

Lin, P. J. (2005). The Use of Cases Helping Teachers Maintaining High-Level Cognitive Demands of Mathematical Tasks in Classroom Practices. Paper presented at the *International Conference of Authentic Science and Mathematics (Teacher) Education*. Nov. 7-11. Taiwan: National Hsinchu University of Education.

The Use of Cases Helping Teachers Maintaining High-Level Cognitive Demands of Mathematical Tasks in Classroom Practices

Pi-Jen Lin

National Hsinchu University of Educational, Taiwan

linpj@mail.nhcue.eud.tw

Abstract

The study was designed to examine how teachers maintained high-level cognitive demand as the tasks were carried out in classroom through the use of research-based cases. The tasks referred to in the study were conceptualized as not only the problems written in a textbook or a teacher's lesson plan, but also the classroom activity that surround the way in which those problems were set up and actually carried out by teachers and students. To achieve the goal, eight in-service teachers enrolling in a course "Theory and Practice of Case Method (TPCM)" in summer M.A. program at the University, participated in this study. The course consisted of three parts. Part I with 24 hours was to conceptualize teachers' knowledge of cases. The teachers were offered five video cases to view and discuss in Part II containing 24 hours. Part III with 16 hours were not required but optional for examining how the use of cases improved the teachers' ability in setting up high-level of tasks and how the tasks were carried out. This study conducted within-cases and cross-cases analyses. The within case were analyzed in accordance with the Task Analysis Guide suggested by Stein et al. (2000). It is found that the use of cases conceptualizing the teachers' understanding of the importance of differentiating levels of cognitive demand of tasks determining students thinking and their ability of maintaining high-level cognitive demands of instructional tasks, since the case discussion created the opportunity of raising the level of discussing among teachers toward a deeper analysis of the relationship between the tasks they created and the level of cognitive engagement that were required of students. These factors including the selection of tasks that built on students' prior knowledge, assisting students thinking by asking thought-provoking questionings that preserve task complexity, and sustaining pressure for explanation and sense-making maintained high-level of cognitive demand of the tasks evolved during a lesson.

Key words: case method, teacher education, cognitive demand, instructional tasks

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INTRODUCTION

Case method can now be observed in a variety of teacher education and staff development programs in many countries (Dolk & den Hertog, 2001; Lin, 2002; Stein, Smith, Henningsen, & Silver, 2000; Silver, 1999). These studies focus on answering about what teachers learn from cases and how they learn it. These cases are performed for various purposes (Merseth, 1996). Cases can be dilemma-driven that used to practice problem solving in which the cases portray problematic situations that require problem identification, analysis, and decision-making (Kleinfeld, 1992). Exposure to the dilemma-driven cases aims to help teachers (1) realize that teaching is an inherently dilemma-ridden enterprise and (2) learn how to think about the trade-offs involved in selecting one course of action over another. Besides, cases can be exemplars to establish the best practice or to make the effective teaching more public and available for others to analyze and review (Sykes & Bird, 1992). It aims to assist teachers to develop (1) an understanding of mathematical tasks and how their cognitive demands evolve during a lesson and (2) the skill of critical reflection on their own practice guided by reference to a framework based on these ideas (Stein, et al., 2000).

These studies on cases used in teacher education agree that cases help teachers increasing their awareness of students' learning and becoming more reflective practitioners. These studies also show that cases teach more effectively than traditional expository approaches to teaching since cases reflect real situations and pose problems and challenges for teachers (Barnett, 1998). However, these studies do not indicate that how the use of cases increases teachers' awareness of different levels of cognitive demands of mathematical tasks resulting in students' different thinking. Thus, helping teachers learn to differentiate levels of cognitive demand of instructional tasks through the use of case becomes the purpose of the study reported here.

TASK ANALYSIS GUIDE FOR COGNITIVE DEMAND OF INSTRUCTIONAL TASKS

What is the role of the cognitive demands of instructional tasks playing student learning? Student learning is not simply created the opportunity by putting students into groups or by placing manipulatives in front of them. Rather, it is the level of thinking in which students engage determines what they will learn. For instance, tasks that require students to perform a memorized procedure lead to low-level thinking; tasks that stimulate students to make purposeful connections to meaning lead to high-level thinking. Stein et al. (2000) differentiate four levels of cognitive demand of instructional tasks as memorization, procedures without connection, procedures with connection, and doing mathematics. They also provide task analysis guide served as a scoring rubric for each level of cognitive demand (as seen in Table 1).

All tasks are not created equal, that is, different tasks require different levels of student thinking. Although it is important to determine the level of cognitive demand of a task, it could be happened that low-level tasks to be identified as high-level such as acquiring the use of

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manipulatives and using real-world contexts. It is also possible for tasks to be designated low-level when in fact they should be considered high-level.

Being aware of the cognitive demands of tasks is a central role in selecting or creating instructional tasks matching to instructional objectives. For example, if a teacher wants students to learn how to justify or explain their solution processes, she should select a task that is deep and rich enough to afford such opportunities. The cognitive demands of tasks can be changed during a lesson. Although starting with high-level task does not guarantee student engagement at a high-level (Stein, Grover, & Henningsn, 1996). As suggested in Stein et al.'s Mathematical Tasks Framework (2000), tasks are seen as passing through three phases: First, as they appear in curricular or instructional materials or as created by teachers; Next, as they are set up or announced by the teachers in the classroom; and finally, as they are carried out by students. All of these, but especially the third phase are viewed as important influences on what students actually learn. This framework indicates that simply selecting and beginning a lesson with a high level task did not guarantee that students would actually think and reason in cognitive complexly ways. What factors would reduce the level of cognitive demand of a task once it is implemented into classroom?

Table 1 The Task Analysis Guide (Stein et al., 2000, p.16)

<i>Lower-Level Demands</i>	<i>Higher-Level Demands</i>
<p>1. Memorization Tasks</p> <ul style="list-style-type: none"> ➤ involving reproducing previous learned facts, rules, formula, or definitions. ➤ cannot be solved using procedures because a procedure does not exist or because the time frame in which the task is being completed is too short to use a procedure. ➤ are not ambiguous -such tasks involve what is to be reproduced is clearly and directly stated. ➤ have no connection to the meaning that underlie the facts, rules, formula, or definitions being learned. <p>2. Procedures Without Connection Tasks</p> <ul style="list-style-type: none"> ➤ are algorithmic. Use of the procedure is either specifically called for or its use is evident based on prior instruction. ➤ require limited cognitive demand for successful completion. There is little ambiguity about what needs to be done and how to do it. ➤ have no connection to the meaning that underlie the procedure being used. ➤ Require no explanation, or explanations that focus solely on describing the procedure that was used. 	<p>3. Procedures with Connections Tasks</p> <ul style="list-style-type: none"> ➤ focus students' attention on the use of procedures for the purpose of developing deeper understanding. ➤ are represented in multiple representations. Making connections among multiple representations help to develop meaning. ➤ require some degree of cognitive effort. Students need to engage with the conceptual ideas that underlie the procedures in order to successfully complete the task and develop understanding. <p>4. Doing Mathematics Tasks</p> <ul style="list-style-type: none"> ➤ require complex thinking (there is not a predictable pathway explicitly suggested by the task or work-out example). ➤ require students to access relevant knowledge and make appropriate use of them in working through the task. ➤ require students to explore and understand the nature of mathematical concepts or relationships. ➤ require considerable cognitive effort and may involve some level of anxiety for the student due to the unpredictable nature of the solution process required.

This is not to suggest that all tasks used by a teacher should engage students in high-level cognitive demand. However, to meet need of the innovative curriculum that is emphasized on reasoning, problem solving, and mathematical communication, students need opportunities to engage with tasks that lead to deeper, more generative understanding with respect to the

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mathematical concepts. Moreover, how can a teacher educator help teachers to provide such an opportunity to students engaging in instructional tasks that are indeed implemented in such a way that students thought in complex and meaningful ways? Stein and his colleagues (2000) suggest that the use of cases can be a device to play this mediating function. Their studies show that teachers become sensitive to important cues in teaching episodes (e.g., Was the teacher tuned into students' needs?). In addition, teachers learn how to interpret those cues as influences on students' opportunities to engage productively with tasks. They explain that once teachers begin to view cases of various patterns of instructional tasks, they can begin to reflect on their own practice through the lens of the cognitive demands of tasks.

Thus, this study was intended to examine how teachers maintained high-level cognitive demand as the tasks were carried out through the use of research-based cases. Here, the research-based cases are featured by they are real-context teaching, they are based on valid research, they are potential to initiate critical discussion by users, they are constructed by classroom teachers and the researchers, they are able to provide vicarious experience, and the instructor in each case can be invited to participate the case discussion for articulating the context of the case teaching. The tasks referred to the study are conceptualized as not only the problems written in a textbook or a teacher's lesson plan, but also the classroom activity that surround the way in which those problems are set up and actually carried out by teachers and students.

METHOD

Participants

Eight teachers, enrolling in a course called "Theory and Practice of Case Method (TPCM)" in summer M.A. program at the University, participated in this study. All participants were in the first year study of their Master degree program. Six participants were female and two were males. Three teachers (T1, T2, T3) were experienced teachers with at least 10 years of teaching experience. Three teachers (T4, T5, T6) had 5 to 10 years of teaching experience and two teachers (T7, T8) had less than 5 years of teaching experience.

Settings

This study was intended to support in-service teachers in bringing recommendation of innovative curriculum into classroom practices through the use of cases. The cases presented in a video form were integrated into the TPCM course. The weekly 2 three-hour TPCM course continuing for 48 hours consists of three parts. Part I consisting of 24 hours, reading book chapters and empirical papers were to enrich the teachers' knowledge about cases and introducing the use of reflective mathematics journals. Then, it was followed by Part II containing 24 hours that was designed to help teachers to learn to provide students with increased opportunities for high-order thinking. During this part, the teachers were offered with five research-based cases from which were conducted by the researcher and a group of classroom teachers. After viewing a video case, each case was immediately discussed in small groups and then discussed in whole class. In Part III,

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teachers took turns observing each other during actual classroom instruction in the school semester after they ended the summer course. The activities of Part III containing 16 hours was to examine how the use of research-based cases improved the teachers' ability in setting up high-level instructional tasks and how the tasks were carried out. The activities of Part III were not required but optional, because some of the teachers did not teach mathematics during the year.

Videotaped Cases

Five video cases were utilized as an object of shared discussion in the course, since videotapes allowed teachers to watch and re-watch a segment, trying to discern exactly what was going on as students worked on a particular task. One of the five videotapes, "Is 2 units of $\frac{1}{7}$ equals to $\frac{2}{7}$?", was an example to illustrate what a case looks like. The case is relevant to third graders' difficulty with understanding about "2 units of $\frac{1}{7}$ equals to $\frac{2}{7}$ ". The video case contains a fragment has 12 minutes in length. The focuses zoomed at the tasks, students' various solutions strategies, and dialogues of students and teachers.

Case: Is 2 units of $\frac{1}{7}$ equals to $\frac{2}{7}$?

Learning objective: To represent a proper fraction in which the denominator is no more than 10.

Task set up by the teacher Yo-Yo: Give each student a strip paper that has been marked into seven equal subparts. Students were asked to shade the parts of $\frac{2}{7}$ on the strip and explain it.

The following three drawings were given by three students of the class.



Wein-Wei



Uei-Shang



Ling-Wei

Dialogues between the teacher and students:

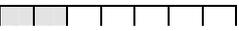
....

T: What is the fraction of the shaded drew by Uei-Shang?

S: $\frac{2}{7}$

T: Is $\frac{2}{7}$ equal to 2 units of $\frac{1}{7}$?

Uei-Shang: 2 units of $\frac{1}{7}$ is not equal to $\frac{2}{7}$, since $\frac{1}{7}$ added $\frac{1}{7}$ is $\frac{2}{14}$.

Sue-Ling: 2 units of $\frac{1}{7}$ is not equal to $\frac{2}{7}$, since their representations are distinct. 2 units of $\frac{1}{7}$ is represented as , while $\frac{2}{7}$ is represented as 

(The class is over)

Case Discussion Session

We usually began the case discussion with small groups of four and then move on to a discussion involving the entire class. The viewing a video was immediately followed by the case discussion lasting for two and half hours. The author was the instructor of the TPCM and was the facilitator of the case discussion. The author was also a member of those who involved in the case construction. Thus, the author knew very well about the context of the case. However, the author did not provide the participants extra information such as guiding question, even though they asked

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about the students' preconception or teacher's goals. The questions they asked became the central issues of the case discussion. The intention of the case was to encourage the participants to identify how mathematical tasks differ with respect to levels of cognitive demand. In video discussion, the participants were asked to answer the following questions: (1) what is the main mathematical idea in the case? (2) Which level of cognitive demand of the instruction task would you like to place in? Why did you do so? (3) What evidence is there that the students learn these ideas or that the difficulties students have in this case? (4) What pedagogical issues would you like to address for sharing with your colleagues? To answer these questions, the participants learned to identify different tasks resulting in different levels of and kinds of students' thinking. The answers to these questions will reveal the cognitive processes required to successfully complete the task.

Data Collection

Data for this study included case analysis of the video. These analyses were audio-taped and transcribed verbally. In addition, teachers were encouraged to write weekly reflective journals as one of the assignments of the course. The reflective journal was to help the participants to draw their attentions to what students are actually doing and thinking about during classroom lessons; rather than, paying too much attention to teachers themselves. This provides a measure of how their thinking has changed as a result of the case discussion. The data collected from Part III of the course also included classroom observations. Four lessons were observed from four of the participants who taught mathematics during the year. The classroom observations were videotaped and audio-taped and transcribed verbally.

This study conducted within case analyses and cross-case analyses to examine how the teachers learned about the cognitive demands from video research-based cases carried out in classrooms. Cross-case analyses were conducted to identify similarities across cases, differences among them, and overall patterns. Due to the space limit, only one of the four lessons relevant to fraction was analyzed to document how the teacher maintained the level of cognitive demands of students thinking.

RESULT

The results of the study includes the responses the teachers made to the questions raised during video discussion and high-level instructional tasks the teachers set up were evolved in a lesson.

Reflection to the Video Case

The answers the teachers responded to the question "what is the main mathematical idea in the case?" included conceptualizing the meaning of fraction (CM), transformation between representations of fraction (TR), and linking the relationship between iteration of unit fraction and fraction in part-whole model (LR).

Excepting the teacher T1, all other three teachers described that the case is relevant to conceptualizing the fraction concept. Nevertheless, they were not aware of differentiating the iteration of unit fraction, such as "2 units of $\frac{1}{7}$ equal to $\frac{2}{7}$ " or " $\frac{2}{7} = \frac{1}{7} + \frac{1}{7}$ " and a nonunit fraction

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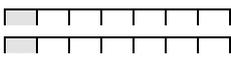
from a part-whole model perspective (e.g., $\frac{2}{7}$ is 2 parts of seven equal-size parts) and making the connection between an iterating unit fraction and a non-unit fraction.

It is found that the teachers did not always agree with each other on how tasks should be categorized, but that both agreement and disagreement provide the opportunity for conceptualizing the fraction teaching. However, they have an agreement to the fraction case as a doing mathematics task. For example, the four teachers (T1, T2, T4, T7) in one group described that the task was featured as follows. (1) It requires an explanation. (2) It is not textbook-like. (3) It involves multiple representations including the transforms from verbal to manipulatives and to diagram. (4) There is no predicable pathway suggested by the task. (5) It requires complex thinking. The other four teachers (T3, T5, T6, T8) in one group added two more features. The task activates students' misconception of $\frac{1}{7} + \frac{1}{7} = \frac{2}{14}$ and makes connections between iteration of unit fraction and a nonunit

fraction with part-whole model (e.g., two-sevenths $\frac{2}{7}$ is equal to $\frac{1}{7} + \frac{1}{7}$). Table 2 summarizes the responses the teachers distributed in two different groups answered to the case.

Table 2 Responses Each Teacher Answered to Each Question

	Main ideas	Level of cognitive demand	Features	Students learned & difficulties
T1, T2, T4, T7	CM TR LR	Doing mathematics	<ul style="list-style-type: none"> ◦ requires an explanation ◦ involves multiple representations ◦ no predicable pathway ◦ requires complex thinking 	<ul style="list-style-type: none"> ◦ shaded in separate areas ◦ perceptual distractors ◦ partitioning odd parts for students
T3, T5, T6, T8	CM TR	Doing mathematics	<ul style="list-style-type: none"> ◦ activates students' misconception ◦ makes connections between fraction meanings 	<ul style="list-style-type: none"> ◦ shaded in separate areas ◦ perceptual distractors

The teachers stated that they have learned from the case teacher of the video in creating the task for provoking to students' difficulties and misconceptions. The eight teachers perceived the effect of perceptual distractors. They were surprised to find out students' difficulty in deciding the fraction $\frac{2}{7}$ while the partitioning line in the diagram was missing. The missing line represented a significant perceptual distractor for students. It is hard for third graders mentally "put in" the line. Besides, they were shocked in students' difficulty with agreement with "2 units of $\frac{1}{7}$ equal to $\frac{2}{7}$ ", since the students agreed that "2 units of $\frac{1}{7}$ is represented as  , rather than represented as . Although they recognized students' difficulty in deciding 2 units of $\frac{1}{7}$ equivalent to $\frac{2}{7}$, they were not able to make further suggestion to solve the instructional puzzle, excepting the teacher T3. T3 stated that it is not unusual that the third-grade students had the difficulty with understanding "2 units of $\frac{1}{7}$ equal to $\frac{2}{7}$ ". This became an evidence for ensuring the

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iteration of unit-fraction to be learned in the fourth grade curriculum.

Through case discussion, some of the teachers were aware of the importance of consolidating fraction concept by shading in two separate areas instead of two successive areas in a rectangle. The two teachers (T3 & T5) appreciated with the case teacher partitioning 7 parts in a strip for third-graders already. As a result, students were not distracted by partitioning 7 parts, but they easily paid attention to shading 2 parts in 7 parts. T4 reflected to her previous teaching and said that she spent much time in partitioning the odd-numbered partitions.

Effect of Using Cases on Maintaining High-Level Cognitive Demand of the Tasks

As ending the TPCM course, each teacher was encouraged to implement what (s)he learned into classroom practice in a school semester year. The evolution of tasks during a lesson taught by T1 is discussed here only. T1 was a sixth grade teacher. In the lesson, the teachers T2, T4, and T7 observed T1's lesson together. The lesson is relevant to ordering fractions. Six graders have learned ordering fractions with same denominator fractions.

In the lesson (as seen in the video), T1 gave students four pairs fractions to decide which is greater. The four pairs ($\frac{1}{5}$ vs. $\frac{1}{7}$; $\frac{5}{16}$ vs. $\frac{5}{9}$; $\frac{4}{9}$ vs. $\frac{8}{12}$; $\frac{11}{12}$ vs. $\frac{14}{15}$) have four basic types: unit fractions, fractions with same numerator or same denominator, and fractions with different numerators and denominators. The four teachers including T1, the instructor of the lesson, focused on the discussion about the cognitive demands of the tasks.

The Setup Phase

This phase includes T1's communication to her students regarding they were expected to decide which of the fractions is greater and how they were expected to compare them. Each student was told to start to work on it and wrote individual solution on each whiteboard.

T2 and T4 identified these four pairs fractions as "procedure with connection", while T7 identified them as low-level demands. T7 claimed that the four pairs of fractions were not involving in problem contexts and they were focused on producing correct answers rather than developing mathematical understanding. Conversely, T4 suggested that T1 purposely changed the tasks with different types of fraction from the textbook for developing students' multiple strategies, so that these tasks required high-level demands. T2 commented that T1 designed intentionally the numerals of numerator and denominator between two fractions for developing students' various strategies rather than emphasizing on the algorithm.

The Implementation Phase

In the study, the implementation phase starts as soon as students began to work on the task and continued until T1 and her students turned their attention to a new task. Both T2 and T4 agreed the tasks set up by TI standing at the cognitive level of "procedure with connection". Analyses suggested five or six different strategies were used by the TI students for the four types of

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conditions. The majority of these was valid strategies and in some way recognized the relative contribution of both numerator and denominator to the overall size of the fraction.

For instance, students used two strategies to compare $\frac{1}{5}$ vs. $\frac{1}{7}$. One is referred to unit fraction. Students realized that there is an inverse relation between the number of parts into which the whole is divided and the resulting size of each part, so that $\frac{1}{5} > \frac{1}{7}$ (as Figure 1a). The other strategy is to make into a same denominator from two different denominators. In this case, finding $\frac{1}{5} = \frac{1 \times 7}{5 \times 7}$, $\frac{1}{7} = \frac{1 \times 5}{7 \times 5}$ as the first step, then $\frac{7}{35}$ is greater than $\frac{5}{35}$ (as Figure 1b).

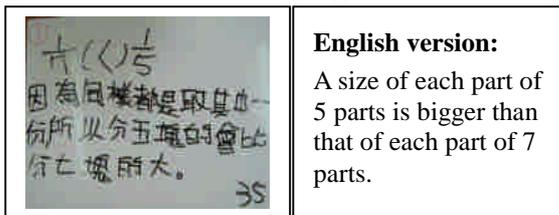


Figure 1a

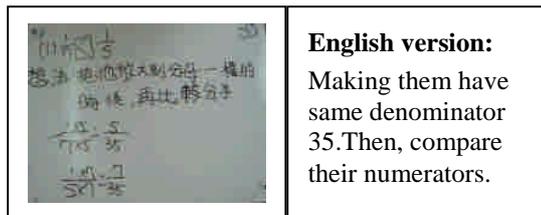


Figure 1b

It was then followed by the second problem “comparing $\frac{5}{16}$ vs. $\frac{5}{9}$ ”. Most of the students still used two previous strategies, partitioning and finding a same denominator. They also developed a new strategy by comparing each to a common third number (usually $\frac{1}{2}$ or 1) and were successfully in order the given fractions. For instance, one of the students used “half of 16 is 8, bigger than 5 and half of 9 is 4.5, less than 5. Thus, $\frac{5}{16}$ is less than $\frac{1}{2}$ and $\frac{5}{9}$ is greater than $\frac{1}{2}$, seen as Figure 2a. To this problem, TI attempted to reduce the use of common denominator, since the product of 16x5 is too big to getting correct answer. TI expected students to learn various strategies and each strategy can be applied in a suitable situation. She pointed to Su-Jing’s solution and had the following conversation with her.

T1: How did you change the number $\frac{5}{16}$ into $\frac{45}{126}$?

Su-Jing: I used the fraction $\frac{5}{16}$ with denominator and numerator multiplying 9 and got the answer $\frac{45}{126}$.

T1: Why did 16 change into 126?

Su-Jing: I made a calculation error. It should be 144.

T1: Did all of you think it is a good strategy to find the common denominator?

Students: No.

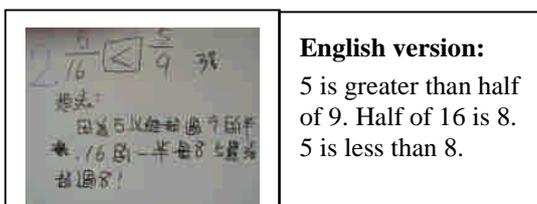


Figure 2a

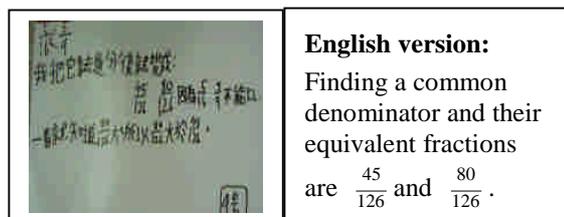


Figure 2b

Moving on to the third problem “Order $\frac{4}{9}$ vs. $\frac{8}{12}$ ”, the two fractions with different numerators and denominators are getting harder for students. In this case, students focused only on the numerator or only on the denominator and as a result made incorrect conclusions.

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We found that T1 encouraged students solved successfully the problem by either using reference point $\frac{1}{2}$ (as Figure 3a), or finding a common denominator requires finding $\frac{4 \times 4}{9 \times 4}$ equivalent to $\frac{4}{9}$ and $\frac{8 \times 3}{12 \times 3}$ equivalent to $\frac{8}{12}$ with the same denominator 36 (as Figure 3b) or finding the same numerator 4 requires finding $\frac{4}{6}$ equivalent to $\frac{8}{12}$ and then ordering $\frac{4}{6}$ and $\frac{4}{9}$ (as Figure 3c), or finding the same numerator 8 requires finding $\frac{8}{18}$ equivalent to $\frac{4}{9}$ and then ordering $\frac{8}{18}$ and $\frac{8}{12}$ (as Figure 3d).

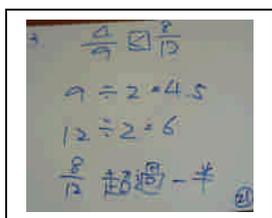


Figure 3a

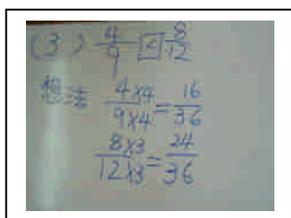


Figure 3b

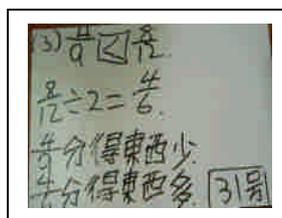


Figure 3c

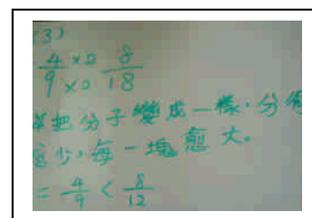


Figure 3d

These analyses indicated that during the implementation phase, both T1 and her students were viewed as important contributors to how tasks were carried out. T1 questioning to students or asking follow-up questions was relied on what her students worked on the task. We found out the ways and extent to which T1 supported students' thinking was a crucial ingredient of maintaining high-level tasks. In this lesson, TI promoted deeper levels of understanding by consistently asking students to explain how they were doing about the problems. After discussing, T7 finally had a commitment to TI maintaining the tasks at the level of procedure with connections. These tasks evolved during the lesson involved multiple strategies, required an explanation, and connected procedures to meaning.

CONCLUSION

The study concluded that the use of cases improved teachers' awareness of the importance of differentiating levels of cognitive demand of tasks determining students thinking. The case discussion created the opportunity of raising the level of discussing among teachers toward a deeper analysis of the relationship between the tasks they created and the level of cognitive engagement that were required of students. However, achieving complete consensus on the each task was not the intention of the case discussion of the study.

Besides, the effect of using cases on teacher's thinking about teaching, it is found that there were usually many support factors present in teachers' classrooms. These factors including the selection of tasks that built on students' prior knowledge, assisting students thinking by asking thought-provoking questionings that preserve task complexity, and sustaining pressure for explanation and sense-making maintained high-level of cognitive demand of the tasks evolved during a lesson. However, it could be happened that the cognitive demands of tasks declined during the implementation phase. The factors of declining the cognitive demands of the tasks in classroom could be a further analysis for the further study.

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