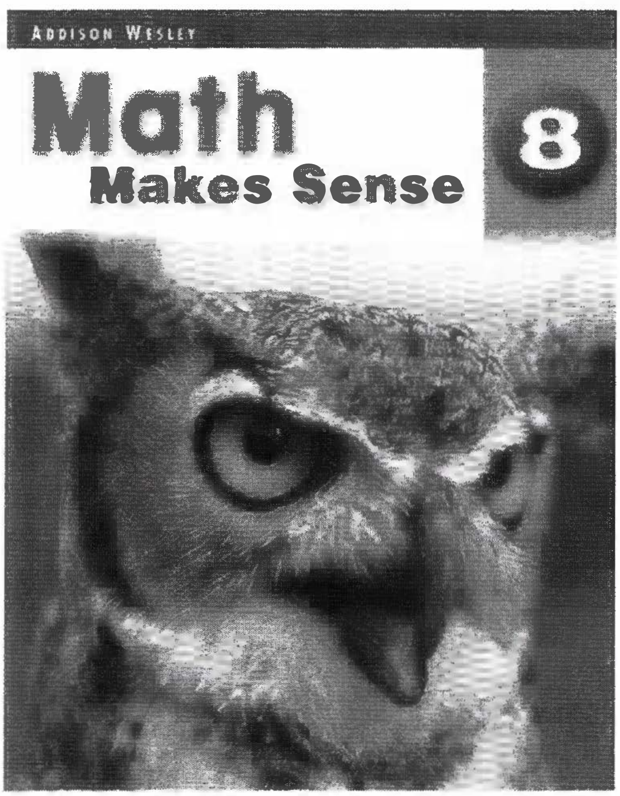
Evaluation of the Tasks from *Math Makes Sense 8*: Focusing on Equation Solving

Xiong Wang

Abstract

Mathematics tasks have been regarded as important for promoting students' understanding in classroom teaching. However, there has not been much research that has closely examined tasks from textbooks or supporting resources that teachers use in daily teaching. This paper aims to evaluate the tasks from the math textbook *Math Makes Sense 8* (Baron et al 2008), which has been adopted in Alberta, Canada. The tasks in question are selected from two lessons, Solving Equations Using Models and Solving Equations Using Algebra, in *Math Makes Sense 8* (6.1 and 6.2), and the corresponding sections in the practice and homework book and the ProGuide for teachers, and are analyzed with three kinds of analysis framework. In order to understand the knowledge level involved in the tasks, the standards for scoring assignments have been used for reference and modified into a knowledge-level framework. In addition, the levels of cognitive demands have been employed as an examiner of the cognitive demands required in the tasks. Finally, the factors associated with the maintenance of high-level cognitive demands have been applied to verify the questions and strategies provided in the ProGuide. The results show that the tasks are eventually coded as submedium knowledge level, medium-level cognitive demands and higher-level knowledge communication, and that scaffolding students' thinking and reasoning is a major factor in the supportive strategies provided for teachers.



Engaging students in mathematical thinking and reasoning has been recognized and held in esteem by many researchers.

Background

Mathematics tasks have been regarded as important vehicles for promoting students' understanding in classroom teaching; for example, Hiebert et al (1997) identify tasks as the core component of classroom teaching. As for the role of mathematics tasks, engaging students in mathematical thinking and reasoning has been recognized and held in esteem by many researchers (Cai and Lester 2005; Stein et al 2000). In fact, in daily teaching practice, teachers rely heavily on textbooks (Pepin and Haggarty 2001) and supporting materials such as students' workbooks and teachers' manuals to manage their teaching. However, analysis of mathematics tasks is too often conducted in the classroom, as Shimizu et al (2010) have done. Very little research has been done focusing on the tasks in textbooks and the role of supporting materials related to the tasks, particularly on the tasks in textbooks used in Alberta. This paper concentrates on the analysis of certain tasks from the Grade 8 *Math Makes Sense* textbook and the corresponding students' workbook and teachers' manual, and on the examination of their features and roles in supporting students' mathematics learning by adopting three kinds of analysis framework: knowledge level, cognitive demands and supportive factors.

Introduction of Solving Equations Using Models and Algebra

The tasks to be analyzed have been selected from two lessons, Solving Equations Using Models (6.1) and Solving Equations Using Algebra (6.2), in the textbook *Math Makes Sense 8* (Baron et al 2008, 318–32). With a view to examining their supports for the students' learning, other relevant resources have been taken into account, such as *Math Makes Sense 8: Practice and Homework Book* (6.1 and 6.2) (Berglind et al 2009, 138–43) and *Math Makes Sense 8: ProGuide* (6.1 and 6.2) (Appel et al 2007, 4–18).

Each resource comprises several parts. Typically, the two lessons selected from the textbook have such similar constructions as Investigate, Connect and Practice. The two lessons from the practice and homework book have similar constructions, such as Quick Review and Practice. The ProGuide book for teachers provides guiding questions and strategies at three stages: before (Get Started), during (Investigate) and after (Connect).

The two lessons are targeted to lead students to solve equations by using algebra tiles, balance scales and algebra. At the end of the two lessons, the students are expected to write an equation to represent a problem.

Methods

Data

Data is taken from *Math Makes Sense 8* (textbook, 6.1 and 6.2), *Math Makes Sense 8 Practice and Homework Book* (6.1 and 6.2) and *Math Makes Sense 8 ProGuide* (6.1 and 6.2) (see Table 1).

Table 1: *Content by resource*

Textbook (T)	Practice and homework book (PH)	ProGuide (PG)
T1 Investigate (T1-I) Connect Example 1 (T1-CE1) Example 2 (T1-CE2) Example 3 (T1-CE3) Practice Check (T1-PC) Apply (T1-PA) Assessment focus (T1-PAF)	PH1 Quick Review (PH1-QR) Practice (1-7) (PH1-P)	PG1 Before (Get Started) (PG1-BGS) During (Investigate) (PG1-DI) After (Connect) (PG1-AC)
T2 Investigate Connect Example 1(T2-CE1) Example 2(T2-CE1) Practice Check (T2-PC) Apply (T2-PA) Assessment focus (T2-PAF)	Quick Review (PH2-QR) Practice (1-5) (PH2-QR)	Before (Get Started) (PG2-BGS) During (Investigate) (PG2-DI) After (Connect) (PG2-AC)

Analysis Frameworks

Three kinds of analysis framework have been adopted to analyze the tasks from the textbook, the practice and homework book and the ProGuide book for teachers. In order to understand the knowledge level involved in the tasks, the standards for scoring assignments (Koh and Lee 2004) have been employed and modified into a knowledge-level framework to analyze the tasks from the textbook and the practice and homework book.

Specifically, three standards (standard 1, standard 2 and standard 3) selected from the standards of scoring assignments from Koh and Lee (2004) have been modified into dimension 1, dimension 2 and dimension 3, respectively, in the knowledge-level framework. Moreover, for the purpose of demonstrating a feature of tasks in the textbook *Math Makes Sense 8*, encouraging students' communication, an extra knowledge level, dimension 4—knowledge communication—is added to the knowledge-level framework. Each category from the four dimensions is coded to the tasks from Solving Equations Using Models (6.1 in the textbook), and its content is modified to inosculate the tasks content. Based on those modifications, the framework of a new knowledge level (see Table 2) is built and capitalized to code all the tasks from the textbook and the practice and homework book.

In addition, the levels of cognitive demands are applied to check the cognitive demands included in these tasks. Finally, the factors associated with the maintenance of high-level cognitive demands are adopted to examine the questions and strategies provided in the ProGuide book.

Table 2: *Knowledge level of tasks*

	Level 1	Level 2	Level 3	Level 4
Dimension 1 Depth of knowledge	**Factual knowledge** Possible indicators are tasks that require students to describe routine computational procedures and perform routine equation operations.	**Procedural knowledge** Possible indicators are tasks that require students to know how to carry out a set of steps to solve equations using models and algebra; to use a variety of computational procedures and tools; and to manipulate the written symbols of algebra.	**Advanced knowledge** Possible indicators are tasks that require students to make connections to other mathematical concepts and procedures; to explain one or more mathematical relations; and to understand how a mathematical topic relates to real-world situations.	
Dimension 2 Knowledge criticism	**Presentation of knowledge as truth or given** Possible indicators are tasks that require students to accept or present ideas or solutions as truth or a fixed body of truths; to perform a well-developed equation; and to perform clear steps.	**Comparing and contrasting information or knowledge** Possible indicators are tasks that require students to compare different methods of solving equations.	**Critiquing information or knowledge** Possible indicators are tasks that require students to comment on different equation solutions; to discuss and evaluate approaches to equation-based problems; and to make mathematical arguments, and pose and formulate equation problems.	
Dimension 3 Knowledge manipulation	**Reproduction** Possible indicators are tasks that require students to reproduce procedures; to recognize equality, to manipulate equation expressions containing symbols and formulae in standard form; to carry out computations; to apply routine mathematical procedures and technical skills, and to apply equality concepts and procedures to the solution of routine equations.	**Organization, interpretation, analysis or evaluation** Possible indicators are tasks that require students to write and interpret equations and to consider alternative solutions or strategies.	**Application or problem solving** Possible indicators are tasks that require students to apply equation concepts to create a problem; and to apply equations to the solution of the problem.	**Generation or construction of knowledge new to students** Possible indicators are tasks that require students to generalize strategies and solutions to new problem situations and to apply modelling to new contexts.
Dimension 4 Knowledge communication	Guides students to represent their thinking in pictures, numbers or symbols.	Provides a balance of oral and written communication opportunities	Reflects different models to solve an equation or different equation types using algebra	

The levels of cognitive demands of tasks (Table 3) are cited directly from Stein et al (2000, 16).

Table 3: *Level of cognitive demand of tasks*

Level 1: Memorization	
• Involve either reproducing previously learned facts, rules, formulas or definitions, or committing facts, rules, formulas or definitions to memory. • 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 the exact reproduction of previously seen material, and what is to be reproduced is clearly and directly stated. • Have no connection to the concepts or meaning that underlie the facts, rules, formulas or definitions being learned or reproduced.
Level 2: Procedures without connections	
• Are algorithmic. Use of the procedure either is specifically called for or is evident from prior instruction, experience or placement of the task. • Require limited cognitive demand for successful completion. Little ambiguity exists about what needs to be done and how to do it. • Have no connection to the concepts or meaning that underlie the procedure being used.	• Are focused on producing correct answers instead of on developing mathematical understanding. • Require no explanations, or explanations that focus solely on describing the procedure that was used.
Level 3: Procedures with connections	
• Focus students' attention on the use of procedures for the purpose of developing deeper levels of understanding of mathematical concepts and ideas. • Suggest explicitly or implicitly pathways to follow that are broad general procedures that have close connections to underlying conceptual ideas as opposed to narrow algorithms that are opaque with respect to underlying concepts.	• Usually are represented in multiple ways, such as visual diagrams, manipulatives, symbols and problem situations. Making connections among multiple representations helps develop meaning. • Require some degree of cognitive effort. Although general procedures may be followed, they cannot be followed mindlessly. Students need to engage with conceptual ideas that underlie the procedures to complete the task successfully and that develop understanding.
Level 4: Doing mathematics	
• Require complex and non-algorithmic thinking—a predictable, well-rehearsed approach or pathway is not explicitly suggested by the task, task instructions or a worked-out example. • Require students to explore and understand the nature of mathematical concepts, processes or relationships. • Demand self-monitoring or self-regulation of one's own cognitive processes.	• Require students to access relevant knowledge and experiences and make appropriate use of them in working through the task. • Require students to analyze the task and actively examine task constraints that may limit possible solution strategies and solutions. • Require considerable cognitive effort and may involve some level of anxiety for the student because of the unpredictable nature of the solution process required.

Six factors associated with the maintenance of high-level cognitive demands (Table 4) are adopted from Stein et al (2000) to examine the supports for students' cognitive processing from the questions and strategies provided in the ProGuide book.

Table 4: *Supportive factors associated with students' cognitive processing (Stein et al 2000)*

Factors
F1: Scaffolding student thinking and reasoning
F2: Offering students the means of monitoring their own progress
F3: Modelling alternative performance
F4: Emphasizing justifications and explanations through questioning
F5: Using students' prior knowledge
F6: Drawing conceptual connections

Code Up Technique

A "code up" technique (Garrison, Anderson and Archer 2001) is employed in the coding process in terms of multiple questions within a task, such as three questions in T1-PC. The highest levels of knowledge and cognitive demands encoded within a task are used as the final code for the entire task.

Coding Reliability

The use of multiple researchers is adopted to confirm the conformability of the data (Ertmer, Sadaf and Ertmer 2011). Specifically, a graduate student from my department is invited to participate in the coding process. The graduate student and I first code the data individually and then collaboratively develop a consensus on the coding results for all the tasks and questions.

Results

The coding results are shown in tables 5, 6 and 7. The sections that follow outline features of tasks that we discovered and make suggestions about future tasks for textbooks and supportive resources.

Submedium Level of Knowledge Type, Criticism and Manipulation

Table 5 panoramically reveals that the knowledge levels of tasks from the textbook and the practice and homework book are low or submedium, with the exception of knowledge communication (dimension 4).

Dimension 1, depth of knowledge, demonstrates that, except for T1-CE3, all the tasks focus mainly on the procedural knowledge (medium level) of equation solving, using either models or algebra. For example, writing an equation and using tiles to solve the equation are required in T1-I.

Dimension 2, knowledge criticism, outlines that 13 out of 17 tasks are at level 1, presentation of knowledge as truth or given. For example, algebra is used in T2-CE2 to solve the equation: $16t-69=-13$, verify the solution and present the solving equation knowledge. Generally, tasks under the dimension-knowledge criticism stay at a lower level. Furthermore, dimension 3 illustrates that 16 of 17 tasks are at L1 (reproduction) and L2 (organization, interpretation, analysis or evaluation), suggesting a lower level of knowledge manipulation. For example, in PH1-P, a model is used in question 7 to solve the problem "one less than three times a number is eleven," verify the solution and write a concluding statement. Using the model to solve the typical quantitative relationship is a reproduction of the knowledge of using the model to solve an equation. Verifying the solution and writing the conclusion statement represent interpretation and analysis of knowledge manipulation.

Higher Level of Knowledge Communication in the Textbook

Table 5 indicates that all 13 tasks from *Math Makes Sense 8* (6.1 and 6.2) at L2 and L3 possess higher levels of knowledge communication. Those tasks have clear guidance to encourage students to communicate with their pair partner or reflect their own ideas. For example, there are distinct statements guiding students to reflect and share in T2-I: "Compare the equation you wrote with that of another pair of classmates; if the equations are different, is each equation correct ..." (Baron et al 2008, 327).

However, tasks from the practice and homework book mainly require students to represent equations in tiles, numbers or symbols and provide their solutions, thus failing to encourage students to communicate or reflect their own ideas. For example, question 3 of PH2-P is designed to "Use algebra to solve each equation. Verify the solution. (a) $6m+5=7$; (b) $3c-2=2$; (c) $2+5y=2$; (d) $4-3x=-5$" (Berglind et al 2009, 143). There is no prompt in the task, to encourage students to communicate or reflect their own ideas. In fact, it is possible to use such prompts to trigger students to reflect on the process of solving equations and recognize the significance and meaning of solving equations using algebra rather than mainly

Table 5: *The knowledge level of tasks*

Tasks	Knowledge Level of Tasks												
	Dimension 1			Dimension 2			Dimension 3				Dimension 4		
	L1	L2	L3	L1	L2	L3	L1	L2	L3	L4	L1	L2	L3
T1-I		●		●				●				●	
T1-CE1		●		●				●				●	
T1-CE2		●		●				●				●	
T1-CE3	●			●			●					●	
T1-PC		●		●			●						●
T1-PA		●		●				●					●
T1-PAF		●				●		●					●
T2-I		●		●				●				●	
T2-CE1		●		●				●				●	
T2-CE2		●		●			●					●	
T2-PC		●				●	●						●
T2-PA		●		●				●					●
T2-PAF		●				●			●				●
PH1-QR		●		●			●				●		
PH1-P		●		●				●			●		
PH2-QR		●		●			●				●		
PH2-P		●				●	●				●		

focus on solving procedures; for example, Baron et al (2008) suggest "Which types of equations do you prefer to solve using algebra? Explain why you may not want to use algebra tiles or a balance-scales model" (p 332).

Medium Level of Cognitive Demands

Table 6 shows that the levels of cognitive demand of tasks generally remain at medium. Specifically, 15 out of 17 tasks at L2 and L3 focus on procedure without connections or with connections. One example of question 3 of PH2-P requires the use of a well-established procedure without connections to meaning for finding the solution of equations. Another example of T1-I, "Marie's bonds," focuses attention on the procedures for finding and solving an equation in a meaningful context.

Only 2 out of the 17 tasks use the Assessment Focus of Practice (PAF) from the textbook. For example, question 14 of T2-PAF requires writing a problem solvable by applying an equation and by adding such information as "Boat rental $300" and "Fishing rod rental $20." This task has no suggestion of any pathway; instead, its focus is on searching for the underlying mathematical equation, which requires complex thinking.

Table 6: *Levels of cognitive demands of tasks*

Tasks	Levels			
	L1	L2	L3	L4
T1-I			•	
T1-CE1			•	
T1-CE2			•	
T1-CE3			•	
T1-PC		•		
T1-PA			•	
T1-PAF				•
T2-I			•	
T2-CE1			•	
T2-CE2		•		
T2-PC		•		
T2-PA			•	
T2-PAF				•
PH1-QR		•		
PH1-P		•		
PH2-QR		•		
PH2-P		•		

Major Factor: Scaffolding Students' Thinking and Reasoning

The ProGuide book indicates that F1 in Table 7 is the major factor, which is broadly demonstrated through a large quantity of suggested questions and instructional strategies (Burnett 2007). For example, in PG1-DI, 12 questions are recommended to observe and understand students' thinking, such as "What problem-solving strategies could you use to help you with this problem?"(p 4) and "How can you check that your expression is correct?" (p 5). Similarly, in PG2-BGS, 11 questions are provided to promote students' thinking, such as "How would you use algebra to solve the equation?" (p 14). In addition to the above questions, alternative instructional strategies are also offered to enhance students' thinking and reasoning. For example, in PG1-AC, an alternative solution is suggested to scaffold students who "may have difficulty using a model to verify the solution to an equation that has negative variable tiles" (p 10). Also, in PG2-AC, an extra strategy is provided to facilitate students' thinking in question 5: "For students who need extra help to complete this question, refer them to Example 1" (p 17).

Table 7: *Factors associated with the maintenance of high-level cognitive demands*

Tasks	Factors: F1, F2, F3, F4, F5, F6
PG1-BGS	F1, F5
PG1-DI	F1, F6
PG1-AC	F1, F4, F5
PG2-BGS	F1
PG2-DI	F1
PG2-AC	F1, F4

Minor Factors: Justifications, Usage of Students' Prior Knowledge, and Conceptual Connections

Several other factors are also employed in the ProGuide book (Burnett 2007) to support teachers' classroom teaching. For example, in PG1-AC, certain questions are suggested to help students make justifications or explanations (F4), such as "Why did you add a unit tile to each side?" (p 6) and "Could we have used a different variable? Justify your answer" (p 8). PG2-AC also offered similar questions, such as "When using algebra to solve the equation, why did you start by subtracting 5 from each side rather than dividing each side by 2?" (p 14).

In addition, some suggestions are presented to remind students of connecting with their prior knowledge (F5). For instance, PG1-BGS suggests that teachers review how to use red and yellow unit tiles to represent positive and negative numbers so that students could recognize different tiles representing different variables. Using those tiles is very helpful for students to solve the equations in the whole lesson. In PG1-AC, the suggestion is made to "remind students to define a variable before they use it in an equation" (p 10). Meanwhile, some questions are brought forward to stimulate students' conceptual connections (F6). For instance, in PG1-DI, such questions as "How did you use tiles to represent the equation?"(p 5) are recommended to facilitate students' understanding of the relationship between tiles representation and equation.

Conclusions

Lower Level of Knowledge and Cognitive Demands of Tasks

Generally speaking, the evaluated tasks are at the lower levels of knowledge type, knowledge criticism and knowledge manipulation. Only a few tasks possess higher-level cognitive demands. However, the results did not imply that all the evaluated tasks under each dimension should reach the high level. My concern was that the lower knowledge level and cognitive demands of the evaluated tasks might lead to students' learning becoming "surface learning" (Davis and Renert 2014, 30), such as memorizing procedures by rote, or "rote learning" (Mayer 2002, 227). Certainly, the efforts of setting certain tasks at the higher level were made to achieve "deep learning" (Davis and Renert 2014, 30) or "meaningful learning" (Mayer 2002, 227). However, the big gap between the major tasks at the lower level and the minor ones at the higher level might "press students toward a more mechanical attitude" (Davis and Renert 2014, 30).

The efforts of setting certain tasks at the higher level were made to achieve "deep learning."

Higher Level of Knowledge Communication in Textbook

Fortunately, an appealing feature emerging from our coding results is that, highlighting the higher levels of knowledge communication, the tasks in *Math Makes Sense 8* (6.1 and 6.2) have very clear statements to encourage students to share their work with their pair partners as well as to reflect their own thinking.

Relative Monotone of Factors Associated with Cognitive Supporting

Among the factors of supporting students' cognitive processing, the major factor in the supportive strategies provided for teachers is scaffolding students' thinking and reasoning. However, very few factors connect with monitoring students' progress, alternative demonstration, justifications, prior knowledge and conceptual understanding. Thus, the ProGuide has some limitations regarding supports for teachers to facilitate students' cognitive processing.

Implications

Generally speaking, the tasks from *Math Makes Sense 8* (6.1 and 6.2), and the practice and homework book (6.1 and 6.2) are procedural in nature. The knowledge communication highlighted in the textbook demonstrates a core idea of *Math Makes Sense*—creating a math community in the classroom (Burnett 2007, 3–11).

The balanced instruction advocated in *Math Makes Sense 8* includes four key components: problem solving, understanding concepts, application of procedures and communication (Burnett 2007, 8). There is still much to be desired in problem solving and understanding concepts. For instance, "Investigate" in each lesson is designed for doing mathematics. However, the tasks involved lower levels of knowledge and their cognitive demands failed to achieve the curriculum goal. Therefore, this study highly recommends that the levels of knowledge and cognitive demands of the tasks be enhanced. I endeavoured to acquire from literature an answer as to how many enhancing degrees are regarded as reasonable, but in vain. After referring to my own teaching and research experience, I believe that balancing the tasks at different levels might be a practical way to select or design the learning tasks so that the lower-level tasks are necessary for advanced-level ones (Brean 2014).

Balancing the tasks at different levels might be a practical way to select or design the learning tasks.

In addition, the tasks within a session do not seem to be designed with cognitive hierarchies, resulting in the failure to nourish higher-level cognitive processing. It is possible to design such tasks by using variation theory (Marton and Booth 1997) to lead students to the access to the level of problem solving. Finally, it is suggested that questions or instructional strategies to support students' cognitive processing pay attention to the conceptual connections in order to promote students' understanding of concepts.

This research not only indicated the knowledge level and cognitive demand level of tasks from the *Math Makes Sense 8* textbook and the supportive factors in the teacher guide book but also presented a way of analyzing tasks applied in teaching practice. The results and the applied method could be used by teachers to help them use the tasks in an analytical way in their classrooms.

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Xiong Wang is a PhD student at the University of Alberta. She was an associate professor for six years at Shanghai Normal University, China, where she taught mathematics and mathematics education to undergraduate and postgraduate students, and directed eight projects. She was also employed as a research fellow for two years at Nanyang Technology University, Singapore, where she worked on two projects. Her research interest focuses on mathematics curriculum development and teachers' professional development.