Educational Studies in Japan: International Yearbook
No.6, December, 2011, pp.5-19

Using Japanese Curriculum Materials to Support Lesson Study Outside Japan: toward Coherent Curriculum[1]

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Lesson study (jugyou kenkyuu) has spread outside Japan in the last decade, providing opportunities to see how lesson study fares in countries where the instructional practices and curriculum materials differ from those in Japan. This study reports an elementary mathematics lesson study cycle from the United States. To investigate the nature of the support for teachers' learning during the curriculum study ("kyouzai kenkyuu") phase of lesson study, we first compared a U.S. and Japanese teacher's manual in their treatment of area of quadrilaterals. The coding scheme captured features hypothesized to influence teachers' learning from curriculum including information on student thinking, learning trajectory and rationale for pedagogical decisions (Ball & Cohen, 1996). While the U.S. teacher's manual provided more correct student answers and more often suggested adaptations for particular categories of students (e.g., English-language learners), the Japanese manual provided more varied individual student responses and more rationale for pedagogical choices. We provided the Japanese curriculum and teacher's manual to a U.S. lesson group and observed them during lesson study; U.S. teachers found some Japanese curriculum features useful (e.g., student thinking) and other features challenging (e.g., focus on a single problem). A comparison of the U.S. teachers' pre- and post- lesson study cycle lesson plans suggested that the teachers more thoroughly anticipated student thinking after working with the Japanese textbooks and teacher's manuals. We suggest that kyouzai kenkyuu on a well-designed teacher's manual may enable "coherent curriculum" at the policy level to be enacted in the classroom.

Introduction

Lesson study originated in Japan and has been practiced there for more than a century (Isoda, 2010; Matoba, Crawford, & Sarkar Arani, 2006; Sugiyama, 2006). Lesson study has spread

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to many other countries since the frist English language descriptions credited lesson study for the steady improvement of Japanese instruction (Lewis & Tsuchida, 1997, 1998; Stigler & Hiebert, 1999). Attendance at conferences sponsored by the World Association of Lesson Study (www.wals.org), APEC (www.criced.tsukuba.ac.jp/math/apec/), universities (www.hiroshima-u.ac.jp/index.html; http://www.wpunj.edu/coe/lessonstudy/), professional organizations (http://igpme.gandi-site.net/), and district-based or voluntary practitioner groups (http://www.lessonstudygroup.net/; http://www.svmimac.org/; http://www.scoe.org/pub/htdocs/lesson-study.html) suggest that lesson study is practiced in at least a dozen countries beyond Japan (Matoba, et al., 2006; Morris & Hiebert, 2011).

In Japan, lesson study enables teachers to test, refine, and share strategies to improve instruction and curriculum (Lewis & Tsuchida, 1997). Lesson study thus provides a potential solution to a fundamental dilemma of educational innovation: how to build teachers' "ownership" and leadership of improvement while at the same time responding to recent research and policy (Fullan, 2001). Figure 1 shows the basic lesson study cycle as it is often represented in the U.S. (Lewis & Hurd, 2011). During this cycle, teachers work collaboratively to study content, teaching materials, standards and related research; enact a classroom "research lesson" that brings to life what they learned; carefully study students' learning during the research lesson; and use the data collected during the lesson to reflect on what was learned about the teaching and learning of the topic and about teaching and learning more broadly (Fernandez & Yoshida, 2004; Lewis, 2002; Lewis, Perry, & Hurd, 2009; Wang-Iverson & Yoshida, 2005).

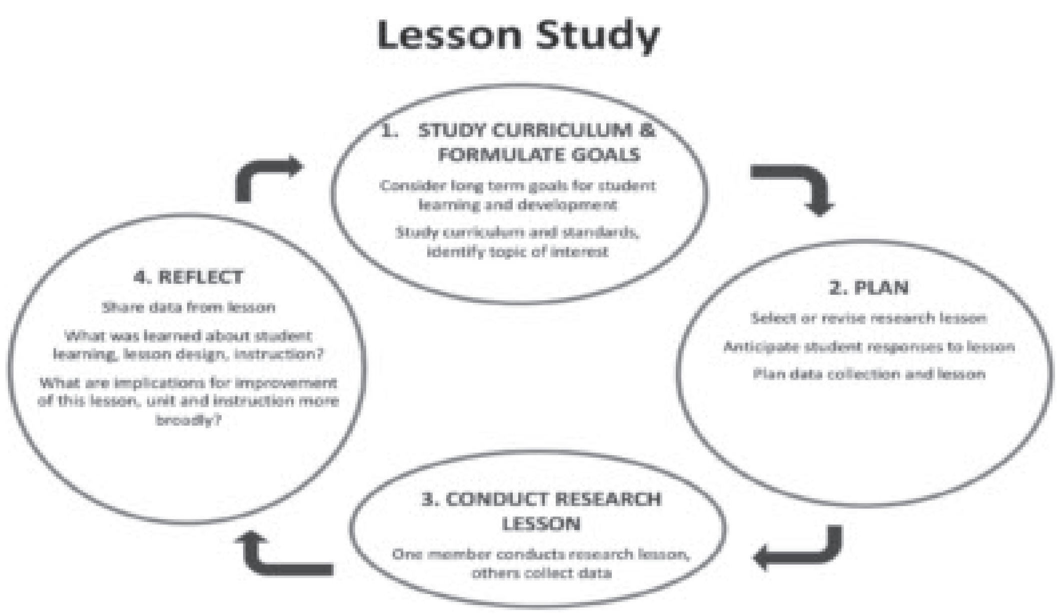


Figure 1 Lesson Study Cycle

The Role of Kyouzai Kenkyuu (Curriculum Study) and the Teacher's Manual in Lesson Study

Lesson study represents a fundamentally new paradigm in the U.S. (and no doubt many other countries), where professional learning typically occurs outside the classroom, organized by outsiders (such as university faculty) and not typically focused on inquiry questions generated by teachers (Garet et al., 2001). One feature of lesson study that has received only modest attention in the U.S. is *kyouzai kenkyuu*—the study of curriculum and teaching materials that occurs early in the lesson study cycle shown in Figure 1. During *kyouzai kenkyuu*, teachers study both the content and its teaching using resources such as content frameworks, textbooks, teacher's manuals and research reports (Lewis & Hurd, 2011; Takahashi, Watanabe, Yoshida, & Wang-Iverson, 2005).

Our group has conducted a series of research projects in which we observe lesson study initiated by U.S educators. Early in our observations, we noticed that some of the textbooks and teacher's manuals consulted by U.S. teachers did not provoke rich discussions of mathematics content or of students'mathematical thinking. We compared Japanese and U.S. curriculum materials on a particular topic of interest to several lesson study groups (area of quadrilaterals) and provided the Japanese teacher's manual to U.S. teachers, observing their use of it during lesson study. Before further description of the study and its results, we briefly review research on the nature of a "coherent curriculum" in order to provide a theoretical context for the study.

The Quest for a "Coherent Curriculum" in the United States

For more than a decade, U.S. researchers have called for a more "coherent curriculum" in the U.S. (Schmidt, McKnight, & Raizen, 1997; Schmidt, Houang, & Cogan, 2002). The dramatic recent embrace of "Common Core State Standards" by 44 U.S. states (Common Core Standards Initiative, 2011) makes it important to unpack what is meant by "coherent curriculum" and how it is thought to be enacted. Our reading suggests that "coherence" is used in somewhat different ways in research conducted at the policy and classroom levels. At the policy level, coherence generally pertains to the *intended curriculum* and is typically measured by the degree to which the curriculum (embodied in textbooks and policy documents) focuses on a small number of key mathematical topics at any given grade level, treating each one in depth and building on it (rather than repeating it) in subsequent years (Schmidt, et al., 2002). It has been noted, for example, that U.S. 8^{th} grade mathematics textbooks include more than 30 topics, while Japanese counterparts include about 10 topics, thus making the Japanese 8^{th} grade *intended* curriculum more coherent (Schmidt, et al., 2002; Schmidt, McKnight, & Raizen, 1997).

Studies of the *enacted curriculum* examine actual classroom instruction, defining coherence in terms of the degree of focus within a lesson (and the consequent likelihood that students engage in sense-making during the lesson). Japanese mathematics lessons typically focus on a single topic or progression of closely related topics for an entire class period, whereas U.S. mathematics lessons may intentionally cover several topics that are unrelated or only tangentially related (Stigler & Hiebert, 1999; Fernandez, Yoshida, & Stigler, 1992). Further, Japanese teachers more often provide "explicit links or connections between different parts of the same lesson" (Fernandez, Yoshida, & Stigler, 1992; Stigler, Gonzales, Kawanaka, Knoll, & Serrano, 1999). Experimental research indicates that, compared to U.S.-style lessons, enacted Japanese-style lessons (i.e., lessons that are focused on a single topic or progression and explicitly connect parts of the lesson) better foster a sense-making orientation in which students actively try to connect different elements of the lesson; this is true even when U.S. students watch the lessons (Fernandez, et al., 1992). Other research indicates that Japanese students more strongly differentiate their attention to relevant statements within a lesson than do U.S. students (who attend to irrelevant and relevant content equally); the implication is that long-term experience of coherent lessons may shape students' orientation to make sense of instruction (Yoshida, Fernandez, & Stigler, 1993). Japanese mathematics *units* as well as individual lessons are characterized by coherence; for example, 11 sequential closely-related lessons within a mathematics unit all focus on building first-graders' capacity to "break apart and make ten," with each lesson carefully using and building on the ideas developed in the previous lesson (Murata & Fuson, 2006; Shimizu, 2002).

In summary, while the operational definitions of coherence in the *intended* and *enacted* curriculum differ, in both cases "coherence" denotes opportunities for students to use and build on knowledge they have previously developed—be it knowledge from an earlier segment of the lesson or unit or from an earlier year of schooling. Coherence at the policy and classroom levels are interdependent. Teachers can focus in depth on a single idea only if sufficient time is available to do so, and sufficient time is available only if topics from prior years of schooling are mastered and moved out of the curriculum—i.e., only if they are enacted coherently, in a way that enables students to make sense of them and be able to build on what they learn. For this reason, achieving a coherent curriculum in the U.S. cannot be achieved by a stroke of the policy pen that reduces 30 topics to 10 in the 8th grade mathematics curriculum (to take the example raised earlier); the *enacted* curriculum during the elementary years must be coherent, so that students master topics that can then exit the curriculum.

What mechanisms have allowed the coherent *intended* Japanese mathematics curriculum to be *enacted* coherently? Some research suggests that lesson study provides one important bridge between policy and its enactment in Japan, by enabling teachers to make shared, collective sense of the intended curriculum and study students' responses to it (Lewis & Tsuchida, 1997; Lewis, 2010). We can imagine, as well, other features of the Japanese system that may influence coherence; for example, Japanese elementary teachers rotate through all elementary grades, giving them opportunities to see the connections between mathematics topics taught at different grade levels. For the current investigation, we limit ourselves to two features of the Japanese system that are transportable for study in other countries—Japanese curriculum materials and lesson study—and we examine whether and how these features enable U.S. teachers to build knowledge about instruction.

Research Methods

Selection of Teacher's Manuals and Units

In each country, we analyzed the teacher's manual of a widely-used textbook series. In both countries textbooks are developed by commercial publishers who compete to have their textbooks adopted by districts. In Japan, the textbooks are reviewed by a committee of the Ministry of Education, Culture, Sports, Science and Technology ("MEXT") to ensure that they meet national content guidelines, and public schools must use MEXT-approved textbooks. In the U.S., states typically approve textbooks for fit with state guidelines.

In Japan, we chose for analysis Tokyo Shoseki's *Mathematics for Elementary School* (Hironaka & Sugiyama, 2006), one of the most widely used Japanese elementary textbook series. Tokyo Shoseki's textbook series is available in English; however, the teacher's manual segments were translated for this work. This Japanese teacher's manual consists of three separate volumes, called "instruction," "research," and "supplementary problems." Only the "instruction" volume was analyzed for this study; it is designed to be used by teachers as they plan and conduct lessons. For the U.S. textbook series, we chose Harcourt Math (Maletsky, 2002) a series widely adopted and used in California. Again, only the main section of this teacher's manual, designed to be used by teachers as they plan and conduct lessons, was analyzed. Our focus on this core portion of the teacher's manual was shaped in part by evidence that teachers often neglect ancillary instructional materials (Remillard & Bryans, 2004).

Within the teacher's manual, we analyzed all lessons primarily focused on area of squares, rectangles and parallelograms. Figures 2 and 3 show the introduction of rectangle area in the U.S. teacher's manual, and Figures 4 and 5 show the same topic in the Japanese teacher's manual. The two teacher's manuals are similar in that they reproduce the student text with a large margin surrounding it, where a sequence of steps for teaching the student material is suggested. Because we could not show the large double page from the teacher's manual in a single figure, we split each presentation in two parts, so that Figures 2 and 4 show the center of the double-page (the student text and any material overlaid on it), and Figures 3 and 5 show the information for teachers that surrounds the student text.

The layout of the two teacher's manuals is similar in a number of ways. Each provides a section directly relevant to instruction (the focus of the current analysis) and separate sections with supplementary problems and additional mathematical background for teachers. In both manuals, each unit begins with a unit overview, learning goals, and suggested time allocation. Both manuals overlay correct answers in red on the student text. The U.S. manual provides, prior to each lesson, additional information not found in the Japan instruction volume, including cross-disciplinary and technology connections, state standards, and suggestions for particular categories of learners (e.g., advanced learners, English language learners). For example, an alternative teaching strategy

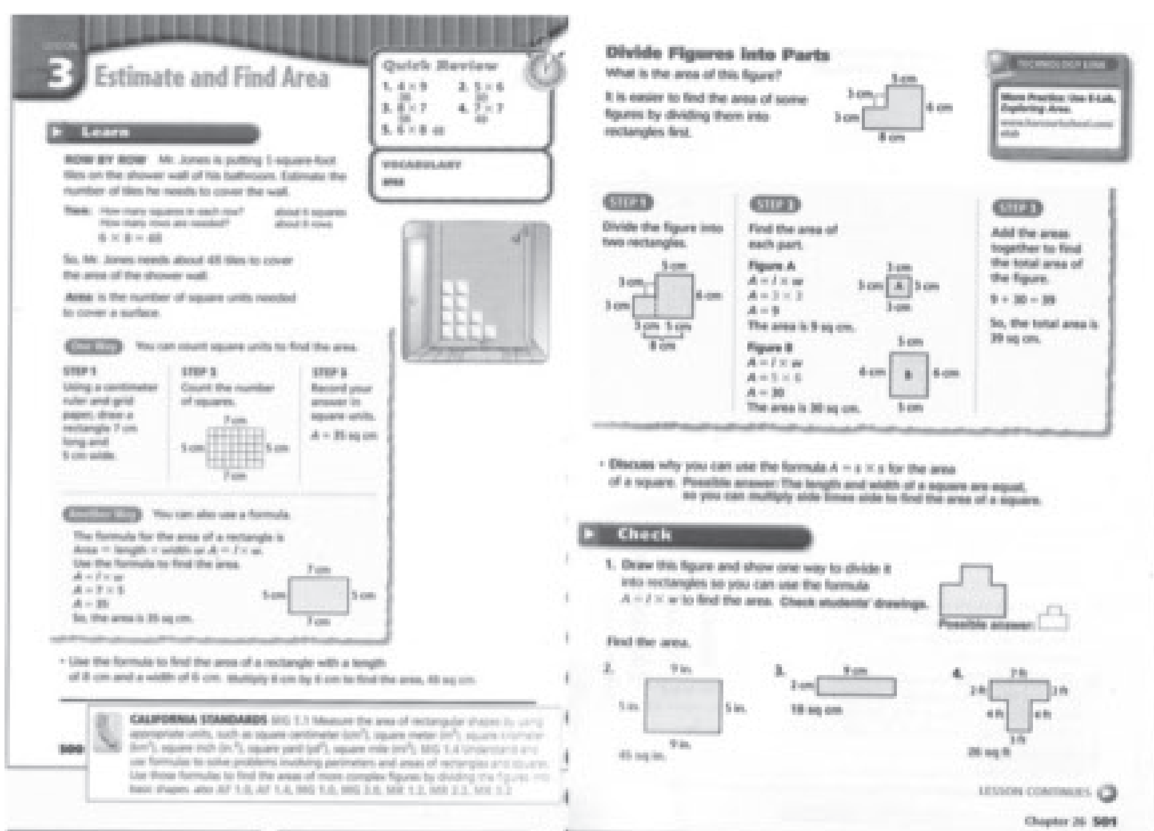
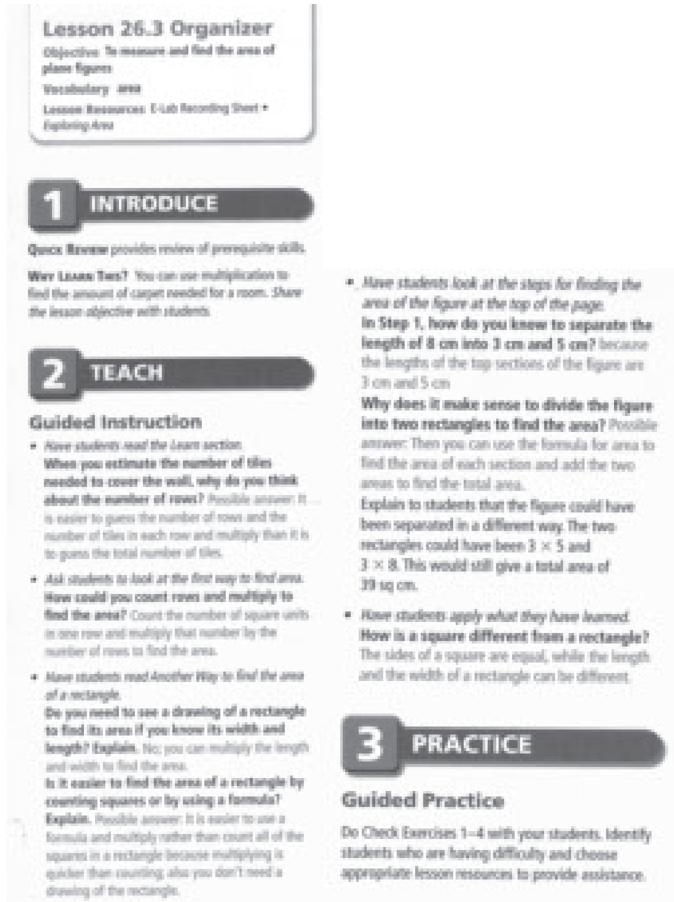


Figure 2 U.S. Student Text: Rectangle Area



Lesson 26.3 Organizer

Objective To measure and find the area of plane figures

Vocabulary area

Lesson Resources E-Lab Recording Sheet • *Exploring Area*

1 INTRODUCE

QUICK REVIEW provides review of prerequisite skills.

WHY LEARN THIS? You can use multiplication to find the amount of carpet needed for a room. *Share the lesson objective with students.*

2 TEACH

Guided Instruction

- *Have students read the Learn section.*
  When you estimate the number of tiles needed to cover the wall, why do you think about the number of rows? Possible answer: It is easier to guess the number of rows and the number of tiles in each row and multiply than it is to guess the total number of tiles.
- *Ask students to look at the first way to find area.*
  How could you count rows and multiply to find the area? Count the number of square units in one row and multiply that number by the number of rows to find the area.
- *Have students read Another Way to find the area of a rectangle.*
  Do you need to see a drawing of a rectangle to find its area if you know its width and length? Explain. No; you can multiply the length and width to find the area.
  Is it easier to find the area of a rectangle by counting squares or by using a formula? Explain. Possible answer: It is easier to use a formula and multiply rather than count all of the squares in a rectangle because multiplying is quicker than counting; also you don't need a drawing of the rectangle.
- *Have students look at the steps for finding the area of the figure at the top of the page.*
  In Step 1, how do you know to separate the length of 8 cm into 3 cm and 5 cm? because the lengths of the top sections of the figure are 3 cm and 5 cm
  Why does it make sense to divide the figure into two rectangles to find the area? Possible answer: Then you can use the formula for area to find the area of each section and add the two areas to find the total area.
  Explain to students that the figure could have been separated in a different way. The two rectangles could have been 3×5 and 3×8. This would still give a total area of 39 sq cm.
- *Have students apply what they have learned.*
  How is a square different from a rectangle? The sides of a square are equal, while the length and the width of a rectangle can be different.

3 PRACTICE

Guided Practice

Do Check Exercises 1–4 with your students. Identify students who are having difficulty and choose appropriate lesson resources to provide assistance.

Figure 3 U.S. Teacher's Manual: Rectangle Area

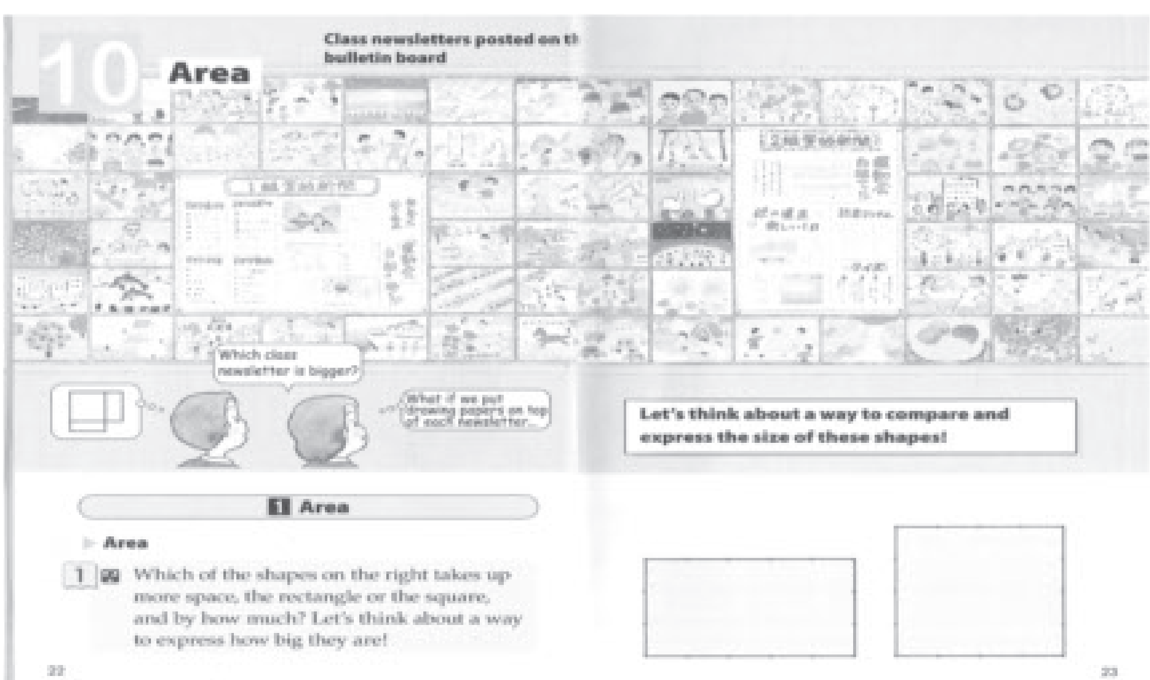
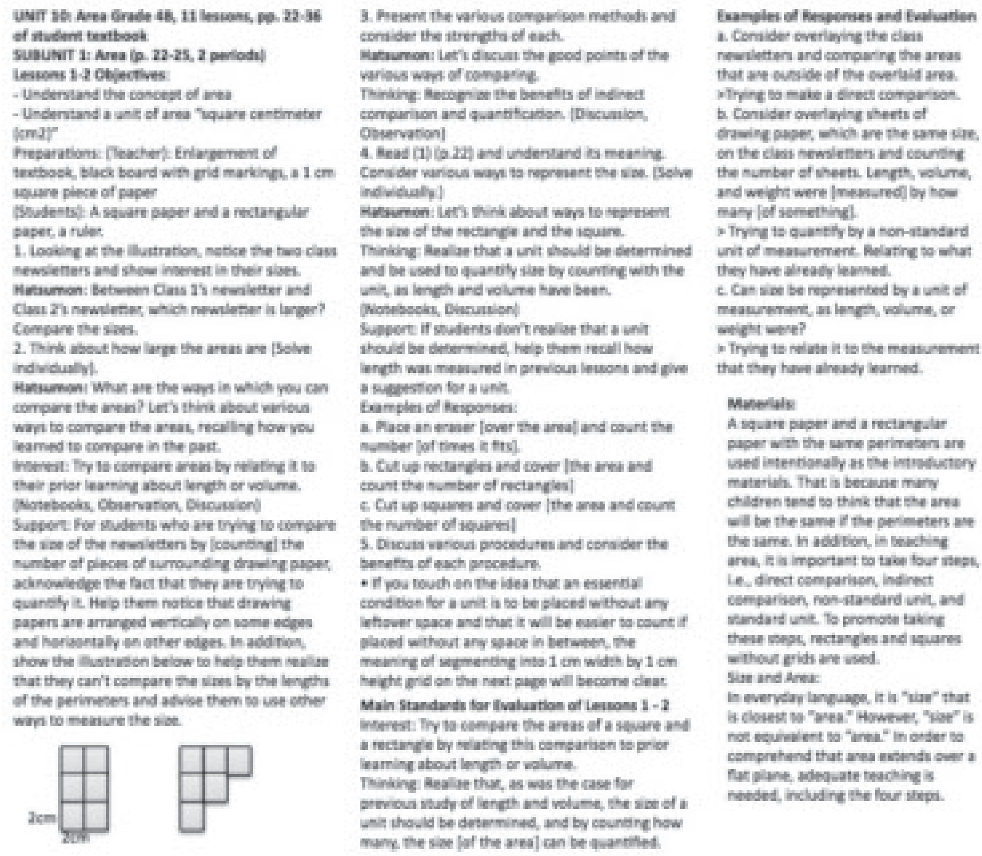


Figure 4 Japanese Student Text: Rectangle Area



UNIT 10: Area Grade 4B, 11 lessons, pp. 22-36 of student textbook
SUBUNIT 1: Area (p. 22-25, 2 periods)
Lessons 1-2 Objectives:
- Understand the concept of area
- Understand a unit of area "square centimeter (cm2)"

Preparations: (Teacher): Enlargement of textbook, black board with grid markings, a 1 cm square piece of paper
(Students): A square paper and a rectangular paper, a ruler.
1. Looking at the illustration, notice the two class newsletters and show interest in their sizes.
Hatsumon: Between Class 1's newsletter and Class 2's newsletter, which newsletter is larger? Compare the sizes.
2. Think about how large the areas are [Solve individually].
Hatsumon: What are the ways in which you can compare the areas? Let's think about various ways to compare the areas, recalling how you learned to compare in the past.
Interest: Try to compare areas by relating it to their prior learning about length or volume. (Notebooks, Observation, Discussion)
Support: For students who are trying to compare the size of the newsletters by [counting] the number of pieces of surrounding drawing paper, acknowledge the fact that they are trying to quantify it. Help them notice that drawing papers are arranged vertically on some edges and horizontally on other edges. In addition, show the illustration below to help them realize that they can't compare the sizes by the lengths of the perimeters and advise them to use other ways to measure the size.

3. Present the various comparison methods and consider the strengths of each.
Hatsumon: Let's discuss the good points of the various ways of comparing.
Thinking: Recognize the benefits of indirect comparison and quantification. (Discussion, Observation)
4. Read (1) (p.22) and understand its meaning. Consider various ways to represent the size. (Solve individually.)
Hatsumon: Let's think about ways to represent the size of the rectangle and the square.
Thinking: Realize that a unit should be determined and be used to quantify size by counting with the unit, as length and volume have been. (Notebooks, Discussion)
Support: If students don't realize that a unit should be determined, help them recall how length was measured in previous lessons and give a suggestion for a unit.
Examples of Responses:
a. Place an eraser [over the area] and count the number [of times it fits].
b. Cut up rectangles and cover [the area and count the number of rectangles]
c. Cut up squares and cover [the area and count the number of squares]
5. Discuss various procedures and consider the benefits of each procedure.
• If you touch on the idea that an essential condition for a unit is to be placed without any leftover space and that it will be easier to count if placed without any space in between, the meaning of segmenting into 1 cm width by 1 cm height grid on the next page will become clear.

Main Standards for Evaluation of Lessons 1 - 2
Interest: Try to compare the areas of a square and a rectangle by relating this comparison to prior learning about length or volume.
Thinking: Realize that, as was the case for previous study of length and volume, the size of a unit should be determined, and by counting how many, the size [of the area] can be quantified.

Examples of Responses and Evaluation
a. Consider overlaying the class newsletters and comparing the areas that are outside of the overlaid area.
>Trying to make a direct comparison.
b. Consider overlaying sheets of drawing paper, which are the same size, on the class newsletters and counting the number of sheets. Length, volume, and weight were [measured] by how many [of something].
> Trying to quantify by a non-standard unit of measurement. Relating to what they have already learned.
c. Can size be represented by a unit of measurement, as length, volume, or weight were?
> Trying to relate it to the measurement that they have already learned.

Materials:
A square paper and a rectangular paper with the same perimeters are used intentionally as the introductory materials. That is because many children tend to think that the area will be the same if the perimeters are the same. In addition, in teaching area, it is important to take four steps, i.e., direct comparison, indirect comparison, non-standard unit, and standard unit. To promote taking these steps, rectangles and squares without grids are used.
Size and Area:
In everyday language, it is "size" that is closest to "area." However, "size" is not equivalent to "area." In order to comprehend that area extends over a flat plane, adequate teaching is needed, including the four steps.

Figure 5 Japanese Teacher's Manual: Rectangle Area

(labeled as "auditory, kinesthetic") from the U.S. teacher's manual proposes that students draw and cut out figures using whole units on grid paper, exchange them with a partner, and find the area by counting and then saying the number of square units. Accordingly, the U.S. teacher's manual is correspondingly larger and heavier (roughly 30 by 25 centimeters and 2.3 kilograms for the half-year volume) than its Japanese counterpart (26 by 18 centimeters and .7 kilograms for the half-year set).

Comparing the Japanese and U.S. teacher's manuals shown in Figures 2–5, we note that the U.S. text begins with a rectangle divided into square units and asks students to find the area by counting the squares or multiplying the number of rows by the number of squares in each row, whereas the Japanese text provides a more open-ended problem, in which students must devise ways to compare the size of two newsletters (a square and rectangle) for which no grid or measurement unit is provided. The Japanese text recommends two periods (versus one in the U.S. text). The Japanese teacher's manual provides background knowledge on student thinking about measurement, suggesting that students need to progress from direct and indirect comparison to measurement using non-standard and standard units, and providing examples of each type of student thinking—for example, overlaying the newsletters to compare directly, using an eraser as a non-standard measurement unit, etc.. In addition, the newsletters in the Japanese problem are bordered with drawing papers in different orientations, so that students will not be able to measure the dimensions simply by counting the number of surrounding drawing papers. Japanese textbooks often introduce new mathematical topics using in-depth problems with several different student solution strategies (Watanabe, 2001; Inoue, 2011). Such problems enable teachers to identify likely student strategies

Coding of Teacher's Manuals

Six features of the teacher's manuals were analyzed. *Allocation of instructional time* captures the amount and distribution of time allocated to a topic. The remaining five features are drawn from Ball and Cohen's (1996) theoretical framework for teachers' learning from curriculum. They theorize that curriculum materials support teachers' learning by: (1) anticipating student thinking; (2) developing teachers' own content knowledge; (3) connecting content over time; (4) making the rationale for pedagogical judgments explicit; and (5) supporting decision-making (e.g., suggesting responses to students' thinking; Ball & Cohen, 1996; Remillard & Bryans, 2004).

The teacher's manuals were divided into sentences and each sentence was coded for the five features proposed by Ball and Cohen (1996). During that process, three of the original five categories proposed by Ball and Cohen were subdivided to capture distinctions found in the materials. *Anticipation of student thinking* was subdivided to distinguish between a single, correct answer (1A) vs. multiple student responses/misunderstandings (1B). Connection of content across time was subdivided to distinguish simply listing the prerequisite skills/standards (3A) vs. drawing instructional implications, e.g., "encourage students to recall what they know about..." (3B). *Support for responding to student thinking* was subdivided into responses to *specific* student ideas or difficulties—for example, what to do when students confuse area and perimeter, or when students can't get started on the problem (5A) vs. responses to *categories* of students (such as English language learners) without providing specific examples of how those students might respond (5B). All identified segments of the manuals were coded by two authors and disagreements discussed. Intercoder reliability for an independently coded subset of about half the material was 91%.

Results

Treatment of Area of Quadrilaterals in the Japanese and U.S. Teacher's Manual

The lessons selected for coding in the teacher's manual are italicized in Table 1. Since area of quadrilaterals is embedded in different ways in the two series, judging whether area of quadrilaterals was the lesson's primary focus was often a difficult call. Several of the U.S. lessons included a mixed focus (for example, on area and perimeter, or on using area in problem-solving) but we included them because quadrilateral area seemed to be the primary focus. On the other hand, the Japanese subunit "Units for large areas" dealt exclusively with area of rectangles and squares, but the primary focus of the unit was to teach measurement units for large areas (meter^2, hectare, and kilometer^2), so these lessons were not included. As shown in Table 1, area of quadrilaterals and triangles is taught over grades 3–5 in the U.S. text and over grades 4–5 in the Japanese text, with a greater allocation of time in Japan (26 45-minute periods) than in the U.S. (11 "days"). Despite the greater time allocation in Japan, the U.S. teacher's manual includes more discussion of the topic (1101 sentences versus 423 sentences in the Japanese teacher's manual).

Table 1 Area of Quadrilaterals in Japan and U.S. Textbooks

	Grade 3	Grade 4	Grade 5
Japan 13 45-minute periods*		**Unit:** Area **Subunits:** 1. *Concept of area and square centimeter (2 periods)* 2. *Area of rectangles and squares (3 periods)* 3. Units for large areas (5 periods) 4. Check (1 period)	**Unit:** Area of Quadrilaterals and Triangles. **Subunits:** 1. *Area of parallelograms (4 periods)* 2. Area of triangles (4 periods) 3. *Area of various quadrilat-erals (4 periods)* 4. Check (1 period) 5. Ideas for finding area [estimation & other polygons] (2 periods)
U.S. 11 "days"*	**Unit:** Perimeter, Area, Volume **Subunits**: 1. *Hands-On: Area of Plane Figures* (pp. 462–463) (1 day) 2. *Problem Solving Skill: Make Generalizations* (pp. 466–467) (1 day)	**Unit:** Perimeter and Area of Plane Figures **Subunits**: 1. *Estimate and Find Area* (pp. 500–503) (1 day) *(example in Fig. 2-3)* 2. *Relate Area and Perimeter* (pp. 504–505) (1 day) 3. *Relate Formulas and Rules* (pp. 506–509) (2 days) 4. *Problem Solving Strategy: Find a Pattern* (pp. 510–511) (1 day) 5. Review	**Unit:** Perimeter and Area **Subunits**: 1. *Algebra: Area of Squares and Rectangles* (pp. 528–259) 2. *Hands on: Relate Perim-eter and Area* (pp. 530–531) (Subunits 1&2 = 1day) 3. *Algebra: Area of Parallel-ograms* (pp. 536–539) (2 days) 4. *Problem Solving Strategy: Solve a Simpler Problem* (pp. 540–541) (1 day)

*Italicized sections were coded; count is for italicized sections

Table 2 Counts of Features in Teacher's Manual (Sections on Area of Quadrilaterals)

Features	Japan Grade 4	Japan Grade 5	US Grade 3	US Grade 4	US Grade 5	Japan Total	US Total
Total Sentences	231	192	198	600	501	423	1101
Anticipate student thinking: single correct answer (1A)	13 (6%)	1 (1%)	27 (14%)	72 (12%)	76 (16%)	14 (3%)	148 (13%)
Anticipate student thinking: varied/ challenges/interpreted responses (1B)	52 (23%)	65 (34%)	5 (3%)	13 (2%)	3 (1%)	117 (28%)	16 (1%)
Teachers' content knowledge (2)	2 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	0 (0%)
Content connection over time: Stated only (3A)	2 (1%)	2 (1%)	31 (16%)	67 (12%)	57 (12%)	4 (1%)	124 (12%)
Content connection over time: Un-packed (3B)	7 (3%)	7 (4%)	0 (0%)	0 (0%)	9 (2%)	14 (3%)	9 (1%)
Provide rationale for pedagogical choice (4)	24 (10%)	16 (8%)	0 (0%)	0 (0%)	0 (0%)	40 (10%)	0 (0%)
Response to specific student thinking (5A)	7 (4%)	5 (0%)	0 (0%)	6 (1%)	3 (0%)	12 (2%)	9 (0%)
Response to category of students (5B)	0 (0%)	0 (0%)	16 (8%)	57 (10%)	41 (8%)	0 (0%)	98 (9%)

Table 2 shows the coding results for teacher's manuals. As it shows, many of the sentences were not coded for any of the features hypothesized to support teachers' learning. For example, no code was given to the following sentences: "Display 3 different-sized rectangles. While comparing 2 of the rectangles, point to the figure with the greatest area while saying "greatest area." (U.S. Teacher's Manual, Grade 3, p.466B).

Two features appear substantially more frequently in the Japanese teacher's manual: anticipation of student thinking beyond a single correct answer, and explicit rationale for pedagogical judgments. For example, as shown in Figure 3, one section of the Japanese teacher's manual anticipates student thinking about a task in which students are asked which of two class newsletters is larger; each newsletter is shown on a bulletin board, surrounded by rectangular drawing paper of a standard size but arranged with different sides along the edge of the newsletter, so that the linear dimensions of the newsletters cannot easily be compared. The teacher's manual (4B, p.34) **anticipates** three types of **student responses** to this task and interprets (>) each:

Student Responses and Interpretation

a. Overlay the class newsletters and compare the areas that are outside of the overlaid area.
   > Trying to make a direct comparison.

b. Overlay sheets of drawing paper, which are the same size, on the class newsletters and count the number of sheets...
   > Trying to quantify by a non-standard unit of measurement...

c. Can size be represented by a unit of measurement, as length, volume, or weight were?
   > Trying to relate it to the measurement that they have already learned.

An example in which the teacher's manual **provides the rationale for the pedagogical choice** (Feature 4) appears in the next task in the textbook, comparing areas of a square and rectangle:

A square paper and a rectangular paper with the same perimeters are used intentionally.... That is because many children tend to think that the area will be the same if the perimeters are the same. In addition, in teaching area, it is important to take four steps, i.e., direct comparison, indirect comparison, non-standard unit, and standard unit. To promote taking these steps, a rectangle and square without grids are used (Tokyo Shoseki, p.35).

Three features appear more frequently in the U.S. teacher's manual: anticipation of student thinking with a single correct answer, connecting content by listing prior standards/skills, and support for responding to *categories* of students. Figure 2 suggests that the greater number of single correct answers provided in the U.S. teacher's manual may have to do with the greater number of problems (including the unrelated "quick review" problems). An example of support for a category of students ("auditory, kinesthetic" learners) is provided earlier in the paper. The third feature that is more common in the U.S. teacher's manual, connecting content connection across time by listing prior standards/skills, tends to be shown just once per grade in the Japanese teacher's manual, but with each unit in the U.S. teacher's manual.

Both the exploration of varied student thinking and the explicit rationale for pedagogical discussions found in the Japanese teacher's manual struck us as features that might support development of teachers' knowledge of student thinking and design of instruction to support student learning. For example, the Japanese teacher's manual explains why a grid is not given, and explains the sequence of experiences (direct comparison, indirect comparison, use of units) through which students may see the meaning of standard measurement units.

Investigation of Materials Use During Lesson Study

In order to investigate how U.S. teachers use the Japanese teacher's manual, we provided the Japanese elementary textbook and teacher's manual (sections on polygon area) to two U.S. lesson study groups during a summer workshop. Both groups received additional materials on area of polygon, including mathematical tasks to solve and discuss and articles to read and discuss. The time of the research lesson to be taught by the group (Thursday in a Monday-Friday workshop) was set. In other respects, lesson study groups had considerable flexibility in deciding how much time to allocate to the various materials and what to choose as a focus for their research lesson.

Each group was observed by two researchers. Data available from the workshop include written daily reflections, video of the groups' meetings and research lessons, and pre- and post-workshop written assessments in which participants were asked to plan a lesson on area of rectangles. For brevity, we focus here on one lesson study group during days two and three of the workshop, when the group engaged in study of the Japanese curriculum materials. This group included four educators with teaching experience ranging from roughly 6–18 years and with lesson study experience ranging from 0 to more than 5 years. Three members were elementary teachers and one member was a mathematics resource specialist; they were asked to teach a 4th grade class.

We tracked teachers' explicit discussion references to the two examples from the Japanese teacher's manual from the time the group first began reviewing the Japanese materials (Tuesday) to the time they began writing up their shared thinking in a lesson plan template (Wednesday); this totaled about 4 hours of discussion. Teacher Number 204 (hereafter T204), the mathematics resource specialist, was the first to mention the pedagogical rationale described in the teacher's manual, remarking that "In the 4th grade, in the teacher's manual... it says when you're teaching area, you want to teach direct comparison, indirect comparison, non-standard unit and standard unit." Her daily reflection sheet mentions how interesting she found this idea. She also noted that she needed the teacher's manuals to expose the pedagogical judgments embedded in the curriculum: "Japanese curriculum is very carefully thought out. Teacher's guides are essential—student books are not enough."

Group members seemed to differ in their initial understanding of the newsletter comparison task in the Japanese textbook, and they repeatedly drew on the teacher's manual to help them unpack the problem's mathematics. From her initial review of the teacher's manual on Tuesday, T204 quickly recognized and shared with the group an interesting design feature of the newsletter task, the different orientations of the surrounding drawing paper. She remarked, "This is cool, when I start to look at this. Because this is your non-standard measure here... it's really hard to compare because this [half-perimeter of one newsletter] is three long sides and three short sides, and this [half-perimeter of other newsletter] is two long sides and four short sides. So you'd *have* to directly compare them." The other three teachers in the group did not immediately pick up on this point. Instead, they focused their comments on ways to make the task more engaging to U.S. students (for example, by making the items to be compared chocolate bars or skateboarding posters).

On Wednesday morning, teachers remarked on feeling pressure to get their lesson planned. To move toward a lesson, they revisited the "big ideas" about area that they had developed during the first two days of the workshop. All members drew on the teacher's manual, though to differing degrees. T204 reiterated an earlier thought that the Japanese lesson with the two newsletters would be a worthwhile focus to bring out the four steps of measurement, and read to the group from the teacher's manual about the pedagogical rationale behind the steps: "The next sentence says 'to promote taking these steps, rectangles and squares without grids are used." T227 agreed that rectangle area might be a good lesson focus, but commented that they did not need to use the exact task in the textbook; her comment suggested that she did not yet understand the rationale behind the design of the task: "[We could] get construction paper and draw a picture on it or whatever. We don't have to use their thing right there." T231 disagreed, pointing out that the lesson task was set up to elicit certain kinds of student thinking, to get "kids to look at both things—the poster and the paper in the background because the kids might begin to get some ideas about how they could measure. They [teacher's manual] were saying that some of the kids might be counting the... drawing papers and confusing the idea of perimeter and area."

Although the teacher's manual provided examples of student responses to the newsletter comparison task, and interpreted the responses, teachers still chose to discuss these examples with team members, to make the ideas more concrete. T231 continued to question her colleagues about the distinction between indirect and non-standard measurement. In response, T227 used the methods of measurement outlined in the teacher's manual to characterize the three student responses provided in the manual. As she spoke, she seemed to notice new pedagogical properties of the task as written and to recognize the difficulties of "tweaking" it in a way that would keep it as mathematically meaningful as its presentation in the Japanese textbook; she concluded that "Now it seems harder and harder to create our own thing..."

Teachers revisited the steps of measurement several times as they prepared their written lesson plan, clarifying them through discussion. The group based their lesson plan closely on the Japanese textbook, using the Japanese newsletter task with a new context (dog run surrounded by patio tiles) but with its original mathematical characteristics. They also incorporated tasks from the *next* lesson of the Japanese textbook, including in their lesson twice the content suggested in the textbook's time allocation. Teachers included in their lesson plan ideas about the direct and indirect methods students might use to use to compare area, as part of their anticipated student responses.

Five teachers (from either one of the lesson study groups) filled out both pre- and post assessments and we coded their lesson plans for the features in Table 2 (anticipation of student thinking, content connections over time, rationale for pedagogy, etc.), using sentence-by-sentence coding as for the teacher's manuals. The initial plans received 21 codes and the plans prepared at the end of the week received 28 codes. Anticipation of student thinking beyond single answers (code 1B) was the only feature to increase by more than 5 instances from the initial plans to the end-of-week plans, increasing from 6 to 16 instances and suggesting that teachers' anticipation of varied student responses was supported by engaging in a lesson study cycle with Japanese teaching materials.

Discussion

We investigated features of teacher's manuals that may enable teachers to create a bridge between coherent *intended* curriculum and coherent *enacted* curriculum. For the topic of quadrilateral area, the Japanese teacher's manual emphasizes two features found less often in the U.S.

teacher's manual: anticipation of student thinking (beyond a single correct answer); and explicit rationale for pedagogical decisions. One example of each feature was selected for study, and references to it were traced over a lesson study cycle in which the Japanese teacher's manual (along with other materials) was made available to U.S. teachers. The U.S. teachers actively made use of the two features studied, referring back to them repeatedly as they worked to plan, teach and analyze a lesson. The discussions appeared to provide certain of the "opportunities for teacher learning" identified by Remillard and Bryans (2004), in particular insights into student thinking and expansion of one's repertoire of activities. The meaning of the material in the teacher's manual and the significance of the problem design was unpacked only gradually by teachers over a period of two days, as research lesson planning forced lesson study team members to make their thinking visible and to negotiate a shared lesson plan.

Much research indicates that teachers' knowledge, instructional beliefs, and teaching contexts substantially constrain their opportunities to learn from curricula, even curricula explicitly designed to promote teacher learning (Collopy, 2003; Remillard & Bryans, 2004; Spillane, 2000). We saw an example of this as U.S. teachers crowded two periods' worth of material from the Japanese textbook into a single-period lesson, perhaps to create a pace more familiar to them. Potentially, such rapid movement through the curriculum may undermine coherence of the curriculum by limiting the opportunity of students to fully make sense of a new concept such as area.

Teachers' on-the-job learning is often represented as a triangle whose three points mark three major sites for learning in and from practice: learning from students; learning from colleagues; and learning from curriculum (including research) (Ball & Lewis, 2002). Placed within that model, our findings suggest the usefulness of approaches that bring the three points of the triangle into closer relationship. In the lesson study cycle we report, teachers worked with one another to make sense of the instructional materials, asking each other questions and working to reconcile different initial interpretations of ideas like the methods of measurement. In effect, the need to collaboratively plan and conduct the research lesson extended backward the phase of "learning through enactment" identified as a particularly potent site for teacher learning by Remillard & Bryans (2004), who reported that "minimal teacher learning resulted from merely reading the teacher's guide... the most significant learning occurred during teachers' processes of enacting curriculum" (Remillard & Bryans, 2004, p.355). Similarly, the points of the triangle that represent "learning from students" and "learning from curriculum" were brought into close connection by teachers' efforts to classify the student responses in the text, understand the task features that would elicit particular student responses, and anticipate student responses. Building a closer connection between the three sites of learning from practice—so that the processes of learning from curriculum, colleagues, and students inform one another more closely—may merit investigation as a general design principle for supporting teachers' on-the-job learning.

Two major legacies of TIMSS in the U.S. have been awareness of the "mile-wide, inch-deep curriculum" and of lesson study. To date, these two legacies have spawned separate strands of educational improvement effort. Our initial findings suggest the importance of opportunities for teachers to bring together the two strands, using lesson study to investigate and enact a coherent curriculum. The textbook and teacher's manual needed discussion before some lesson study team members grasped their significance—for example, before they could understand why borders of different units were shown. Several team members grasped the reason for the border design only after some discussion and planning, suggesting the need for the teacher's manual to be used in a context of collegial learning.

Recently, Morris & Hiebert (2011) have argued that shareable, improvable tools can play a central role in educational improvement, enabling practitioners to share and refine the knowledge needed to teach. The Japanese curriculum provides one model of a shareable, improvable tool that has accumulated knowledge teaching and learning gained from lesson study (Lewis, Tsuchida, & Coleman, 2002) and that, in this case, was used by U.S. lesson study practitioners to build their own knowledge about teaching of rectangle area.

For lesson study sites outside Japan, it may be important to check whether teacher's manuals contain features likely to support teachers' knowledge development, such explicit pedagogical rationale and anticipation of varied student solution strategies. Our findings also suggest the challenges that may occur as teachers outside Japan use Japanese curriculum materials, such as adoption of a faster pace than is expected in the Japanese materials.

Note

1 This material is based upon work supported by the National Science Foundation under Grant No. REC-0633945. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. We wish to acknowledge Akihiko Takahashi, Tad Watanabe and Makoto Yoshida for help translating and interpreting the teacher's manual and Tokyo Shoseki Co., Ltd., for allowing us to translate segments of the Teachers Manual.

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