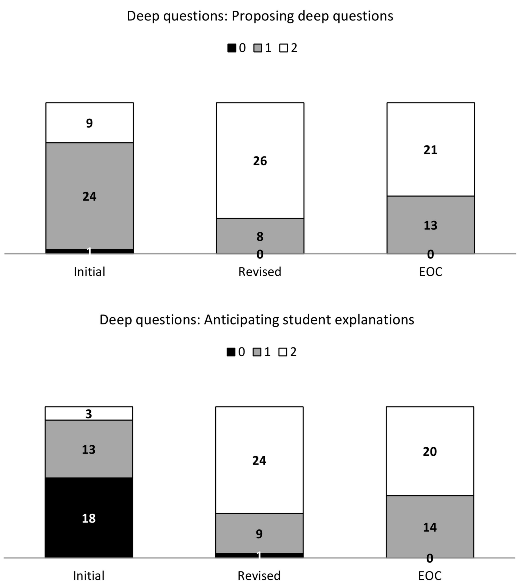

Figure 5. Number of teachers who received a score of 0, 1, and 2 for deep questioning.

fourth issue was revealed by teachers who captured the underlying idea but whose questions in the lesson plans were not likely to elicit students' deep explanations of the concept. T26 planned to teach students a "part-part-whole" song ("Part, part, whole, that means addition" and "Whole, part, part, that means subtraction") and then ask, "Is $5 + 2 = 7$ an example of part, part, whole or whole, part, part? Is $7 - 2 = 5$ an example of part, part, whole or whole, part, part?" In our feedback to such lesson plans, we suggested that teachers utilize their worked example situation (e.g., orange and blue cubes) and raise questions that prompt a comparison between the corresponding number sentences. Finally, a few teachers (e.g., T3, T16) planned to ask the deep question, "How are $5 + 2 = 7$ and $7 - 2 = 5$ related?" which was suggested in the textbook's "guided practice" section (see Fig. 1). However, these teachers did not raise a similar question during the teaching of worked examples, perhaps because that part of the textbook did not provide a similar deep question. In our feedback, we acknowledged teachers' deep questions and suggested that they ask such questions earlier during their teaching of the worked example.

In the revised lesson plan, most of the teachers addressed our feedback by asking questions about the inverse relations (e.g., How are the addition and subtraction sen-

tences related?). In the EOC plan, more than half of the teachers employed this instructional principle, asking questions to stress the key ideas, such as the commutative property of addition (e.g., How are $3 + 2$ and $2 + 3$ the same and different?) and the multiplicative inverses (e.g., What are the similarities and differences between $20 \div 4 = 5$ and $4 \times \_\_\_ = 20$?). These questions shared the same feature, targeting the "relationships" among quantities. These lesson plans were consistent with teachers' postsurvey comments, such as, "I will use deep questioning throughout the lesson to guide student thinking" (T27).

Although teachers made progress in the revised and EOC plans, we noted ongoing challenges in asking deep questions. Teachers who planned a topic that was not covered in this course (e.g., place value) had the most difficulty. Even among those teachers who designed a plan around topics covered in this course, some did not recognize the opportunity to ask deep questions. T34 planned a lesson that involved the commutative property. However, most of this teacher's questions in the lesson plan required only single-word answers. When she asked a "why" question, she planned to explain it herself. In addition, the teacher herself implicitly stated the property and did not ask a deep question to elicit students' understanding. In her reflections, this teacher expressed unreserved satisfaction with her plan: "I asked questions throughout the lesson to enhance their thinking. I asked 'why?' whenever I felt like I would need more of an answer." T34's case indicated the challenging nature of helping teachers understand what is meant by deep questions during lesson planning.

Anticipating student explanations. Compared with the other five subcategories we assessed, anticipating deep explanations was weakest on teachers' initial plans. First, some teachers ($n = 18$) did not provide any anticipated responses to any questions. Second, teachers who provided anticipated responses ($n = 13$) did not stress the main mathematical point. For example, a few teachers who asked how $5 + 2 = 7$ and $7 - 2 = 5$ were related suggested that "both sentences have the same numbers so they are related." In our feedback, we suggested that teachers guide students to see the relationships among quantities, rather than seeing the quantities only. For example, they could develop prompts to help students understand that when you combine two parts, you will obtain the whole, and when you take away one part from the whole, you will obtain the other part. We also used two Chinese sample plans that included possible teacher-student dialogue to discuss this issue.

Adding anticipated responses to teacher questions helped improve revised and EOC plans. A few teachers' anticipated explanations were even more thorough than what the textbooks suggested. For example, T20 in her EOC plan asked the question suggested by the textbook, "Why does the array model only include two number sentences in this fact family, $4 \times 4 = 16$ and $16 \div 4 = 4$?" The textbook explained that there were "same" numbers (4 and 4) in the multiplication sentence ($4 \times 4 = 16$). T20 went beyond this explanation. She planned to first guide students to compare this array (4 groups of 4 dots, thus 4×4) to a second array (3 groups of 4 squirrels, thus 3×4). She then expected students to see that if they rotated the arrays, they would obtain 4 groups of 3 squirrels (4×3), but the arrangement of dots would stay the same (4 groups of 4 dots or 4×4).

However, difficulties anticipating deep explanations increased from 10 teachers in the revised plan to 14 teachers in the EOC plan (see Fig. 5). Predictably, teachers who did not ask a deep question did not anticipate deep explanations. Yet, even teachers who asked good questions did not necessarily predict deep explanations. In addition, some teachers moved to the opposite extreme. A few teachers tried to write down every possible student reaction—including nonmathematical responses such as "students are laughing" on their EOC lesson plans. It is likely that our teacher participants tried to mimic the detailed Chinese plans but did so at a superficial level. We would have preferred that our teacher participants spend time and energy anticipating deep and appropriate explanations to their questions, and considering follow-up prompts if students could not provide the explanations they were looking for.

Discussion

This study reports an attempt to use IES-recommended instructional principles (Pashler et al., 2007) to support elementary teachers' learning as they construct high-quality mathematics lesson plans. Our summer course experience with teachers reveals both successes and challenges related to teacher learning, as well as factors that may support or hinder teacher learning. It also offers insights for future professional development.

The Successes and Challenges Related to Teachers' Learning

Teachers' lesson plans in this study demonstrate successes in unpacking worked examples and practice problems, and using concrete representations. Most teachers' initial plans were insufficient because the examples were brief and relied only on abstract or semiconcrete representations. However, with the guidance of the IES recommendations, many teachers situated worked examples in rich story situations. Some teachers also tried to incorporate the concreteness-fading method (Goldstone & Son, 2005) to unfold tasks (Charalambous, 2010). As such, our teachers' lesson plans, resulting from deliberate learning experiences, seem to be different from those of their peers in prior studies (Kagan & Tippins, 1992; Sardo-Brown, 1990) but similar to their international counterparts (Cai, 2005; Fernandez & Cannon, 2005). However, we caution against overgeneralizing our findings because teachers' successes in planning were due, at least in part, to their attempts to follow the detailed feedback made by the course instructors. In fact, the decrease in teachers' performance on several categories in the EOC plans that were independent work calls this to attention.

Teachers' challenges were mainly related to connecting concrete to abstract, asking deep questions, and anticipating deep explanations, which are key factors in supporting students' mathematical learning (Cai, 2004; Chi et al., 1994; NCTM, 2000). In this study, in spite of two rounds of planning for the same lesson, including detailed feedback from the instructors, some teachers continued to struggle. Some faded story situations into number sentences but did not ask questions to make explicit connections between these representations. Some asked deep questions but anticipated only superficial explanations (e.g., that $5 + 2 = 7$ and $7 - 2 = 5$ are related because they have the same numbers). A focus on quantities and operations rather than the underlying relationships and structures raises potential challenges in meeting Nunes, Bryant, and Watson's (2009) recent call for shifting students' attention "from quantifying to relationships between quantities; from operations to structures of operations" (p. 12).

The above challenges also indicate that there is indeed room to improve teachers' capacity to incorporate worked examples in planning. In this study, the coding of worked examples was separated from the coding of representations and questions in order to avoid redundancy. However, these components cannot be separated in the act of teaching. Thus, if teachers' ability to connect concrete to abstract, ask deep questions, and anticipate deep explanations can be improved, so too might the quality and depth of their worked-example design. In addition, we acknowledge that the 0–2 scale on our rubric may not have adequately captured the connections among worked examples, representations, and questions in a teacher's lesson plan.

Textbook Potential in Supporting Teachers' Lesson Planning

In this study, we expected teachers to conduct lesson planning based on textbook materials. Teachers' transformation of textbook resources into lesson plans revealed the affordance and limitations of textbooks (Remillard, 1999). As reported, teachers in this study tended to discard the textbook example or the key illustration. For example, many teachers ignored the mathematical and pedagogical potential of the kitten illustration. This may reflect teachers' limited pedagogical design capacity (Brown, 2009; Brown & Edelson, 2003). However, our teachers' omission of the kitten illustration was also likely due to its location at the bottom of the worked example. Such arrangement of the illustration could have emphasized its decorative and organizational function (Mayer, Sims, & Tajika, 1995)—separating the worked example from the guided practice, similar to the bunny illustration on the right-hand page (see Fig. 1). We suggest that textbook designers place key illustrations on the first half of the textbook page so that they are clearly a component of the worked example. Such a rearrangement may draw teachers' attention to the textbook's existing rich, concrete situations and facilitate their pedagogical design capacity during lesson planning (Brown, 2009). In addition, the sequences of teachers' representation uses in their lesson plans were directly aligned with the textbook presentation starting with the definition of the "related facts." This sequence may reflect a symbol-precedence view that is common in textbooks but ineffective in supporting student learning (Nathan et al., 2002). Thus, we suggest that textbook designers present abstract statements or definitions after a worked example, thus facilitating teachers' use of the concreteness-fading method (Goldstone & Son, 2005) to teach abstract ideas meaningfully.

In this study, some teachers planned to ask deep questions during guided practice as suggested in the textbook, such as, "How are the number sentences $5 + 2 = 7$ and $7 - 2 = 5$ related?" However, questions like this were not asked within the plans for teaching a worked example. We noticed that when textbooks suggested deep questions, teachers were likely to recognize and use them in lesson plans. When such questions were absent from the textbooks, teachers did not necessarily develop them on their own. We suggest that textbook designers arrange a few deep questions early in a worked example to assist teachers' unpacking of the example. Such an arrangement offers choices but not full guidance for teachers, and thus may serve as a possible solution to the tension in designing educative curriculum materials (Davis & Krajcik, 2005).

Factors that May Hinder Teachers' Lesson Planning

During the summer course, we heard teachers voice concerns about implementing what they learned. One concern was related to the requirement of fidelity to district-selected curricula. For example, teachers who used Saxon textbooks shared that they were required to follow lesson scripts and had little flexibility when it came to modifying the scripts to incorporate the IES recommendations. Promisingly, one teacher who used Saxon shared how she resolved this conflict in her reflection. Her textbook directly introduced "1 + 4 and 4 + 1" and called it the commutative property. This teacher felt that this presentation emphasized memorization rather than understanding. She designed a story problem that could be solved using same-number sentences, which led to the revealing of the property. The teacher said that this was a way to keep the integrity of the textbook and also use what she learned from the summer course. This teacher's strategy aligns with our course expectations—that teachers design high-quality plans based on the IES recommendations by adapting rather than improvising or off-loading (Brown, 2009; Davis, Beyer, Forbes, & Stevens, 2011) the textbook materials.

Another concern expressed by many teachers was that they do not have time to design detailed lesson plans because mathematics is only one of the many subjects they teach. This again cautions against overgeneralizing teachers' successes in this study because teachers' high-quality lesson plans may be partially due to their commitment to the course work. Thus, it is reasonable to question how teachers' learned planning skills might be applied during their busy daily schedules. During our class conversations and teachers' overall reflections on the summer course, some teachers suggested promising solutions. For example, they planned to focus on a few key lessons in detail, thus starting the long journey of building their professional library of lesson plans. Other teachers planned to focus on the worked example of each lesson and design that part in detail. Regardless of the potential challenges our teachers faced, they acknowledged the great impact the IES recommendations had on their thinking, planning, and teaching. A few teachers expressed excitement, saying that they could not wait until the fall semester to implement all their new knowledge.

Implications for Professional Development

Our summer course is designed to deliberately support teachers' lesson-planning skills. This approach is different from previous research on natural processes of teachers' lesson planning (e.g., Brown, 1988; Cai, 2005; Fernandez & Cannon, 2005; Kagan & Tippins, 1992; Peterson, Marx, & Clark, 1978; Sardo-Brown, 1990) in that our focus is on specific interventions intended to improve teachers' planning skills. Our findings suggest that professional support plays a critical role. As seen in teachers' presurveys and their initial lesson plans, many teachers who had read the IES recommendations did not understand how these principles could be incorporated into their plans. In contrast, after they received our timely and targeted feedback based on the IES recommendations, most of the teachers improved their understanding of the guidelines and consequently generated high-quality revised plans. We also observed some degree of transfer into teachers' EOC plans. Our teachers' growth shows the importance and promise of carefully supported lesson planning in future professional development.

Throughout the course, we worked with teachers on only one lesson plan and required them to go through a revision process. We consider teachers' experience planning one lesson as a "worked example" in and of itself, which may build their schema (Sweller, 2006) for understanding how to incorporate the IES recommendations in their future planning and teaching. Teachers' EOC plans confirm the "worked-example effect." Our findings suggest that, instead of asking teachers to practice writing many lesson plans, teacher educators and professional developers may first focus on one plan and ask teachers to make revisions rather than beginning again with a new topic. Through intensive work on developing, evaluating, and revising lesson plans, teachers will likely improve their knowledge of and for teaching (Beyer & Davis, 2012).

Of course, learning takes time (Pashler et al., 2007), and promoting teacher learning is even more complex than promoting student learning (Davis & Krajcik, 2005). The challenges revealed by the EOC lesson plans demonstrate a need to enhance teachers' domain-specific knowledge so they can recognize underlying ideas and plan appropriate representations and questions. This calls for more than a 2-week summer course. The challenges in EOC plans also call for more "guided practice" in the form of ongoing support for teachers in lesson planning. At our university, we are working with teachers who recently graduated from this project through study groups, during which teachers discuss lesson plans and enact teaching from perspectives of worked examples, representations, and deep questions. To obtain a sense of how teachers may transform their lesson plans into classrooms and gather information to better support teachers, we also have observed six teachers' implementation of their EOC plans in their fall classrooms and documented their accomplishments and unexpected challenges. Our effort is a step toward supporting elementary teachers' success. Further studies into the identified difficulties in lesson planning, the continuous support, and the transformation processes from textbook resources to lesson plans and classroom teaching can lead to necessary changes in teaching and learning of elementary mathematics.

Note

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References

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Anderson, J. R., Reder, L. M., & Simon, H. A. (2000, Summer). *Applications and misapplications of cognitive psychology to mathematics education. Texas Educational Review*, 29–49.

Atkinson, R. K., Renkl, A., & Merrill, M. M. (2003). Transitioning from studying examples to solving problems: Effects of self-explanation prompts and fading worked-out steps. *Journal of Educational Psychology*, **95**, 774–783. doi:10.1037/0022–0663.95.4.774

Ball, D. L. (1996). Teacher learning and the mathematics reforms: What we think we know and what we need to learn. *Phi Delta Kappan*, **77**(7), 500–508.
Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher*, **25**(9), 6–8, 14.
Beyer, C. J., & Davis, E. A. (2012). Learning to critique and adapt science curriculum materials: Examining the development of preservice elementary teachers' pedagogical content knowledge. *Science Teacher Education*, **96**, 130–157. doi:10.1002/sce.20466
Boaler, J., & Staples, M. (2008). Creating mathematical futures through an equitable teaching approach: The case of railside school. *Teachers College Record*, **110**, 608–645.
Brown, D. S. (1988). Twelve middle school teachers' planning. *Elementary School Journal*, **89**, 69–87.
Brown, M. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J. Remillard, G. Lloyd, & B. Herbel-Eisenmann (Eds.), *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17–36). New York: Routledge.
Brown, M., & Edelson, D. (2003). *Teaching as design: Can we better understand the ways in which teachers use materials so we can better design materials to support their changes in practice?* Evanston, IL: Center for Learning Technologies in Urban Schools.
Burns, R. B., & Lash, A. A. (1988). Nine seventh-grade teachers' knowledge and planning of problem-solving instruction. *Elementary School Journal*, **88**, 369–386
Cai, J. (2004). Why do U.S. and Chinese students think differently in mathematical problem solving? Exploring the impact of early algebra learning and teachers' beliefs. *Journal of Mathematical Behavior*, **23**, 135–167. doi:10.1016/j.jmathb.2004.03.004
Cai, J. (2005). U.S. and Chinese teachers' constructing, knowing, and evaluating representations to teach mathematics. *Mathematical Thinking and Learning*, **7**, 135–169. doi:10.1207/s15327833mtl0702_3
Cai, J., & Wang, T. (2010). Conceptions of effective mathematics teaching within a cultural context: Perspectives of teachers from China and the United States. *Journal of Mathematics Teacher Education*, **13**, 265–287. doi:10.1007/s10857–009–9132–1
Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (1999). *Children's mathematics: Cognitively guided instruction*. Reston, VA: National Council of Teachers of Mathematics.
Charalambous, C. Y. (2010). Mathematical knowledge for teaching and task unfolding: An exploratory study. *Elementary School Journal*, **110**, 247–278. doi:10.1086/648978
Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, **13**, 145–182. doi:10.1016/0364–0213(89)90002–5
Chi, M. T. H., de Leeuw, N., Chiu, M., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, **18**, 439–477. doi:10.1016/0364–0213(94)90016–7
Clark, C. M., & Yinger, R. J. (1987). Teacher planning. In J. Calderhead (Ed.), *Exploring teachers' thinking* (pp. 84–103). London: Cassell.
Craig, S. D., Sullins, J., Witherspoon, A., & Gholson, B. (2006). The deep-level-reasoning-question effect: The role of dialogue and deep-level-reasoning questions during vicarious learning. *Cognition and Instruction*, **24**, 565–591. doi:10.1207/s1532690xci2404_4
Davis, E. A., Beyer, C., Forbes, C. T., & Stevens, S. (2011). Understanding pedagogical design capacity through teachers' narratives. *Teaching and Teacher Education*, **27**, 797–810. doi:10.1016/j.tate.2011.01.005
Davis, E. A., & Krajcik, J. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher*, **34**(3), 3–14. doi: 10.3102/0013189X034003003
Ding, M., & Li, X. (2010). A comparative analysis of the distributive property in the U.S. and Chinese elementary mathematics textbooks. *Cognition and Instruction*, **28**, 146–180. doi: 10.1080/07370001003638553
Ding, M., Li, Y., Li., X, & Gu, J. (in press). Knowing and understanding instructional mathematics content through intensive studies of textbooks. In Y. Li & R. Huang (Eds.), *How Chinese teach mathematics and improve teaching*. New York: Routledge.

Drake, C., & Sherin, M. G. (2006). Practicing change: Curriculum adaptation and teacher narrative in the context of mathematics education reform. *Curriculum Inquiry*, **36**, 153–187. doi10.1111/j.1467–873X.2006.00351.x
Fernandez, C., & Cannon, J. (2005). What Japanese and U.S. teachers think about when constructing mathematics lessons: A preliminary investigation. *Elementary School Journal*, **105**, 481–498. doi:10.1086/431886
Forbes, C. T. (2011). Preservice elementary teachers' adaptation of science curriculum materials for inquiry-based elementary science. *Science Education*, **95**, 927–955. doi:10.1002/sce.20444
Forbes, C. T., & Davis, E. A. (2010). Curriculum design for inquiry: Preservice elementary teachers' mobilization and adaptation of science curriculum materials. *Journal of Research in Science Teaching*, **47**, 820–839. doi:10.1002/tea.20379
Fyfe, E. R., & McNeil, N. M. (2009, October). *Benefits of "concreteness fading" for children with low knowledge of mathematical equivalence.* Poster presented at the biennial meeting of the Cognitive Development Society, San Antonio, TX.
Goldstone, R. L., & Son, J. Y. (2005). The transfer of scientific principles using concrete and idealized simulations. *Journal of the Learning Sciences*, **14**, 69–110. doi:10.1207/s15327809jls1401_4
Greenes, C., Larson, M., Leiva, M. A., Shaw, J. M., Stiff, L., Vogeli, B. R., & Yeatts, K. (2005). *Houghton Mifflin*. Boston: Houghton Mifflin.
Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, **42**(2), 99–107. doi:10.1080/00461520701263368
Howell, D. C. (2002). *Statistical methods for psychology* (5th ed). Belmont, CA: Duxbury.
Kagan, D. M., & Tippins, D. J. (1992). The evolution of functional lesson plans among twelve elementary and secondary student teachers. *Elementary School Journal*, **92**, 477–489.
Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologists*, **41**(2) 75–86. doi:10.1207/s15326985ep4102_1
Koedinger, K. R., Alibali, M. W., & Nathan, M. J. (2008). Trade-offs between grounded and abstract representations: Evidence from algebra problem solving. *Cognitive Science*, **32**, 366–397. doi:10.1080/03640210701863933
Leech, N. L., Barrett, K. C., & Morgan, G. A. (2008). *SPSS for intermediate statistics: Use and interpretation* (3rd ed.). New York: Erlbaum.
Li, X., Ding M., Capraro, M. M., & Capraro, R. M. (2008). Sources of differences in children's understandings of mathematical equality: Comparative analysis of teacher guides and student texts in China and in the United States. *Cognition and Instruction*, **26**, 195–217. doi:10.1080/07370000801980845
Lloyd, G. M. (1999). Two teachers' conceptions of a reform curriculum: Implications for mathematics teacher development. *Journal of Mathematics Teacher Education*, **2**, 227–252. doi:10.1023/A:1009965804662
Lloyd, G. M., & Behm, S. L. (2005). Preservice elementary teachers' analysis of mathematics instructional materials. *Action in Teacher Education*, **26**(4), 48–62.
Mayer, R. E., Sims, V., & Tajika, H. (1995). A comparison of how textbooks teach mathematical problem solving in Japan and the United States. *American Educational Research Journal*, **32**, 443–460. doi:10.3102/00028312032002443
Murata, A. (2008). Mathematics teaching and learning as a mediating process: The case of tape diagrams. *Mathematical Thinking and Learning*, **10**, 374–406. doi:10.1080/10986060802291642
Nathan, M. J., Long, S. D., & Alibali, M. W. (2002). The symbol precedence view of mathematical development: A corpus analysis of the rhetorical structure of textbooks. *Discourse Processes*, **33**, 1–21. doi:10.1207/S15326950DP3301_01
National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
Nunes, T., Bryant, P., & Watson, A. (2009). *Key understandings in mathematics learning: A report to the Nuffield Foundation*. London: Nuffield Foundation.

Pashler, H., Bain, P. M., Bottge, B. A., Graesser, A., Koedinger, K., McDaniel, M., & Metcalfe, J. (2007). *Organizing instruction and study to improve student learning* (NCER 2007–2004). Washington, DC: National Center for Education Research.
Peterson, P. L., Marx, R. W., & Clark, C. M. (1978). Teacher planning, teacher behavior, and student achievement. *American Educational Research Journal*, **15**, 417–432. doi:10.3102/00028312015003417
Pintó, R. (2005). Introducing curriculum innovations in science: Identifying teachers' transformations and the design of related teacher education. *Science Education*, **89**, 1–12. doi:10.1002/sce.20039
Remillard, J. T. (1999). Curriculum materials in mathematics education reform: A framework for examining teachers' curriculum development. *Curriculum Inquiry*, **29**, 315–342. doi:10.1111/0362–6784.00130
Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research*, **75**, 211–246. doi:10.3102/00346543075002211
Renkl, A., Atkinson, R. K., & Große, C. S. (2004). How fading worked solution steps works: A cognitive load perspective. *Instructional Science*, **32**, 59–82. doi:10.1023/B:TRUC.0000021815.74806.f6
Resnick, L. B., Cauzinille-Marmeche, E., & Mathieu, J. (1987). Understanding algebra. In J. Sloboda & D. Rogers (Eds.), *Cognitive processes in mathematics* (pp. 169–203). Oxford: Clarendon.
Sardo-Brown, D. (1990). Experienced teachers' planning practices: A U.S. survey. *Journal of Education for Teaching*, **16**(1), 57–71. doi:10.1080/0260747900160104
Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, **15**(2), 4–14.
Stein, M. K., Remillard, J., & Smith, M. S. (2007). How curriculum influence student learning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (Vol. **1**, pp. 319–369). Charlotte, NC: Information Age.
Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, **12**, 257–285. doi:10.1016/0364–0213(88)90023–7
Sweller, J. (2006). The worked example effect and human cognition. *Learning and Instruction*, **16**, 165–169. doi:10.1016/j.learninstruc.2006.02.005
Sweller, J., & Cooper, G. A. (1985). The use of worked examples as a substitute for problem solving in learning algebra. *Cognition and Instruction*, **2**, 59–89. doi:10.1207/s1532690xci0201_3
Valencia, S. W., Place, N. A., Martin, S. D., & Grossman, P. L. (2006). Curriculum materials for elementary reading: Shackles and scaffolds for four beginning teachers. *Elementary School Journal*, **107**, 93–120. doi:10.1086/509528
Yinger, R. (1980). A study of teacher planning. *Elementary School Journal*, **80**, 107–127.

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